ADVANCES IN CLEANING AND SANITATION IN FOOD INDUSTRY

The Seventeenth Short Course

March 3-23, 2004

CENTRE OF ADVANCED STUDIES

DIVISION OF DAIRY TECHNOLOGY
NATIONAL DAIRY RESEARCH INSTITUTE
(Deemed University)
(Indian Council of Agricultural Research)
KARNAL-132001 (Haryana) India

2004
Indian food industry can be a global competitor in the food market, only if it can be viable in terms of quality. Currently, the industry is at crossroads. On the one hand we have enormous wealth in terms of surplus raw material and technical know-how and on the other hand we fall behind in terms of quality. It is imperative, therefore, that stringent quality measures are followed in all areas of production and post-harvest handling of food products to maintain strategic advantage in the world market.

Implementation of good hygienic practices (GHP) at primary food production level and decoding these as good manufacturing practices (GMP) at industrial level is the primary requirement in maintaining good food quality. The industry will now have to adopt HACCP in a big way as a strategic quality management programme. Another measure to be adopted at the grassroots level is the education of farmers on maintaining hygienic environments during food production, health and hygiene of animals, precautions to be exercised in the use of veterinary drugs and medicines and the significance of high levels of antibiotics and their residues in food. Adequate initiatives to produce food, fodder and feed free from pesticides, aflatoxins and heavy metals will have to be taken.

It is evident that to ensure quality and safety in food products, the industry needs to maintain wholehearted commitment to food quality management right from the farm to the consumer. The post-WTO scenario suggests that for sustainability, the Indian food industry will have to step forward with a positive and definite attitude towards implementing clean and hygienic practices.

The time is ripe, therefore, to recapitulate our knowledge on progress in the quality management processes that are adopted in the food industry. I am certain that the 17th Short Course on Advances in Cleaning and Sanitation in Food Industry to be held under the aegis of the Centre of Advanced Studies in Dairy Technology is aimed at achieving this. I hope this course will help to inculcate adequate motivation and an unquestionable resolve among the participants to herald in quality maintenance and safety assurance in food processing activities.

(NAGENDRA SHARMA)
Director, NDRI
ACKNOWLEDGEMENT

The Indian Council of Agricultural Research hailed the Division of Dairy Technology of NDRI as a Centre of Excellence in Dairy Technology for its Centre of Advanced Studies programme in the VIII Plan and subsequently renewed it in the Xth Plan based on admirable performance. We are highly grateful to Dr. J.C. Katyal, Deputy Director General (Education) for grant of funds, and encouragement through the years. We also place on record, our gratitude to Dr. H.S. Nainawatee, ADG (HRD-II) for prompt sanction of budgets and his keen interest in the programme.

We express our sincere gratitude to Dr. Nagendra Sharma, Director NDRI who helped us in all facets and supported us through our endeavour. We also thank Dr. Balaraman, Joint Director (Research) for the valuable suggestions and guidance to carry out the CAS programmes.

Dr. Latha Sabikhi, Senior Scientist and Course coordinator deserves a special mention for her diligent efforts that made the initiation of this programme a success. Compilation of various lectures into a compendium, its editing and formatting is a very difficult task, especially when semester is in progress and teaching load is at its peak.

We are highly indebted to the guest speakers, Dr. N. Kondaiah (Professor & Head, Division of LPT, IVRI, Izatnagar), Mr. Sohrab (Chief Executive, Quality Care and former Director of BIS), Dr. T.R. Sreekrishnan (Associate Professor, Department of Biochemical Engg. & Biotechnology, IIT, New Delhi), Dr. G.S. Rajorhia (former Principal Scientist, Dairy Technology Division, NDRI) and Dr. A. K. Rathour (Deputy General Manager-Production, Mahaan Proteins, Kosi Kalaan), who contributed the lecture material well in time and traveled to Karnal to share their valuable expertise with the participants.

We must convey our special thanks to the faculty of Dairy Technology, Dairy Chemistry, Dairy Microbiology, Computer Centre, Dairy Engineering and Dairy Economics, Statistics and Management for submission of lectures and for actively participating in conducting the theory and practical classes. We specially thank Dr. D.K. Thompkinson, Dr. G.K. Goyal, Dr. R.S. Mann, Dr. A.A. Patel and Dr. R.R.B. Singh for their assistance. The credit for photocopying and binding of the compendium to bring it to its final shape goes to Dr. Jancy Gupta (in-charge, Communication Centre) and her team from the NDRI press.

We are sincerely grateful to Mr. Aniruddha Kumar (Technical Officer), Mr. Tanweer Alam and Ms. Bhavana Vashishtha (Research Scholars) for their time and efforts. We also express our appreciation for the office staff of our division, Ms. Prem Mehta, Mr. Lakhvinder Singh and Ms. Kusum Lata for all the assistance provided. I thank all our staff in the Experimental Dairy and supporting staff in the Division for helping us in each and every way to make the CAS programme a success.

(G.R. PATIL)
Director, CAS
COMMITTEES FOR ORGANIZATION OF THE
17TH SHORT COURSE
ON
ADVANCES IN CLEANING AND SANITATION IN FOOD
INDUSTRY
MARCH 3-23, 2004

ORGANISING COMMITTEE
Dr. G.R. Patil (Course Director)
Dr. Latha Sabikhi (Course Co-ordinator)
  Dr. A.A. Patel
  Dr. R.S. Mann
  Dr. D.K. Thompkinson
  Dr. Dharam Pal

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Dr. Dharam Pal
  (Chairman)
Dr. B.B. Verma
Dr. Alok Jha

TECHNICAL COMMITTEE
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Dr. S.K. Kanawjia
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Dr. A.K. Singh

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Dr. R.S. Mann
  (Chairman)
Dr. Abhay Kumar
Dr. G. K. Goyal

PURCHASE COMMITTEE
Dr. D.K. Thompkinson
  (Chairman)
Mr. F.C. Garg
Dr. A.K. Singh
<table>
<thead>
<tr>
<th>No.</th>
<th>Title of lecture</th>
<th>Author(s)</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Food safety: Global perspectives and challenges</td>
<td>Dr. S. Singh</td>
<td>1-6</td>
</tr>
<tr>
<td>2</td>
<td>Microworld activity in food industry: Foodborne hazards</td>
<td>Dr. S.K. Tomer</td>
<td>7-15</td>
</tr>
<tr>
<td>3</td>
<td>Spoilage organisms: Banes of processing in dairy industry</td>
<td>Dr. R.K. Malik</td>
<td>16-24</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Mr. Kunal Chaudhary</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>Antibiotic residues in milk: Consequences and management</td>
<td>Dr. Sumit Arora</td>
<td>25-31</td>
</tr>
<tr>
<td>5</td>
<td>Pesticide residues in food products: Consequences and management</td>
<td>Dr. (Mrs.) B.K. Wadhwa</td>
<td>32-37</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Dr. Vivek Sharma</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>Clean milk production</td>
<td>Dr. Latha Sabikhi</td>
<td>38-43</td>
</tr>
<tr>
<td>7</td>
<td>Deposit formation on food processing equipments</td>
<td>Dr. G.R. Patil</td>
<td>44-50</td>
</tr>
<tr>
<td>8</td>
<td>Microbial resistance and adaptation to preservatives and sanitizers</td>
<td>Dr. Sharmila Sawant</td>
<td>51-57</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Dr. Naresh Kumar</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Dr. R.K. Malik</td>
<td></td>
</tr>
<tr>
<td>9</td>
<td>Biofilms: Barriers to effective cleaning &amp; sanitation</td>
<td>Dr. S.K. Anand</td>
<td>58-63</td>
</tr>
<tr>
<td>10</td>
<td>Cleaning of food processing equipment</td>
<td>Dr. B.B. Verma</td>
<td>64-68</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Mr. F.C. Garg</td>
<td></td>
</tr>
<tr>
<td>11</td>
<td>Conventional detergents used in the food industry</td>
<td>Dr. R.S. Mann</td>
<td>69-74</td>
</tr>
<tr>
<td>12</td>
<td>Conventional sanitisers used in the food industry</td>
<td>Dr. Abhay Kumar</td>
<td>75-82</td>
</tr>
<tr>
<td>13</td>
<td>Cleaning systems and equipments</td>
<td>Dr. Alok Jha</td>
<td>83-90</td>
</tr>
<tr>
<td>14</td>
<td>Role of equipment planning and design in sanitation and food safety</td>
<td>Prof. I.K. Sawhney</td>
<td>91-96</td>
</tr>
<tr>
<td>15</td>
<td>Advances in the CIP system</td>
<td>Dr. D.K. Thompkinson</td>
<td>97-101</td>
</tr>
<tr>
<td>16</td>
<td>Computer-aided expert systems for CIP management in food processing industries</td>
<td>Mr. A.P. Ruhil</td>
<td>102-108</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Mr. D.K. Sharma</td>
<td></td>
</tr>
<tr>
<td>17</td>
<td>Fouling, cleaning and sanitation of membranes</td>
<td>Dr. V.K. Gupta</td>
<td>109-114</td>
</tr>
<tr>
<td>18</td>
<td>Formulation of detergents for cleaning of membranes</td>
<td>Dr. A.K. Rathour</td>
<td>115-120</td>
</tr>
<tr>
<td>19</td>
<td>Protocols for inspecting efficacy of the sanitation programmes in food industry</td>
<td>Mr. F.C. Garg</td>
<td>121-124</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Dr. B.B. Verma</td>
<td></td>
</tr>
<tr>
<td>20</td>
<td>New sanitation technologies</td>
<td>Dr. Shilpa Vij</td>
<td>125-128</td>
</tr>
<tr>
<td>21</td>
<td>Application of biodetergents in dairy &amp; food industry</td>
<td>Dr. S.K. Kanawjia</td>
<td>129-136</td>
</tr>
<tr>
<td>22</td>
<td>Bioluminescence: Realtime indicators of hygiene</td>
<td>Dr. S.K. Anand</td>
<td>137-143</td>
</tr>
<tr>
<td>23</td>
<td>Impact of single-use foodservice packaging in sanitation</td>
<td>Dr. G.K. Goyal</td>
<td>144-147</td>
</tr>
<tr>
<td>24</td>
<td>Safe food handler: Personnel hygiene and employee sanitation training</td>
<td>Dr. Vaishali</td>
<td>148-153</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Dr. Naresh Kumar</td>
<td></td>
</tr>
<tr>
<td>25</td>
<td>Dealing with sanitation regulations &amp; standards: Legal aspects</td>
<td>Mr. B.B. Raina</td>
<td>154-159</td>
</tr>
<tr>
<td>26</td>
<td>Good manufacturing practices</td>
<td>Dr. G.S. Rajorhia</td>
<td>160-165</td>
</tr>
<tr>
<td>No.</td>
<td>Title</td>
<td>Authors</td>
<td>Pages</td>
</tr>
<tr>
<td>-----</td>
<td>-----------------------------------------------------------------------</td>
<td>----------------------------------------------</td>
<td>--------</td>
</tr>
<tr>
<td>27</td>
<td>Good laboratory practices</td>
<td>Dr. Y.S. Rajput</td>
<td>166-168</td>
</tr>
<tr>
<td>28</td>
<td>Principles of HACCP system in food quality assurance</td>
<td>Mr. Sohrab</td>
<td>169-178</td>
</tr>
<tr>
<td>29</td>
<td>Water quality management</td>
<td>Dr. Vivek Sharma Dr. (Mrs.) B.K. Wadhwa</td>
<td>179-186</td>
</tr>
<tr>
<td>30</td>
<td>Waste management in the dairy sector: Economic &amp; environmental issues</td>
<td>Dr. Latha Sabikhi</td>
<td>187-191</td>
</tr>
<tr>
<td>31</td>
<td>Waste management in the meat industry</td>
<td>Dr. N. Kondaiah</td>
<td>192-197</td>
</tr>
<tr>
<td>32</td>
<td>Application of membrane processing in wastewater/effluent recycling in food industry</td>
<td>Dr. Dharam Pal</td>
<td>198-201</td>
</tr>
<tr>
<td>33</td>
<td>Treatment of dairy industry effluents through biological processes</td>
<td>Dr. T.R. Sreekrishnan</td>
<td>202-206</td>
</tr>
<tr>
<td>34</td>
<td>Analysis of organochloro pesticide residues in milk and milk products</td>
<td>Dr. (Mrs.) B.K. Wadhwa Dr. Vivek Sharma</td>
<td>207-208</td>
</tr>
<tr>
<td>35</td>
<td>Evaluation of dairy detergents and sanitizers</td>
<td>Dr P.K. Aggarwal Dr Rattan Chand</td>
<td>209-212</td>
</tr>
<tr>
<td>36</td>
<td>Efficiency of effluent treatment process</td>
<td>Mr. Rajeev Patel</td>
<td>213-216</td>
</tr>
</tbody>
</table>
### PROGRAMME

#### 3.3.2004 (WEDNESDAY)

<table>
<thead>
<tr>
<th>Time</th>
<th>Activity</th>
<th>Speaker</th>
</tr>
</thead>
<tbody>
<tr>
<td>9:30 AM- 9.55 AM</td>
<td>Registration</td>
<td>Dr. A.K. Singh</td>
</tr>
<tr>
<td>10.00 AM-10.40 AM</td>
<td>Inauguration</td>
<td>Mr. Dharamveer, Mr. Ram Swarup</td>
</tr>
<tr>
<td>10.40 AM-11.30 AM</td>
<td>Visit to Audio-Visual Lab</td>
<td>Mr. Dharamveer, Mr. Ram Swarup</td>
</tr>
<tr>
<td>11.30 AM-11.45 PM</td>
<td>Visit to Library</td>
<td>Mr. P. Muruganatham</td>
</tr>
<tr>
<td>11.45 AM –12.15 AM</td>
<td>Visit to Model Dairy Plant</td>
<td>Mr. B.B. Raina</td>
</tr>
<tr>
<td>12.15 PM- 1.00 PM</td>
<td>Visit to Experimental Dairy</td>
<td>Mr. Hari Ram Gupta</td>
</tr>
<tr>
<td>1.00 PM – 2.00 PM</td>
<td>LUNCH</td>
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<tr>
<td>2.15 PM- 3.15 PM</td>
<td>Food safety: Global perspectives and challenges</td>
<td>Dr. S. Singh</td>
</tr>
<tr>
<td>3.15 PM – 3.30 PM</td>
<td>TEA BREAK</td>
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</tr>
<tr>
<td>3.30 PM – 4.00 PM</td>
<td>Visit to D.T. Division</td>
<td>Mr. Ram Swarup</td>
</tr>
</tbody>
</table>

#### 4.3.2004 (THURSDAY)

<table>
<thead>
<tr>
<th>Time</th>
<th>Activity</th>
<th>Speaker</th>
</tr>
</thead>
<tbody>
<tr>
<td>9:45 AM- 10.45 AM</td>
<td>Clean milk production</td>
<td>Dr. Latha Sabikhi</td>
</tr>
<tr>
<td>10.45 AM-11.15 AM</td>
<td>Discussion</td>
<td></td>
</tr>
<tr>
<td>11.15 AM-11.30 PM</td>
<td>Tea break</td>
<td></td>
</tr>
<tr>
<td>11.30 AM-12.30 PM</td>
<td>Conventional detergents used in the food industry</td>
<td>Dr. R.S. Mann</td>
</tr>
<tr>
<td>12.30 PM- 1.00 PM</td>
<td>Discussion</td>
<td></td>
</tr>
<tr>
<td>1.00 PM – 2.00 PM</td>
<td>Lunch</td>
<td></td>
</tr>
<tr>
<td>2.15 PM- 3.15 PM</td>
<td>Conventional sanitisers used in the food industry</td>
<td>Dr. Abhay Kumar</td>
</tr>
<tr>
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<td>3.30 PM – 4.30 PM</td>
<td>Library consultation</td>
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#### 5.3.2004 (FRIDAY)

<table>
<thead>
<tr>
<th>Time</th>
<th>Activity</th>
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</thead>
<tbody>
<tr>
<td>9:45 AM- 10.45 AM</td>
<td>Deposit formation on food processing equipments</td>
<td>Dr G.R. Patil</td>
</tr>
<tr>
<td>10.45 AM-11.15 AM</td>
<td>Discussion</td>
<td></td>
</tr>
<tr>
<td>11.15 AM-11.30 PM</td>
<td>Tea break</td>
<td></td>
</tr>
<tr>
<td>11.30 AM-12.30 PM</td>
<td>Dealing with sanitation regulations &amp; standards: Legal aspects</td>
<td>Mr B.B. Raina</td>
</tr>
<tr>
<td>12.30 PM- 1.00 PM</td>
<td>Discussion</td>
<td></td>
</tr>
<tr>
<td>1.00 PM – 2.00 PM</td>
<td>Lunch</td>
<td></td>
</tr>
<tr>
<td>2.15 PM- 3.15 PM</td>
<td>Cleaning of food processing equipments</td>
<td>Dr B.B. Verma</td>
</tr>
<tr>
<td>3.15 PM - 3.30 PM</td>
<td>Tea</td>
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</tr>
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<td>3.30 PM – 4.30 PM</td>
<td>Library consultation</td>
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</tr>
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</table>

#### 6.3.2004 (SATURDAY)

<table>
<thead>
<tr>
<th>Time</th>
<th>Activity</th>
<th>Speaker</th>
</tr>
</thead>
<tbody>
<tr>
<td>9:45 AM- 10.45 AM</td>
<td>Cleaning assessment methods: recent advances</td>
<td>Dr A.A. Patel</td>
</tr>
<tr>
<td>10.45 AM-11.15 AM</td>
<td>Discussion</td>
<td></td>
</tr>
<tr>
<td>11.15 AM-11.30 PM</td>
<td>Tea break</td>
<td></td>
</tr>
<tr>
<td>Time</td>
<td>Session</td>
<td>Presenter(s)</td>
</tr>
<tr>
<td>---------------</td>
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<td>-------------------------------------</td>
</tr>
<tr>
<td>11.30 AM-12.30 PM</td>
<td>Protocols for inspecting efficacy of the sanitation programmes in food industry</td>
<td>Mr. F.C. Garg</td>
</tr>
<tr>
<td>12.30 PM- 1.00 PM</td>
<td>Discussion</td>
<td></td>
</tr>
<tr>
<td>1.00 PM – 2.00 PM</td>
<td>Lunch</td>
<td></td>
</tr>
<tr>
<td>2.15 PM- 4.30 PM</td>
<td>Efficacy of cleaning &amp; sanitation protocol (Practicals)</td>
<td>Dr. Jessa Ram and Mrs. Savitri Jhamb</td>
</tr>
</tbody>
</table>

**8.3.2004 (MONDAY)**

<table>
<thead>
<tr>
<th>Time</th>
<th>Session</th>
<th>Presenter(s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>9:45 AM-10.45 AM</td>
<td>Application of biodetergents in dairy &amp; food industry</td>
<td>Dr. S.K. Kanawjia</td>
</tr>
<tr>
<td>10.45 AM-11.15 AM</td>
<td>Discussion</td>
<td></td>
</tr>
<tr>
<td>11.15 AM-11.30 PM</td>
<td>Tea break</td>
<td></td>
</tr>
<tr>
<td>11.30 AM-12.30 PM</td>
<td>Principles of HACCP system in food quality assurance</td>
<td>Mr. Sohrab (Guest lecture)</td>
</tr>
<tr>
<td>12.30 PM- 1.00 PM</td>
<td>Discussion</td>
<td></td>
</tr>
<tr>
<td>1.00 PM – 2.00 PM</td>
<td>Lunch</td>
<td></td>
</tr>
<tr>
<td>2.15 PM- 3.15 PM</td>
<td>Microworld Activity in Food Industry: Foodborne Hazards</td>
<td>Dr. S.K. Tomer</td>
</tr>
<tr>
<td>3.15 PM - 3.30 PM</td>
<td>Tea &amp; Discussion</td>
<td></td>
</tr>
<tr>
<td>3.30 PM – 4.15 PM</td>
<td>Computer-aided expert systems for CIP management in food processing industries</td>
<td>Mr. A.P. Ruhil</td>
</tr>
<tr>
<td>4.15 PM – 4.30 PM</td>
<td>Discussion</td>
<td></td>
</tr>
</tbody>
</table>

**9.3.2004 (TUESDAY)**

<table>
<thead>
<tr>
<th>Time</th>
<th>Session</th>
<th>Presenter(s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>9:45 AM-10.45 AM</td>
<td>Antibiotic residues in milk: Consequences and management</td>
<td>Dr. Sumit Arora</td>
</tr>
<tr>
<td>10.45 AM-11.15 AM</td>
<td>Discussion</td>
<td></td>
</tr>
<tr>
<td>11.15 AM-11.30 PM</td>
<td>Tea break</td>
<td></td>
</tr>
<tr>
<td>11.30 AM-12.30 PM</td>
<td>Pesticide residues in food products: Consequences and management</td>
<td>Dr. (Ms) B.K. Wadhwa</td>
</tr>
<tr>
<td>12.30 PM- 1.00 PM</td>
<td>Discussion</td>
<td></td>
</tr>
<tr>
<td>1.00 PM – 2.00 PM</td>
<td>Lunch</td>
<td></td>
</tr>
<tr>
<td>2.15 PM- 4.30 PM</td>
<td>Analysis of organochloro pesticide residues in milk and milk products (Practicals)</td>
<td>Dr. (Ms) B.K. Wadhwa</td>
</tr>
</tbody>
</table>

**10.3.2004 (WEDNESDAY)**

<table>
<thead>
<tr>
<th>Time</th>
<th>Session</th>
<th>Presenter(s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>9:45 AM-10.45 AM</td>
<td>Spoilage organisms: Banes of processing in dairy industry</td>
<td>Dr. R.K. Malik</td>
</tr>
<tr>
<td>10.45 AM-11.15 AM</td>
<td>Discussion</td>
<td></td>
</tr>
<tr>
<td>11.15 AM-11.30 PM</td>
<td>Tea break</td>
<td></td>
</tr>
<tr>
<td>11.30 AM-12.30 PM</td>
<td>Good Manufacturing practices</td>
<td>Dr. G.S. Rajorhia (Guest lecture)</td>
</tr>
<tr>
<td>12.30 PM- 1.00 PM</td>
<td>Discussion</td>
<td></td>
</tr>
<tr>
<td>1.00 PM – 2.00 PM</td>
<td>Lunch</td>
<td></td>
</tr>
<tr>
<td>2.15 PM- 4.30 PM</td>
<td>Assessment of water quality (Practicals)</td>
<td>Dr. Jessa Ram and Mr. Lahiri Singh</td>
</tr>
</tbody>
</table>

**11.3.2004 (THURSDAY)**

<table>
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<tbody>
<tr>
<td>9:45 AM-10.45 AM</td>
<td>Good laboratory practices</td>
<td>Dr. Y.S. Rajput</td>
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<tr>
<td>10.45 AM-11.15 AM</td>
<td>Discussion</td>
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<tr>
<td>11.15 AM-11.30 PM</td>
<td>Tea break</td>
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<tr>
<td>11.30 AM-12.30 PM</td>
<td>Fouling, cleaning and sanitation of membranes</td>
<td>Dr. V.K. Gupta</td>
</tr>
<tr>
<td>12.30 PM- 1.00 PM</td>
<td>Discussion</td>
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<tr>
<td>Time</td>
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<tr>
<td>1.00 PM – 2.00 PM</td>
<td>Lunch</td>
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<tr>
<td>2.15 PM – 4.30 PM</td>
<td>Cleaning of common membrane systems (Practicals)</td>
<td>Dr V.K. Gupta</td>
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**12.3.2004 (FRIDAY)**

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<tbody>
<tr>
<td>9:45 AM – 10.45 AM</td>
<td>Predictive modelling in fouling</td>
<td>Dr R.R.B. Singh</td>
</tr>
<tr>
<td>10.45 AM-11.15 AM</td>
<td>Discussion</td>
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<tr>
<td>11.15 AM-11.30 PM</td>
<td>Tea break</td>
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<tr>
<td>11.30 AM-12.30 PM</td>
<td>Waste management in the dairy sector: Economic &amp; environmental issues</td>
<td>Dr Latha Sabikhi</td>
</tr>
<tr>
<td>12.30 PM – 1.00 PM</td>
<td>Discussion</td>
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<td>1.00 PM – 2.00 PM</td>
<td>Lunch</td>
<td></td>
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<tr>
<td>2.15 PM – 4.30 PM</td>
<td>Efficiency of effluent treatment process (Practicals)</td>
<td>Mr Rajiv Patel (MDP)</td>
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**15.3.2004 (MONDAY)**

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<tr>
<th>Time</th>
<th>Activity</th>
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<tbody>
<tr>
<td>9:45 AM – 10.45 AM</td>
<td>Water quality management</td>
<td>Vivek Sharma</td>
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<tr>
<td>10.45 AM-11.15 AM</td>
<td>Discussion</td>
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<tr>
<td>11.15 AM-11.30 PM</td>
<td>Tea break</td>
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<tr>
<td>11.30 AM-12.30 PM</td>
<td>New sanitation technologies</td>
<td>Dr Shilpa Vij</td>
</tr>
<tr>
<td>12.30 PM – 1.00 PM</td>
<td>Discussion</td>
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<tr>
<td>1.00 PM – 2.00 PM</td>
<td>Lunch</td>
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</tr>
<tr>
<td>2.15 PM – 3.15 PM</td>
<td>Formulation of detergents for cleaning of membranes</td>
<td>Dr. A. K. Rathour (Guest Lecture)</td>
</tr>
<tr>
<td>3.15 PM - 3.30 PM</td>
<td>Tea</td>
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<td>3.30 PM – 4.00 PM</td>
<td>Discussion</td>
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<td>4.00 PM – 4.30 PM</td>
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**16.3.2004 (TUESDAY)**

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<tbody>
<tr>
<td>9:45 AM – 10.45 AM</td>
<td>Application of membrane processing in wastewater/effluent recycling in food industry</td>
<td>Dr Dharam Pal</td>
</tr>
<tr>
<td>10.45 AM-11.15 AM</td>
<td>Discussion</td>
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<td>11.15 AM-11.30 PM</td>
<td>Tea break</td>
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<tr>
<td>11.30 AM-12.30 PM</td>
<td>Biofilms – Barriers to effective cleaning &amp; sanitation</td>
<td>Dr S.K. Anand</td>
</tr>
<tr>
<td>12.30 PM – 1.00 PM</td>
<td>Discussion</td>
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<tr>
<td>1.00 PM – 2.00 PM</td>
<td>Lunch</td>
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<tr>
<td>2.15 PM – 4.30 PM</td>
<td>Effect of fouling on efficiency of membrane processing (Practicals)</td>
<td>Dr Dharam Pal</td>
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**17.3.2004 (WEDNESDAY)**

<table>
<thead>
<tr>
<th>Time</th>
<th>Activity</th>
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<tbody>
<tr>
<td>9:45 AM – 10.45 AM</td>
<td>Waste management in the meat industry</td>
<td>Dr. N. Kondaiah (Guest Lecture)</td>
</tr>
<tr>
<td>10.45 AM-11.15 AM</td>
<td>Discussion</td>
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<tr>
<td>11.15 AM-11.30 PM</td>
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<tr>
<td>11.30 AM-12.30 PM</td>
<td>Role of equipment planning and design in sanitation and food safety</td>
<td>Prof. I.K. Sawhney</td>
</tr>
<tr>
<td>12.30 PM – 1.00 PM</td>
<td>Discussion</td>
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<tr>
<td>1.00 PM – 2.00 PM</td>
<td>Lunch</td>
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<tr>
<td>2.15 PM – 3.15 PM</td>
<td>Advances in the CIP system</td>
<td>Dr D.K. Thompkinson</td>
</tr>
<tr>
<td>3.15 PM - 3.30 PM</td>
<td>Tea/Discussion</td>
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</tr>
<tr>
<td>3.30 PM – 4.15 PM</td>
<td>Cleaning systems and equipments</td>
<td>Dr Alok Jha</td>
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<tr>
<td>4.15 PM – 4.30 PM</td>
<td>Discussion</td>
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### 18.3.2004 (THURSDAY)

<table>
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<tr>
<th>Time</th>
<th>Topic</th>
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<tbody>
<tr>
<td>9:45 AM- 10.45 AM</td>
<td>Microbial resistance and adaptation to preservatives and sanitizers</td>
<td>Dr Naresh Kumar</td>
</tr>
<tr>
<td>10.45 AM-11.15 AM</td>
<td>Discussion</td>
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<tr>
<td>11.15 AM-11.30 PM</td>
<td>Tea break</td>
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<tr>
<td>11.30 AM-12.30 PM</td>
<td>Bioluminescence – Realtime indicators of hygiene</td>
<td>Dr S.K. Anand</td>
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<tr>
<td>12.30 PM- 1.00 PM</td>
<td>Discussion</td>
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<tr>
<td>1.00 PM – 2.00 PM</td>
<td>Lunch</td>
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<tr>
<td>2.15 PM- 4.30 PM</td>
<td>Evaluation of dairy detergents and sanitizers (Practicals)</td>
<td>Dr P.K. Aggarwal &amp; Dr Rattan Chand</td>
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### 19.3.2004 (FRIDAY)

<table>
<thead>
<tr>
<th>Time</th>
<th>Topic</th>
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<tbody>
<tr>
<td>9:45 AM- 10.45 AM</td>
<td>Waste management in fruits &amp; vegetables</td>
<td>Dr A.K. Singh</td>
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<tr>
<td>10.45 AM-11.15 AM</td>
<td>Discussion</td>
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<td>11.15 AM-11.30 PM</td>
<td>Tea break</td>
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<tr>
<td>11.30 AM-12.30 PM</td>
<td>Treatment of dairy industry effluents through biological processes</td>
<td>Dr. T.R. Sreekrishnan (Guest Lecture)</td>
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<tr>
<td>12.30 PM- 1.00 PM</td>
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<td>Lunch</td>
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<tr>
<td>2.15 PM- 4.30 PM</td>
<td>Effectiveness of heat treatment – Determination of F-value (Practicals)</td>
<td>Dr Alok Jha Mr. Ram Swarup</td>
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### 20.3.2004 (SATURDAY)

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<tr>
<th>Time</th>
<th>Topic</th>
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<tbody>
<tr>
<td>9:45 AM- 10.45 AM</td>
<td>Safe food handler - Personal hygiene and employee sanitation training</td>
<td>Dr Vaishali</td>
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<tr>
<td>10.45 AM-11.15 AM</td>
<td>Discussion</td>
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<td>Tea break</td>
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<tr>
<td>11.30 AM-1.00 PM</td>
<td>Identification of common pathogens in food products (Practicals)</td>
<td>Dr S.K. Tomer</td>
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<td>1.00 PM – 2.00 PM</td>
<td>Lunch</td>
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<tr>
<td>2.15 PM- 4.30 PM</td>
<td>Identification of common spoilage organisms in food products (Practicals)</td>
<td>Dr Naresh Kumar</td>
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### 22.3.2004 (MONDAY)

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<th>Time</th>
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<tbody>
<tr>
<td>9:45 AM- 1.00 AM</td>
<td>Computer-aided statistical packages for food processing applications (Practicals)</td>
<td>Dr. R.K. Malhotra</td>
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<td>1.00 PM – 2.00 PM</td>
<td>Lunch</td>
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<tr>
<td>2.15 PM- 3.15 PM</td>
<td>Impact of single-use foodservice packaging in sanitation</td>
<td>Dr G.K. Goyal</td>
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<td>3.15 PM - 3.30 PM</td>
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### 23.3.2004 (TUESDAY)

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<tr>
<td>9:45 AM- 10.45 AM</td>
<td>Course evaluation</td>
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<td>10.45 AM-11.00 AM</td>
<td>Discussion</td>
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<tr>
<td>11.00 AM-1.00 PM</td>
<td>Interaction with faculty</td>
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<tr>
<td>1.00 PM – 2.00 PM</td>
<td>Lunch</td>
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<tr>
<td>2.30 PM- 3.30 PM</td>
<td>Valedictory function</td>
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1. INTRODUCTION

Food safety has become a major concern for the public in the ever-expanding food industry. Food supply has taken a global dimension. With fast-expanding urbanization and modernization more food is prepared and consumed away from homes. Consumers want food that is tasty, healthy and safe for their families. Safety is the basic requirement for most people. However, zero risk of microbiological hazard is not possible, and no one method will eliminate pathogens or toxins from the food chain. A combination of safety measures and processing methods is used to ascertain nutritional quality and safety of foods reaching the consumers, e.g. a combination of heating, aseptic packing and refrigeration. However, bacteria may survive despite aggressive control at all processing levels and food can become contaminated during preparation, cooking, serving, storage and distribution. Controlling food-borne pathogens is a constant challenge.

Public health concerns pertaining to food safety centers on chemical residues, antibiotic resistance and emerging pathogens. A number of food safety issues have received attention worldwide. For example, the recent scare of cancer-causing dioxin contamination of animal food from Belgium, *E. coli* 0157: H7 out break with beef burgers in Pacific (North-west America) in 1993 in which normal children became permanently disabled, and listeriosis which can cause miscarriage and even death. Most recent outbreak of mad-cow disease, SARS and bird flue have created panic in public. The cost of food-borne illness is tremendous, which include loss of productivity, cost of hospitalization, long-term disability and even death.

Earlier people only knew that germs caused food poisoning or food spoilage. As knowledge progressed people began to identify specific organisms that cause the problems. With the advancement of science more sophisticated tools and techniques are developed which enable us to identify with good accuracy causative organisms that were not recognized 20 years ago. Currently, there is great concern of food poisoning caused by *E. coli* 0157: H7, *Salmonella enteritidis*, *Listeria monocytogenes* and *Campylobacter jejuni*. Others of equal importance are pathogens *Vibrio vulnificus*, *Yersinia enterocolitica*, *Clostridium perfringens* and *Staphylococcus aureus*. Some of these pathogens grow inside the intestinal tract and irritate the lining of intestines, while others produce toxins in the foods.

Microorganisms continue to adapt and evolve and therefore, increase their degree of virulence. These pathogens found new modes of transmission, i.e. not just from raw meat but also from other sources. For example, *Salmonella enteritidis* was found to contaminate the exterior of eggs, but now it is found inside many eggs, making uncooked eggs no longer safe. It seems that these emerging pathogens demand even greater food safety vigilance than what was required before.
Growth-enhancing antibiotics are sometimes added in animal diets and such antibiotic usage may have selected antibiotic resistant organisms. It has been reported that some of the pathogens isolated from a variety of foods are resistant to more than one antibiotic tested. The impact of the presence of such antibiotic resistant organisms comes from the fact that there are often no therapeutic agents commercially available and/or established efficacies for patients affected by such organisms.

A rising trend has been observed for branded packed milk due to fear of adulteration and un-safety of unbranded milk sold by locals, likely to cause human health hazard. Health hazardous practices include mixing of non-potable water, neutralizer, detergents, preservatives, urea etc., and use of hormone injection to milch animals and presence of residues of pesticide, heavy metals, antibiotics, aflatoxins, drugs, etc. in excess quantities. Improper handling of milk can serve as a potential vehicle for transmission of many diseases like tuberculosis, brucellosis, diphtheria, anthrax, foot and mouth disease, hepatitis, Q-fever, listeriosis, salmonellosis, shigellosis, streptococcal infections, staphylococcal poisoning, E. coli poisoning and botulism. Now a days public are also concerned about synthetic milk. Therefore, full assurance for the supply of safe milk has added an edge on quality.

Food safety is of primary concern to world bodies like FAO and WHO involved in ensuring food and nutritional security. FAO defined it as providing assurance that food will not cause harm to the consumers when it is prepared and/or eaten according to its intended use (FAO, 1996). Food safety was declared a global priority for WHO for 2002-2003 at the 105th session of the Executive Board in January 2000. WHO will, therefore, be increasing its collaboration with its member states to improve the safety and wholesomeness of food in markets, shops, streets, institutions and households. Support for the framework food and water surveillance system will be strengthened in cooperation with collaborating institutions.

2. SYSTEM FOR IMPROVING FOOD SAFETY

Food Science and Technology are complex disciplines involving specialized knowledge in a wide range of fields much as chemistry, biochemistry, microbiology, toxicity and related fields. In view, of the wider scope of food safety and quality problems personnel must be trained periodically in developing new food products, new technologies new food processing methods, testing and food analysis methods.

Food safety is reflected by food quality. Quality is no more the concern of only the quality control department. Today its all-encompassing canvas includes ISO, HACCP systems, human resource, environment management and above all consumer satisfaction. Emphasis on good manufacturing practices (GMP) food plant improvement programme (FPIP) and total quality management (TQM) need to be enhanced.

2.1 Total Quality Management (TQM)

TQM is a process, which has evolved over a period of time with many people contributing to what it is today. The central themes of TQM are customer focus, continuous improvement in quality, problem solving through PDCA (Plan, Do, Check, Act) and involvement of people. Thus TQM is management led never ending process in which top management commitment is essential. TQM may be defined as an integrated organizational approach in delighting customers (both external and internal) by meeting their expectations on continuous basis through everyone involved with the organization working on continuous improvement in all products, services and processes along with proper problem solving methodology.
TQM is a journey. It is the path as well as goal. It is transformation, which takes place over a period of time. It has its ups and downs.

2.2 Hazard Analysis Critical Control Point (HACCP)

The HACCP as it applies to food is considered to be a food safety management system using the approach of controlling critical control points in food handling to prevent food safety problems. It is a system, which can be used to assure food safety at all levels of food handling, i.e. from the primary production till it is finally consumed, and is an important element in the overall management of food quality and safety more commonly referred as a Good Manufacturing Practices (GMP). The HACCP concept was developed in the late 60s as a quality assurance system to enhance food safety and increase consumer confidence in the food consumed by them. NASA adopted this approach in the beginning for the foods to be used by the Skylab project. The interest has also been shown by the WHO in this approach as a possible cost effective means of improving the safety of foods. HACCP, a system of safety controls focuses on prevention of product contamination at strategic points. The GATT supports the HACCP as many countries move forward HACCP based standards for domestic and exported food products. The Codex Alimentarius Commission (CAC) recognizes this system of food safety control.

The basic principles underlying the concept were not new, but the introduction of HACCP signaled a shift in emphasis from resource intensive and product inspection and testing to prevention/control of hazards at all stages of food production. HACCP was initially developed by the food industry for use by food processors to prevent or control hazards, thereby improving the food safety. The application of HACCP system has been evaluating and expanding to form a basis for official food control and for establishing food safety standards for the international trade as well. HACCP is considered to be one of the most effective and efficient systems to enhance food safety.

It is a process control system that identifies where hazards might occur in the food production process and puts into stringent action to prevent hazard from occurring. HACCP is an effective food safety control. It is a systematic approach to ensure product safety by implementing preventive measures to manage the hazards associated with foods. It is a system, which has been recognized internationally and required under CAC HACCP application consists of a logical sequence of twelve steps encompassing seven basic principles. These are 1) conducting a hazard analysis, 2) identifying the critical control points, 3) establishing critical limits, 4) establishing critical control points (CCP) monitoring requirements, 5) establishing corrective actions, 6) establishing effective-record procedures and 7) establishing procedures for verifying.

HACCP enables defects with impact on food safety to be readily detected and corrected at specific points (CCP) during receiving of ingredients, handling, processing, storage and distribution of foods, instead of relying on end product inspection and testing. HACCP have been proven effective in managing food safety because it focuses on real hazards and its management, it needs less inspection and relies more on preventive steps, it conforms with requirements of importing countries, it increases customer confidence with the products.

3.0 INTERNATIONAL STANDARDS

The quality has become the buzzword of the new millennium encompassing the quality of life, quality of goods and services and quality of environment. The global economy today centers around technology, quality and international competitiveness.
Standardization and quality management systems play a major role in the assimilation of technology, effecting economy in production and stimulating competitiveness. Standardization encapsulates technological results and becomes a vehicle for technology transfer while quality is the key for facilitating trade and satisfying customers. The ISO 9000 Quality Management System standards combine these two and present worldwide integration of standards.

One of the most far reaching developments in the late 20th century in the quality arena affecting world trade has been the evolution of ISO 9000 series of standards on quality management systems. It has ushered a new era of concept of quality in the world. It provides an overall improved competitiveness as it ensures control, consistency, and assurance of high standards, improved productivity and most importantly improved quality. Emerging international scenario shows an enormous acceleration of interest in and widening of the boundaries of quality. With global competition increasing, companies must establish dynamic forward-looking cultures of quality to survive in the global village of the business world. It is an attempt to harmonize quality management practices on an international scale and support the growing impact of quality as a factor in international trade.

ISO 9000 is internationally recognized benchmark for measuring quality in trade context. This is the reason why in a short span of time, the ISO 9000 series of standards has become a ubiquitous standard being applied by majority of nations around the globe, and over, 2,50,000 enterprises are certified to ISO 9000.

The worldwide growth of QMS has been phenomenal. But just as momentum has grown so too has the criticisms such as it is slow and bureaucratic with emphasis on procedures and form filling and as a control mechanism adding a little value in the way of improved working. With the experiences gained worldwide for over last 12 years, the ISO committee of Quality Management System has decided to launch the ISO 9000: 2000 series of standards with the changed focus to meet the challenges of the new millennium. These standards are seen as strategic tools designed to deliver business objectives.

With the changed focus on quality issues worldwide, the ISO 9000 standards will necessitate organizations to reorient to address process centered approach to quality management system to meet customer requirements and gauge their satisfaction and place the system on a continual improvement mode.

According to international organization of standards (ISO), quality encompasses safety, hygiene, reliability, wholesomeness and acceptance by consumers.

4.0 CLEANING AND SANITIZATION

To successfully provide the atmosphere for proper food safety, the basics must be thoroughly understood. The basics of food safety begin with good understanding of sanitation processes, food-handling procedures that protect from, or eliminate cross contamination problems, and specific attention to inspection of and follow up for all processes. Food safety activities need to be programmed into available time of day scheduling just as production requirements do. Whether special personnel or separate shifts handle cleaning responsibilities or you clean as you go on the production line, time must be made available. Safe product leaving the facility must be the watchword of all employees involved with the process.

In order to ensure safe food supply a high level of sanitation should be maintained throughout the food production chain. The word ‘sanitation’ is derived from
the Latin word “sanitas” which means “health”. To further apply this word to the food industry, sanitation is the creation and maintenance of hygienic and healthful conditions when processing, preparing and handling food. Sanitation is the application of a science to provide wholesome food handled in a hygienic environment by healthy food handlers to prevent contamination by food spoilage microorganisms. Effective sanitation refers to the mechanisms, which accomplish these goals.

It is said, ‘there is no single factor as important in the production of fine quality food as absolute and complete cleanliness’. It is not enough to provide food for man but it must be of high quality. It would be impossible to provide man with food products of superior quality if we were unable to remove food soil and to kill residual microorganisms. This can be achieved through effective cleaning and sanitization.

Normally cleaning and sanitation does not receive the importance that they deserve from food manufacturers. Intensive labour and learning are necessary before one can become skilled in this field. Traditionally, the inexperienced and less skilled employees have been relegated to responsibilities related to sanitation. These workers normally receive little or no training related to sanitation. Even those involved in the management of a sanitation programme during the past have had only a limited access to material on this subject. Technical information has previously been confined primarily to a limited number of training manuals provided by regulatory agencies, industry-association manuals, and recommendations from firms that manufacture equipment and cleaning compounds. Most of this material lacks specific direction related to the selection of appropriate cleaning methods, equipments, compounds and sanitizers for maintenance of hygienic conditions in food processing and preparation facilities.

Cleaning and sanitization has a very broad scope. It encompasses the entire environment of food processing, premises, cleaning compounds, sanitizers, cleaning equipment, waste disposal, pest control and quality assurance.

The increased volume of food processed and/or prepared outside the home has increased the importance of sanitary practices and hygienic conditions in the food industry. Even though food plants are hygienically designed, foods can be contaminated with spoilage microorganisms or food poisoning microorganisms if proper sanitary practices are not followed. Protection of food through sanitary handling previously was relegated only to the homemaker. It has been the responsibility of those who prepare food in homes to maintain the purity and cleanliness of food for the family. As society has evolved, a large percentage of food consumed by humans has been processed and/or prepared outside the home. This changing pattern has increased the importance that food be handled in a sanitary manner. With volume processing and preparation of food, effects of contamination are accentuated if sanitary practices are not followed.

Added mechanization and large volume operations of food processing and preparation have increased the need for workers in all segment of the food industry to have an understanding of sanitary practices and how hygienic conditions can be attained and maintained.

The trend in the food industry is toward more processing at a plant near the area of production rather than in the store, restaurants, or consumers kitchen. This continuing development presents those involved with sanitation with increased responsibility to preserve the basic quality of food.

Scientific advances during the past century in food production, processing, preparation and packaging have contributed to improved food quality and a more economical price. However, with increased productivity, convenience foods and other
processed foods remain vulnerable to problems created through advanced technology. The major problems have been food contamination and waste disposal.

Cleaning implies a process of removing soil from the material being cleaned. In order to ensure effective cleaning, the quality of water, the characteristics of detergents, method of cleaning and type of cleaning equipment play a major role. Optimization of these conditions poses a great challenge.

Sanitization is the process of treating surfaces with physical or chemical agents that kill most but not necessarily all microorganisms present. It is usually interpreted to mean that microorganisms that produce disease are destroyed. Sterilization, the process of killing all microorganisms is not necessarily accomplished. Heat, as steam, hot water or hot air may be used as sanitizer but it is more costly than chemical sanitization. Chemical sanitizers may have either a bactericidal effect or a bacteriostatic effect. A large number of chemical sanitizers are available. These include compounds bearing chlorine-bromine mixtures, compounds bearing iodine, quaternary ammonium compounds and acid wetting agent sanitizers. Use of right kind of sanitizers in an appropriate manner presents challenge in food processing plants.

5. CONCLUSION

The WTO has endorsed Codex standards as the basis for international trade. The Indian food industry will be on the global scene only if it takes on a new standpoint on the quality and food safety issues and assume the necessary measures to ensure that these issues are understood by all concerned. An important point to be remembered during all stages of production is the maintenance of hygienic conditions. Food safety and quality, thus, demand collective efforts from all quarters of food production.
1. INTRODUCTION

The deposit formation on food processing plant is the main cause of progressive decline in efficiency and performance of the plant. Deposits are invariably poor thermal conductors, and the built-up of deposits on metal surfaces restricts both heat transfer and fluid flow. This results into reduction in time for which a plant can be operated without intermediate cleaning, which is economically undesirable as it reduces the availability of expensive plant and increases the processing costs. Also the problem of deposit formation manifests itself economically through the time and materials required to clean the soiled surfaces and through loss of product and losses of minerals and other nutrients in the deposit layer. This paper deals with deposit formation in heat exchange in general and in UHT processing plants in particular as the problem of deposit formation is more severe in UHT plants due to high processing temperatures.

2. TYPES OF DEPOSITS AND THEIR DISTRIBUTION

In most indirectly heated UHT plants, the deposit formation is greatest in final heating section, where steam or pressurized hot water is the heating medium, and milk is heated from about 85 to 140°C. The type of deposit formed and their distribution throughout the plant is, however, dependent upon whether the milk is preheated (to temperatures above 65°C for some time) or not. If the milk has not been preheated, the maximum amount of deposits occurs at a relatively low temperature (i.e. on 100-150°C) zone of heat exchanger, and the deposits then decreases to comparatively small quantities at the heater outlet (Fig. 1).

![Fig.1. Distribution of deposits without preheating](image)

The type of deposit also changes throughout the heater. The lower temperature deposit (Type A), which comprises the largest amount, it is soft, voluminous, curd-like material, white or cream in colour. It is made up of protein (50-60%), mineral matter (30-35%) and fat content (4-8%). In the higher-temperature part of the heating section,
this deposit charges imperceptibly into a second type (Type-B) which is brittle, gritty, and grey in colour except where it has been overheated at a surface. This deposit has a higher ash content than type A (about 70%) and lower protein content (15-20%). The fat content is similar in 2 types.

When milk is not preheated, plant operation is affected through the restriction of flow passages by the type A deposit in the early part of the final heating section. This results the pressure drop through the plant to increase, but not linearly with time. First there is a period during which the pressure charge is comparatively slight: there is then a sudden change to a much more rapid increase in pressure drop.

If the milk has been preheated, a very different picture appears. After preheating of milk to 85°C for 4-6 min., the type A deposit is absent, the type B deposits occupies the whole of the final heating section. Since the type A deposit, which is very effective in blocking flow passage, it absent after preheating milk, there is much less increase in pressure during an operating run. Pressure is, therefore, much less of a factor in limiting the length of run. Temperature now becomes more important. The deposit is its heaviest in the highest temperature regions of the heat exchanger, reducing the heat transfer coefficients at the last stage of heating. The control system can only react by increasing the temperature & heating medium until, it can go no higher, and the milk processing temperature can be held no longer.

Deposits also occur in the sections before the final heating section, if the temperature is high enough (above 90°C) which are of ‘A’ type. Small amounts of white deposits are also found on cooling section. Deposits found on unheated surfaces of holding section contain high fat (34%), with 37% ash & 20% protein (Burton, 1968).

3. FACTORS AFFECTING DEPOSIT FORMATION

3.1 Plant Operating Conditions

At pasteurization temperatures, milk flow velocity and temperature difference between heating medium and milk are both important. Increase in the flow velocity, reduces the rates of deposition, but the effect becomes less with increasing processing temperature, and at 90°C the effect of velocity is negligible (Gynning et al. 1958).

3.2 Air Content

Air content of heated milk has significant effect on deposit formation. Gynning et al. (1958) found that the total amount of deposit formed was reduced by 50 to 75% during pasteurization at 85°C if air was removed from the milk before processing.

3.3 Age of Milk

Aging of milk after production with the change of pH, either at normal temperature or under refrigeration, causes a marked decrease in the amount of deposit. The amount of deposit falls approximately exponentially with time (Fig.2). The deposit is at its minimum after 15-30 h and then appears to rise slightly (Burton, 1964, 1966). This may be due to redistribution of some of the mineral components following the drop in temperature when to milk leaves the udder or it may be cased by the disappearance of some minor proteins on aging.

3.4 Season

Deposit formation in plate heat exchangers varies with the season. Minimum deposits were observed in May-July of maximum in September-March months. This
variation is probably related to calving period and feeding variations as influenced by season.

3.5 Forewarming of Milk

The value of forewarming of milk in reducing deposits formation was first shown by Bell and Sanders (1944); they found the effects to deposit formation to be reduced to half by preholding conditions of 85°C to 15 sec., 74°C for 10 min. or 71°C for 30 min. Patil & Reuter (1986a, b), studied extensively the deposit formation as influence by the forewarming of milk in direct or indirectly heated UHT Plants.

It was observed that higher the preheating temperature lower was the pressure build up in direct as well as in indirect heat exchangers. The forewarming temperatures up to 80 ºC had no marked effect on the deposit formation. But temperatures beyond 90ºC reduced the deposit formation considerably. The minimum pressure build up was observed at 110 ºC. However, this forewarming temperature resulted in excessive deposits and a corresponding increase in pressure drop in preheater (Fig.3).
pressure build up per litre milk processed than direct process. The corresponding actual weight of the deposits per litre milk processed in final heater was also more in indirect process than in direct process. This may be due to increased surface area available for deposit adsorption in indirect process.

![Fig 4. Effect of forewarming temperatures on distribution of deposits in UHT plant](image)

Fig.4 shows the distribution of deposits as the temperature changes in different regions of the indirect plant. It was observed that more deposits are obtained at the temperature range of 70-100°C when forewarming temperatures below 100°C are used. However, when forewarming temperature of 110°C used, the deposit formation was observed throughout the preheating sections covering the temperature range of 35-110°C. This could be due to the large difference in the temperature between heating surface and milk. The overall deposit formation was less up to 120°C temperature in heating region when 90°C forewarming temperature was used.

The maximum deposits were observed at the temperatures of 135-140°C as can be observed from the peak in this region. Therefore, the deposits formed at this temperature range (which is mostly composed of last two passes of plate heat exchanger) could be responsible for the increase in the pressure in the heat exchanger. It can also be noticed that both the peak height and peak spread is reduced with increasing the forewarming temperatures. The forewarming temperatures did not have any effect on the deposit formation in the temperature range of 135-75°C of cooling region.

The visual observation of deposits at different temperatures of heating and cooling regions showed that the deposits in the temperature range of 35-100°C were soft, voluminous material having white or cream colour and could be classified as type A as per Burton's terminology. The deposits in temperature range of 100-130°C were of both type A or B depending upon the forewarming temperature used. Lower forewarming temperatures from 70-90°C tended to give type A deposits and higher forewarming temperatures of 100-110°C gave type B deposits. The deposits from temperature range of 130-140°C of heating region and range of 135-75°C of cooling region were mainly of type B. The deposits from the last pass of heat exchanger of indirect process as well as from steam injector in direct process were very hard and brown in colour.

The forewarming treatments affected not only the amount of deposit formed but also the composition of the deposits. The increase in the forewarming temperature significantly decreased the protein content and increased the ash content of deposits from...
the final heat exchangers of direct and indirect plants. This observed trend leads us to speculate the possible role of proteins (more specifically serum proteins) in the mechanism of deposit formation as well as the action of forewarming treatments in reducing the deposit formation.

When the unforewarmed milk, where serum proteins are undenatured, is subjected to the high temperature prevalent in final heat exchangers of UHT plants, the instantaneous denaturation and excessive aggregation of serum proteins would be occurring, in way similar to sterilization of unforewarmed evaporated milk. The aggregated denatured serum proteins would then act as nuclei for crystallization of supersaturated minerals resulting in crystal growth and increased deposit formation. However, when milk is forewarmed to the time temperature combination sufficient enough to denature the serum proteins and their depletion through complex formation with k-casein and partly through deposition in low temperature sections of the plant (i.e. preheater etc.), and thus making it unavailable to act as nuclei for the crystal growth. This effect coupled with the favourable changes in salt balance of milk either through conversion of soluble and ionic calcium and phosphorus to colloidal state or recrystallization of calcium phosphate to hydroxyapatite may be responsible in increasing the stability of milk against deposition. More work regarding the characterization of the proteins included in the deposits is necessary before the possible role of proteins in mechanism of deposit formation as well as their role in preventing deposit formation in forewarmed milk can be well explained. However, Lyster has showed evidence for an interaction between denatured β-lactoglobulin and precipitated calcium phosphate when solutions of milk salts and β-lactoglobulin was heated to 100ºC. This seems to explain, at least in part, the intimate relation between minerals and proteins in deposits from heated milk.

The variation in the composition of deposits as the temperature changes progressively in the indirect processing plant was also studied. The forewarming of 90ºC for 90 sec. was used. It was observed that (Fig.5) the deposits formed below 100ºC tended to contain higher protein and lower ash than the deposit formed at the temperatures between 100-140ºC.

![Fig.5. Composition of deposits in different sections of UHT plant](image)

The protein content tended to decrease progressively with increase in the temperature up to 140ºC except at 103 and 140ºC, occasional rise in protein content was observed. The protein content of the deposit again increased in the cooling section. The ash, calcium and phosphorus content of the deposit showed the tendency exactly apposite
to the protein content. The fat content of the deposits was found to be higher in the temperature range of 100-120°C.

Fig.6 shows the effect of preholding time on deposit formation. Some reduction in pressure increase was observed as preholding time was increased from 30 sec. to 120 sec. in both direct and indirect processes. However, the effect was not as perceptible as obtained with increased forewarming temperatures. Also, the increase in the preholding time did not appreciably change the deposition pattern at different temperatures of heating and cooling region of the plant.

![Graph showing the effect of preholding time on deposit formation in UHT plants](image)

**Fig. 6. Effect of preholding time on deposit formation in UHT plants**

### 3.6 pH of milk

The pH of milk showed remarkable influence on the pressure increase in final heat exchanger as well as on the weights of the deposits formed. The relationship between deposit formation and pH was nonlinear, so that the effect of pH became greater as the pH reduced.

![Graph showing the effect of pH on deposit formation in UHT plant](image)

**Fig 7. Effect of pH on deposit formation in UHT plant**

Fig.7 shows the pressure increased per litre milk processed in direct and indirect UHT plants. The reduction in pH up to 6.6 had no marked effect on pressure build up in both UHT plants. The rate of pressure build-up increased considerably as the pH fell below 6.6. This effect was more in indirect than in direct plant. The operation time of indirect plant was drastically reduced when the milk of pH 6.5 was processed indicating...
that the milk of pH 6.5 and below was impossible to process in the indirect processing plant. On the contrary, the direct UHT plant showed better ability to process the low pH milk than indirect process. This could be either due to the effect of dilution of milk, which is taking place due to condensation of steam in direct process or due to the availability of less surface area for deposition (Patil and Reuter, 1988a,b).

![Fig.8. Effect of pH on distribution of deposits in UHT plant](image)

Fig.8 shows that the deposition behaviour of milk of different pH as the temperature changes in the different regions of the indirect plant. As can be seen from the figure that reducing the pH of milk from 6.75 to 6.5 did not show the difference in deposit formation until temperature rises up to 110ºC. Only in the temperature range of 110-140ºC the effect of pH is perceptible, the milk of pH 6.5 showing maximum deposit in this temperature range. The difference between the milks of pH 6.6 and 6.75 was not appreciable. In cooling region also, the 6.5 pH milk showed highest deposits, which were mainly consisted of the particles dislodged from final heating section redepositing in cooling section.

4. CONCLUSION

Deposit formation in heat exchanger is the main cause of progressive decline in efficiency of the plant manifesting itself economically through the time and material required for cleaning. Forewarming of milk at 90-100ºC for 90-120 sec. seems to be the only effective way in reducing deposit formation and increasing the operational time of heat treatment plants.

5. REFERENCES

INTRODUCTION

Cleaning within the food industry has traditionally been as much an art as a science. This can be accounted for by the need to develop detergents before the processes of soiling, cleaning and disinfections were fully understood or analyzed in a scientific manner. Early detergents and their method of application were, therefore, by design, aimed at providing a satisfactory performance. As the function of specific chemicals and the contribution of other factors were researched and, as improvements in plant design, detergent handling and control came about, detergents gradually improved, leading to the high standards expected and obtainable today.

The determination of the correct detergent for any cleaning process in a food or beverage factory is subject to a number of selection criteria. These criteria include plant design and construction, the result required, cleaning techniques available, the type of soil present, the manner in which the soil is formed, the nature of the production process and the chemical composition of water supplies.

2 CRITERIA FOR CLEANLINESS

A successful cleaning application is reliant on consideration of a number of selection criteria. These criteria will vary according to the food product and process concerned. In all cases, the result required must be considered before detergents are selected. There are three commonly used classifications for the level of cleanliness: physically clean, chemically clean and microbiologically clean.

A physically clean surface is one, which is visually cleaned to a satisfactory standard. Within the food processing environment, this standard is limited to nonfood contact areas and covers such applications as floor cleaning in warehouse areas, yards and so on. At the basic level, this standard may not require the use of a detergent, with a satisfactory result obtained using; physical means only, other applications may require the use of light-duty detergents.

A chemically clean standard is applied to all applications within the food processing area. In this instance, plant is cleaned to a standard at which anything in contact with the cleaned surface suffers no contamination. This standard is sometimes referred to as ‘water-break-free’, indicating that the cleaned surface is easily wetted by water. The materials used to provide this standard are numerous, varying from acidic, through neutral to alkaline detergents.

A microbiologically clean standard is required for all direct and indirect food contact surfaces. This standard involved the creation of a water and break-free surface with the elimination of food spoilage and food poisoning microorganisms and a reduction in total viable colonies to an acceptable level. The acceptable level is determined by legislative standards set in a country. The materials used to achieve the microbiologically clean standard are again numerous, and include those used to achieve a chemically clean surface.
For a microbiologically clean surface, the detergents are used in a conjunction with disinfectants to achieve the desired result. Alternatively, combined detergent and disinfectant products, known as sanitizers, may be used.

3 TYPES OF SOILS

Soil may be defined as any unwanted material on a surface. In general, soil may be categorized as organic (derived from living matter) or inorganic (derived from minerals). Primarily alkaline materials remove the former whilst the latter require the use of acids. In reality, the soils encountered are a combination of both inorganic and organic components. Soils vary substantially in composition, which is dependent on processing parameters, including the foodstuffs produced, the processing temperature, the age of the soil and water hardness conditions. (Table 1).

<table>
<thead>
<tr>
<th>Table 1. Variations in milk soil compositions</th>
</tr>
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<tbody>
<tr>
<td></td>
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<tr>
<td>Milk soil on</td>
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<tr>
<td>cold surface</td>
</tr>
<tr>
<td>Average</td>
</tr>
<tr>
<td>Fresh milk</td>
</tr>
<tr>
<td>High bacteria</td>
</tr>
<tr>
<td>Increased milk</td>
</tr>
<tr>
<td>temperature</td>
</tr>
<tr>
<td>Milk soil on</td>
</tr>
<tr>
<td>heated surfaces</td>
</tr>
<tr>
<td>averages</td>
</tr>
<tr>
<td>Increased temperature</td>
</tr>
<tr>
<td>Milk held in</td>
</tr>
<tr>
<td>holding section before heating to high temperature</td>
</tr>
<tr>
<td>Aged milk</td>
</tr>
</tbody>
</table>

Soils produced on heated surface differ significantly from those produced on non-heated surfaces. These variations can have a number of origins. The high temperature of heat exchange units can cause the denaturation of proteins, caramelization of sugars and precipitation of mineral salts, which readily plate out on heat exchange surfaces. In general, oils and fats enter soil residues unaltered, but excessively high temperatures may lead to polymerization of these components.

Food soils obviously vary from one food industry to the next, components of soil types in different applications are determined by the raw materials used during
processing; hence meat and poultry soils have a major fat content, whilst bakery soils may contain carbonized starch and sugar deposits.

To further complicate the matter a combination of processes involved in the manufacture of the food product will modify the raw materials used and, consequently the soil composition. However, some generalizations can be made. Mineral content of soils increases as the temperature is raised. Fat deposits tend to decrease with an increase in temperature but also depend on the history of the milk. Interestingly enough, fresh milk tends to give greater amount of soil, in particular fat, than milk, which has been aged.

Heat exchanger surfaces, such as those found in HTST (high temperature, short time) pasteurizers, usually have only a small amount of fat present, which is presumed to be entrapped by other soils such as proteins. It has also been shown that air drying (as opposed to steam drying), turbulence of the flow of milk products, the microbial quality of the milk, and the acidity of the milk can all affect the nature of milk soils.

4 DETERGENTS AND THEIR SELECTION

The compatibility of the materials used in construction of a process plant with the detergents used to clean that plant is of utmost importance. Any detergent used should not detrimentally affect the construction materials. Limitations due to this factor should be determined at the earliest opportunity to prevent costly damage to capital items. The majority of modern plant is constructed of stainless steel, which is generally resistant to corrosion by detergents and disinfectants. However, in older production plants or in areas were specific materials are required for processing seasons, incompatibility may occur.

A major concern with respect to compatibility is the effect of sodium hydroxide (caustic-soda)-based detergents on aluminium, galvanized and other soft metal surfaces. Contact with such materials will lead not only to rapid corrosion, but also to the release of hydrogen gas, which can form an explosive mixture with air.

Plant design will restrict the detergent selection and method of application. Electrical installations and moisture sensitive processes require the minimal use of water; hence the need for detergents which contain nontoxic and nontainting alcohols. Intricately designed plant which is both difficult and time consuming to clean by hand may require the use of foam-or gel-cleaning techniques which, through longer contact times and greater coverage, can achieve the desired result more rapidly and with a minimum level of manual input. With regard to automated cleaning techniques, such as cleaning-in-place (CIP) and bottle washing, even the equipment used to clean the process plant may dictate detergent selection.

More often than not, cleaning within the food and beverage industries is automated through the use of CIP techniques. In these instances, powerful materials are used, leading to greater reproducibility of results. CIP techniques provide greater control, in terms of temperature, contact time and detergent strength, when compared with manual cleaning.

However, there are areas in which manual cleaning or a degree of manual input is necessary. The use of such aggressive materials in this instance should be avoided on health and safety grounds. In manual cleaning applications, the use of neutral or near-neutral materials is recommended.
The chemical composition of the local water supply will affect the selection of detergents. Water, falling as rain, dissolves gases and becomes mildly acidic. As it percolates through soil and flows over various strata, minerals are dissolved in the water. These dissolved minerals are collectively termed ‘water hardness’ and are measured in parts per million of calcium carbonate (CaCO₃). The quality and quantity of water hardness will vary according to the composition of the rock strata.

Water hardness may be broken down into temporary hardness, which is precipitated by heat, and permanent hardness, which is precipitated by high alkalinity. In any application where alkaline detergents are used at elevated temperatures, there is then the potential for scale deposition on plant surfaces. The result is unsightly and, if it occurs on a direct or indirect food contact surface, it may become a source of physical and microbial contamination. In order to prevent scale deposition, sequestering and dispersing materials are used in alkaline formulations.

In addition to the criteria listed above, there are factors specific to individual applications, which affect detergent selection. Fermentative applications, for example, will generate carbon dioxide, which will rapidly break down sodium hydroxide to sodium carbonates. These will subsequently precipitate as process generated scale.

As can be seen, there is no such entity as the universal detergent and these various selection criteria require the formulation of specific detergents. Not only is the ability of the detergent to clean important, its ease of dispensing, rinsability, chemical stability and other factors, which include safety and cost, must also be given serious consideration. Formulated detergents are a direct response to these challenges.

Formulated detergents are based on acids, alkalis or neutral materials. These materials have inherent properties, which are desirable within a detergent formulation. Acids are effective in dissolving mineral salts and in the hydrolysis of proteins, whilst caustic alkalis will break down carbonized deposits and saponify fats and oils. The neutral materials such as sequestrants and surfactants are used to prevent precipitation of water hardness salts in hot or alkaline solutions and for wetting of soil, soil penetration, soil suspension, reduce surface tension respectively. (Table 2).

It may be argued that since these raw materials have desired properties, there is no need for formulated detergents. However, the drawbacks, in terms of comparatively high use rates, poor rinsability, lack of soil suspension, a reliance on more than one material to achieve the required result, and the time required to clean, far outweigh any advantage. Furthermore, modern process plant demands the use of high-performance, formulated detergents and there are certain applications (e.g. bottle washing) in which raw material alone will not achieve the required result.

Formulated detergents combine the inherent properties of the raw material with those of other components to produce the following required physical and chemical interactions:

1. Wetting of the surface to allow intimate contact between detergent and soil.
2. Chemical reaction with the soil. At least three distinct interactions may occur: saponification by caustic reaction with oils and fats, hydrolysis reactions to solubilize proteins, acidic dissolution of mineral salts.
3. Dispersion of large soil particles into finely divided ones.
4. Suspension of removed soil in the detergent solution.
### Table 2. Detergent types

<table>
<thead>
<tr>
<th>Detergent type</th>
<th>pH range</th>
<th>Commonly used components in order of importance</th>
<th>Typical applications</th>
</tr>
</thead>
<tbody>
<tr>
<td>Caustic</td>
<td>13+</td>
<td>Caustic soda or potash Sequestrants Surfactants</td>
<td>CIP, HTST, cleaning, bottle-washing</td>
</tr>
<tr>
<td>Alkaline</td>
<td>10-13</td>
<td>Carbonates Silicates Phosphates Caustic sods Sequestrants Surfactants</td>
<td>CIP, tray-and crate-washing, floors</td>
</tr>
<tr>
<td>Neutral</td>
<td>5-10</td>
<td>Surfactants Phosphates Solvents</td>
<td>Manual hand-cleaning of plant surfaces, utensils, etc., janitorial applications, personal hygiene products</td>
</tr>
<tr>
<td>Acidic</td>
<td>0-5</td>
<td>Phosphoric acid Nitric acid Sulphamic acid Hydrochloride acid Surfactants Microbiocide</td>
<td>Descalants, formulated acid detergents for low-pH (fermentative) applications, formulated detergents for use in light soil areas (e.g. milk applications in dairies)</td>
</tr>
<tr>
<td>Nonaqueous</td>
<td>5-10</td>
<td>Alcohol Surfactant Microbiocide</td>
<td>Moisture-sensitive areas</td>
</tr>
<tr>
<td>Gel</td>
<td>1-14</td>
<td>Dependent on application</td>
<td>Specialist applications where a long contact time is required to produce a satisfactory result. Materials are either self-gelling on dilution with water or are supplied as gel to be used neat</td>
</tr>
<tr>
<td>Foam</td>
<td>1-14</td>
<td>Dependent on application</td>
<td>Specialist applications. Contact times not as long as gel but better visibility. Air required to generate foam either as secondary injection or by venturi action</td>
</tr>
<tr>
<td>Additives</td>
<td>1-14</td>
<td>Dependent on application</td>
<td>Added to existing detergent or rinsing applications. Categories include scale control, foam control, microbiostatic control (preservative)</td>
</tr>
</tbody>
</table>
5 REFERENCES

British Standard BS 7229. 1989. Quality audit systems, Milton Keynes BSI.
1. INTRODUCTION

In the food facilities, an important routine operation is the cleaning and sanitization of all food contact surfaces. Sanitization is the process of reducing microorganisms to a level acceptable by public health authorities in terms of destruction of pathogens and minimizing other micro flora. While, sanitizers are agents that reduce microbiological contamination to levels confirming to public health requirements. Agents employed for sanitization in food industry may be 1) thermal 2) radiation or 3) chemical Sanitizers.

2. THERMAL SANITIZERS

The effectiveness of thermal sanitizing in dependent upon a number of factors including: microbial contamination load humidity, pH, temperature and time.

2.1 Steam

The use of steam as sanitizer has limited application. It is generally expensive compared to alternatives, and it is difficult to regulate and monitor contact temperature and time. Further, the by-products of steam condensation can complicate cleaning operations.

2.2 Hot Water

Hot-water sanitizing-through immersion (small parts, knives, etc.), spray (dishwashers), or circulating systems-is commonly used. The temperature of the water determines the time required. Typical regulatory requirements (Food Code 1995) for use of hot water in dishwashing and utensil sanitizing applications specify: immersion for at least 30 sec. at 77°C (170°F) for manual operations; a final rinse temperature of 74°C (165°F) in single tank, single temperature machines and 82°C (180°F) for other machines.

Many state regulations require a utensil surface temperature of 71°C (160°F) as measured by an irreversibly registering temperature indicator in ware washing machines. Recommendations and requirements for hot water sanitizing in food processing may vary. The Grade A Pasteurized Milk Ordinance specifies a minimum of 77°C (170°F) for 5 min. Other recommendations for processing operations are: 85°C (185°F) for 15 min., or 80°C (176°F) for 20 min.

The primary advantages of hot-water sanitization are: relatively inexpensive, easy to apply and readily available, generally effective over a broad range of microorganisms, relatively non-corrosive, and penetrates into cracks and crevices. Hot-water sanitization is a slow process, which requires come-up and cool-down time; can have high-energy costs; and has certain safety concerns for employees. The process also has the disadvantages of forming or contributing to film formations, and shortening the life of certain equipment or parts thereof (gaskets, etc.)
3. RADIATION

Radiation in the form of ultra violet, high-energy cathode or gamma rays rapidly destroys microorganisms. Ultraviolet in the wavelength of 25 Angstrom units has been used extensively in the form of “sterilizing” lamp to destroy undesirable organisms in schools, hospitals, homes and for foods on assembly lines, bakeries and other similar applications. Ultraviolet radiations may also be used (contact time in excess of 2 minutes) on surfaces that are heat sensitive viz. flexible packing materials.

4. CHEMICAL SANITIZERS

The ideal chemical sanitizer should

- be approved for food contact surface application
- have a wide range or scope of activity
- destroy microorganisms rapidly
- be stable under all types of conditions
- be tolerant of a broad range of environmental conditions
- be readily solubilized and possess some detergency
- be low in toxicity and corrosivity and
- be inexpensive.

No available sanitizer meets all of the above criteria. Therefore, it is important to evaluate the properties, advantages, and disadvantages of available sanitizer for each specific application.

5. REGULATORY CONSIDERATIONS

The regulatory concerns involved with chemical sanitizers are” antimicrobial activity or efficacy, safety of residues on food contact surfaces, and environmental safety. It is important to follow regulations that apply for each chemical usage situation. The registration of chemical sanitizers and antimicrobial agents for use on food and food product contact surfaces, and on nonproduct contact surfaces, is through the U.S. Environmental Protection Agency (EPA). (Prior to approval and registration, the EPA reviews efficacy and safety data, and product labeling information.

The U.S. Food and Drug Administration (EDA) is primarily involved in evaluating residues form sanitizers use which may enter the food supply. Thus, the FDA must approve any antimicrobial agent and its maximum usage level for direct use on food or on food product contact surfaces. Approved no-rinse food contact sanitizes and nonproduct contact sanitizers, their formulations and usage levels are listed in the Code of Federal Regulations (21 CFR 178.1010). The U.S. Department of Agriculture (USDA) also maintains lists of antimicrobial compounds (i.e., USDA List of Proprietary Substances and Non Food Product Contact Compounds) which are primarily used in the regulation of means, poultry, and related products by USDA’s Food Safety and Inspection Service (FSIS.)

6. SPECIFIC TYPES OF CHEMICAL SANITIZERS

The chemical described here are those approved by FDA for use as no-rinse, food-contact surface sanitizers. In food-handling operations, these are used as rinses, sprayed in to surfaces, or circulated through equipment in CIP operations. In certain
applications the chemicals are foamed on a surface or fogged into the air to reduce airborne contamination.

6.1 Chlorine-based Sanitizers

6.1.1 Chlorine compounds: Chlorine, in its various forms, is the most commonly used sanitizer in food processing and handling applications. Commonly used chlorine compounds include: liquid chlorine, hypochlorites, inorganic chloramines, and organic chloramines. Chlorine-based sanitizers form hypochlorous acid (HOCl, the most active form) in solution. Available chlorine (the amount of HOCl present) is a function of pH. At pH 5, nearly all is in the form of HOCl. At pH 7.0, approximately 75% is HOCl. The maximum allowable level for no-rinse applications is 200 ppm available chlorine, but recommended usage levels vary. For hypochlorites, an exposure time of 1 min at a minimum concentration of 50 ppm and a temperature of 24°C (75°F) are recommended. For each 10°C (18°F) drop in temperature, a doubling of exposure time is recommended. For chloramines, 200 ppm for 1 min is recommended. Chlorine compounds are broad-spectrum germicides, which act on microbial membranes, inhibit cellular enzymes involved in glucose metabolism, have a lethal effect on DNA, and oxidize cellular protein. Chlorine has activity at a low temperature, is relatively cheap, and leaves minimal residue or film on surfaces.

The activity of chlorine is dramatically affected by such factors as pH, temperature, and organic load. However, chlorine is less affected by water hardness when compared to other sanitizers (especially the quaternary ammonium compounds). The major disadvantage to chlorine compound is corrosiveness to many metal surfaces (especially at higher temperature). Health and safety concerns can occur due to skin irritation and mucous membrane damage in confined areas. At low pH (below 4.0), deadly Cl₂ (mustard gas) can form. In recent years, concerns have also been raised about the use of chlorine as a drinking water disinfectant and as an antimicrobial with direct food contact (meat, poultry and shellfish). This concern is based upon the involvement of chlorine in the formation of potentially carcinogenic trihalomethanes (THMs) under appropriate conditions. While chlorine's benefits as a sanitizer far outweigh these risks, it is under scrutiny.

6.1.2 Chlorine dioxide: Chlorine dioxide (ClO₂) is currently being considered as a replacement for chlorine, since it appears to be more environmentally friendly. Stabilized ClO₂ has FDA approval for most applications in sanitizing equipment or for use as a foam for environmental and non-food contact surfaces. Approval has also been granted for use in flume waters in fruits and vegetables operations and in poultry process waters. ClO₂ has 2.5 times the oxidizing power of chlorine and, thus, less chemical is required. Typical use concentrations range from 1 to 10 ppm. ClO₂’s primary disadvantages are worker safety and toxicity. Its highly concentrated gases can be explosive and exposure risks to workers are higher than that for chlorine. Its rapid decomposition in the presence of light, or at temperatures greater than 50°C (122°F) makes on-site generation a recommended.

6.2 Iodine

Use of iodine as an antimicrobial agents date back to the 1800s. This sanitizer exists in many forms and usually exists with a surfactant as a carrier. These mixtures are termed iodophors. The most active agent is the dissociated free iodine (also less stable). This form is most prevalent at low pH. The amount of dissociation from the surfactant is dependent upon the type of surfactant. Iodine solubility is very limited in water. Generally recommended usage for iodophors is 12.5 to 25ppm for 1 min. It is generally
thought that the bactericidal activity of iodine is through direct halogenation of proteins. More recent theories have centered upon cell wall damage and destruction of microbial enzyme activity.

Iodophors, like chlorine compounds, have a very broad spectrum: being active against bacteria, viruses, yeasts, molds, fungi, and protozoans. Iodine is highly temperature-dependent and vaporizes at 120°F. Thus, it is limited to lower temperature applications. The degree to which iodophors are effective depends on properties of the surfactant used in the formulation. Organic matter and water hardness generally affect iodophors less than chlorine. However, loss of activity is pronounced at high pH. Iodine has a long history of use in wound treatment. However, ingestion of iodine gas does pose a toxicity risk in closed environments. The primary disadvantage is that iodine can cause staining on some surfaces (especially plastics).

6.3 Quaternary Ammonium Compounds (QACs)

Quaternary ammonium compounds (QACs) are a class of compounds, which have the general structure as follows (Figure 1):

![Structure of Quaternary Ammonium Compounds](image)

The properties of these compounds depend upon the covalently bound alkyl groups (R groups), which can be highly diverse. Since QACs are positively charged cations, their mode of action is related to their attraction to negatively charged materials such as bacterial proteins. It is generally accepted that the mode of action is at the membrane function. The carbon length of R-group side chain is, generally, directly related with sanitizer activity in QACs composed of large carbon chains, these sanitizers may have lower activity than short chain structures.

QACs are active and stable over a broad temperature range. Because they are surfactants, they possess some detergency. Thus, they are less affected by light soil than are other sanitizers. However, heavy soil dramatically decreases activity. QACs generally have higher activity at alkaline pH. While lack of tolerance to hard water is often listed as a major disadvantage of QACs when compared to chlorine, some QACs are fairly tolerant of hard water. Activity can be improved by the use of EDTA as a chelator. QACs are effective bacteria, yeasts, mold and viruses.

An advantage of QACs in some applications is that they leave a residual antimicrobial film. However, this would be a disadvantage in operations such as cultured dairy products, cheese, and beer, etc. where microbial starter cultures are used. QACs are generally more active against gram positive than gram-negative bacteria. They are not highly effective against bacteriophages. Their incompatibility with certain
detergents makes through rinsing following cleaning operations imperative. Further, many QAC formulations can cause foaming problems in CIP applications. Under recommended usage and precautions, QACs pose little toxicity or safety risks. Thus, they are in common use as environmental fogs and as room deodorizers. However care should be exercised in handling concentrated solutions or use as environmental fogging agents.

6.4 Acid-Anionic Sanitizers

Like QACs, acid-anionic sanitizers are surface-active sanitizers. These formulations include an inorganic acid plus a surfactant, and are often used for the dual function of acid rinse and sanitization. Whereas QACs are positively charged, these sanitizers are negatively charged. Their activity is moderately affected by water hardness. Their low use pH, detergency, stability, low odor potential, and non-corrosiveness make them highly desirable in some applications. Disadvantages include: relatively high cost, a closely defined pH range of activity (pH 2 to 3), low activity on molds and yeasts, excessive foaming in CIP systems, and incompatibility with cationic surfactant detergents.

6.5 Fatty Acid Sanitizers

Fatty acid or carboxylic acid sanitizers were developed in the 1980s. Typical formulations include fatty acids plus other acids (phosphoric acids, organic acids). These agents also have the dual function of acid rinse and sanitization. The major advantage over acid anionics is lower foaming potential. These sanitizers have a broad range of activity, are highly stable in dilute form, are stable to organic matter, and are stable to high temperature applications. These sanitizers have low activity above pH 3.5-4.0, are not very effective against yeasts and molds, and some formulations lose activity at temperatures below 10°C (50°F). They are also can be corrosive to soft metals and can degrade certain plastics, or rubber.

6.6 Peroxides

Peroxides or peroxy compounds contain at least one pair of covalently bonded oxygen atoms (-O-O-) and are divided into two groups: the inorganic group, containing hydrogen peroxide (HP) and related compounds, and the organic group, containing peroxyacetic acid (PAA) and related compounds.

Hydrogen peroxide (HP), while widely used in the medical field, has found only limited application in the food industry. FDA approval has been granted for HP use in sterilizing equipment and packages in aseptic operations. The primary mode of action for HP is through creating an oxidizing environment and generation of singlet or superoxide oxygen (SO). HP is fairly broad spectrum with slightly higher activity against gram-negative than gram-positive organisms. High concentrations of HP (5% and above) can be an eye and skin irritant. Thus, high concentrations should be handled with care.

Peroxyacetic Acid (PAA) has been known for its germicidal properties for a long time. However, it has only found food-industry application in recent years and is being promoted as a potential chlorine replacement. PAA is relatively stable at use strengths of 100 to 200ppm. Other desirable properties include: absence of foam and phosphates, low corrosiveness, tolerance to hard water, and favorable biodegradability. PAA solutions have been shown to be useful in removing biofilms. While precise mechanisms of mode of action mechanisms have not been determined, it is generally theorized that
the PAA reaction with microorganisms is similar to that of HP. PAA, however, is highly active against both gram-positive and gram-negative microorganisms. The germicidal activity of PAA is dramatically affected by pH. Any pH increase above 7-8 drastically reduced the activity. PAA has a pungent odor and the concentrated product (40%) is a highly toxic, potent irritant, and powerful oxidizer. Thus, care must be used in its use.

A general comparison of the chemical and physical properties of commonly used sanitizers is presented in Table 3.

7. FACTORS AFFECTING SANITIZER EFFECTIVENESS

7.1 Physical Factors

7.1.1 Surface Characteristics: Prior to the sanitization process, all surfaces must be clean and thoroughly rinsed to remove any detergent residue. An unclean surface cannot be sanitized. Since the effectiveness of sanitization requires direct contact with the microorganisms, the surface should be free of cracks, pits, or services, which can harbor microorganisms. Surfaces, which contain biofilms, cannot be effectively sanitized.

7.1.2 Exposure Time: Generally, the longer time a sanitizer chemical is in contact with the equipment surface, the more effective the sanitization effect; intimate contact is as important as prolonged contact.

7.1.3 Temperature: Temperature is also positively related to microbial kill by a chemical sanitizer. Avoid high temperatures (about 55°C (131°F) because of the corrosive nature of most chemical sanitizers.

7.1.4 Concentration: Generally, the activity of a sanitizer increases with the increased concentration. However, a leveling off occurs at high concentrations. A common misconception regarding chemicals is that “if a little is good, more is better”. Using sanitizer concentrations above recommendations does not sanitizer better and, in fact, can be corrosive to equipment and in the long run lead to less cleanability. Follow manufacturer’s label instructions.

7.1.5 Soil: The presence of organic matter dramatically reduces the activity of sanitizers and may, in fact, totally inactivate them. The adage is “you cannot sanitize an unclean surface”.

7.2 Chemical Factors

7.2.1 pH: Sanitizers are dramatically affected by the pH of the solution. Many chlorine sanitizers, for example, are almost ineffective at pH values above 7.5.

7.2.2 Water properties: Certain sanitizers are markedly inactivators may react chemically with sanitizers giving rise to non-germicidal products. Some of these inactivators are present in detergent residue. Thus, it is important that surfaces be rinsed prior to sanitization.

7.3 Biological Factors

The microbiological load can affect sanitizer activity. Also the type of microorganisms present is important. Spores are more resistant than vegetative cells. Certain sanitizers are more active against gram positive than gram-negative microorganisms, and vice versa. Sanitizers also vary in their effectiveness against yeasts, mold, fungi, and viruses.
8. REFERENCES

Table 3. Comparison of the Chemical and Physical Properties in Commonly Used Sanitizers*

<table>
<thead>
<tr>
<th></th>
<th>Chlorine</th>
<th>Iodophors</th>
<th>QACs</th>
<th>Acid anionic</th>
<th>Fatty Acid</th>
<th>Peroxyacetic acid</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Corrosive</strong></td>
<td>Corrosive</td>
<td>Slightly corrosive</td>
<td>Noncorrosive</td>
<td>Slightly corrosive</td>
<td>Slightly corrosive</td>
<td>Slightly corrosive</td>
</tr>
<tr>
<td><strong>Imitating to skin</strong></td>
<td>Irritating</td>
<td>Not irritating</td>
<td>Not irritating</td>
<td>Slightly irritating</td>
<td>Slightly irritating</td>
<td>Not irritating</td>
</tr>
<tr>
<td><strong>Effective at pH 7</strong></td>
<td>Yes</td>
<td>Depends on type</td>
<td>In most cases</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td><strong>Effective at acid pH</strong></td>
<td>Yes, but unstable</td>
<td>Yes</td>
<td>In come cases</td>
<td>Yes, below 3.0-3.5</td>
<td>Yes, below 3.5-4.0</td>
<td>Yes</td>
</tr>
<tr>
<td><strong>Effective at alkaline pH</strong></td>
<td>Yes, but &lt; neutral pH</td>
<td>No</td>
<td>In most cases</td>
<td>No</td>
<td>No</td>
<td>Less effective</td>
</tr>
<tr>
<td><strong>Affected by organic material</strong></td>
<td>Yes</td>
<td>Moderately</td>
<td>Moderately</td>
<td>Moderately</td>
<td>Partially</td>
<td>Partially</td>
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<tr>
<td><strong>Affected by water hardness</strong></td>
<td>No</td>
<td>Slightly</td>
<td>Yes</td>
<td>Slightly</td>
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<td>Slightly</td>
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<tr>
<td><strong>Residual antimicrobial activity</strong></td>
<td>None</td>
<td>Moderate</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>None</td>
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<td><strong>Cost</strong></td>
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<td>High</td>
<td>Moderate</td>
<td>Moderate</td>
<td>Moderate</td>
<td>Moderate</td>
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<td><strong>Incompatibilities</strong></td>
<td>Acid solutions, phenols, amines</td>
<td>High alkaline detergents</td>
<td>Anionic wetting agents, soaps, and acids</td>
<td>Cationic surfactants and alkaline detergents</td>
<td>Cationic surfactants and alkaline detergents</td>
<td>Reducing agents, metal ions, strong alkalis</td>
</tr>
<tr>
<td><strong>Stability of use solution</strong></td>
<td>Dissipates rapidly</td>
<td>Dissipates slowly</td>
<td>Stable</td>
<td>Stable</td>
<td>Stable</td>
<td>Dissipates slowly</td>
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<tr>
<td><strong>Maximum level permitted by FDA without rinse</strong></td>
<td>200ppm</td>
<td>25ppm</td>
<td>200ppm</td>
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<td>Varied</td>
<td>100-200ppm</td>
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<td><strong>Water temperature sensitivity</strong></td>
<td>None</td>
<td>High</td>
<td>Moderate</td>
<td>Moderate</td>
<td>Moderate</td>
<td>None</td>
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<td><strong>Foam level</strong></td>
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<td>Moderate</td>
<td>Low/Moderate</td>
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<tr>
<td><strong>Phosphate</strong></td>
<td>None</td>
<td>High</td>
<td>None</td>
<td>High</td>
<td>Moderate</td>
<td>None</td>
</tr>
<tr>
<td><strong>Soil load tolerance</strong></td>
<td>None</td>
<td>Low</td>
<td>High</td>
<td>Low</td>
<td>Low</td>
<td>Low</td>
</tr>
</tbody>
</table>

*Comparison made at approved “no-rinse” use levels. Adapted from B.R. Cords and G.R. Dychdala, 1993.
1 INTRODUCTION

Milk is the most nutritious and complete food for neonates and adult human beings. For the same reasons, it is also a perfect breeding ground for umpteen microorganisms including pathogens and a potential source for chemical contaminants such as antibiotics and pesticides. In view of the immense dietary importance of milk, the need to produce safe, clean and wholesome milk is of profound significance. The two principles that universally guide the safe handling of raw milk are:

- Avoiding or minimizing contamination at various stages of handling raw milk
- Reducing the growth and activity of microorganisms in raw milk.

Knowledge of the possible unhygienic practices that lead to the gross contamination of milk will be useful in realizing the gravity of the situation and in evolving improved strategies. The possible undesirable practices that are prevalent may broadly be classified into four categories:

- Practices related to the animal: unhealthy animal, unclean body and udder of the animal
- Practices related to the milking personnel: unhealthy milker, unclean hands and clothes of the milker, unhygienic personal habits of the milker
- Practices related to the milking process: incomplete milking, wrong milking procedure, unclean vessels for milk collection
- Practices related to the environment: poor housing and feeding of the animal, unhygienic surroundings

2 MEASURES FOR PRODUCTION OF CLEAN MILK

Milk plays a vital role in human health and therefore, it is important to device steps to ensure production of ‘clean’ and ‘safe’ milk free from visible dirt and extraneous particles, harmful microorganisms and hazardous chemicals such as residues of antibiotics and pesticides. Improving the methods of milk production in villages would be the foremost step in the introduction of any comprehensive system of public health supervision and quality control. It is, therefore, necessary to establish a minimum set of practices that would improve significantly, the quality of milk at the level of the individual producer. The following hygienic practices are to be strictly adhered to by the producer, to ensure clean milk production.

2.1 Hygiene of the animal

2.1.1 Health of the animal: The animals should be examined periodically for udder and other infections. Infected animals should be treated by a qualified veterinarian and should be isolated. Sanitary precautions to prevent and control the disease should be adopted. Milk of the infected animal should never be pooled with the bulk milk until the animal recovers from the illness fully.
2.1.2 Cleanliness of body: The coat of the animal should be washed, brushed and clipped regularly. This is more important in the case of buffaloes, as they wallow in dirty ponds and carry mud and filth on their body. The grooming of the animals should be done well before the milking process, so that the dirt particles in the air do not fall into milk. From time to time, hair from hind legs, udder and tail of the animal to be milked should be shaved off.

2.1.3 Udder washing: All udder washing and cleaning should be done gently so as not to damage the orifices and clefts between the quarters of the udder. For all washing, two buckets (one with plain water and a second, which carries the disinfecting solution) with two separate cloths for both the purposes are required. A third bucket with a mild detergent solution and a third cloth is recommended for wiping the teats after milking. Addition of hypochlorite (500 ppm) helps to disinfect the udder. Quaternary ammonium compounds (200 to 400 ppm) are better substitutes due to their less harmful effect on tissues. Under Indian conditions, the easily available Dettol or Savlon may be diluted as per the manufacturers’ instructions and used to disinfect the udder and teats. Disposable paper towels may be used instead of cloth. However, under the Indian conditions, these may be impractical.

2.2 Hygiene of personnel

Clothes & attire of the milking personnel should be clean. They should cover their head to avoid hair falling into the milk. Persons with injury, skin and infectious diseases should not handle the milk. There should be no smoking, eating, chewing pan, spitting, cleaning nose etc. during milking. The milker should keep his fingernails short and clean. He should clean his hands with soap and clean water followed by an antiseptic solution. They should then be wiped dry with a clean towel. It is recommended that persons engaged in milking and handling of milk should be subjected to regular medical inspection.

2.3 Hygienic practices during milking

The milking should be complete, with no milk left in the udder after milking. The first few ml of milk should be discarded, as this contains a large number of microorganisms. This forestripping should be collected in a cup or a utensil and not thrown on the floor, so that flies and other insects may not be attracted towards it. Milking should be done with full hands, quickly and completely, followed by stripping, if so required. Milking operation should be complete in 7-8 minutes. In farms with more than 8 high-yielding cows, it is preferable to use a milking machine. If the herd exceeds 100, a separate milking parlour will ensure better hygiene. Sick cows should be milked at the end to prevent infection. The animals should be dried off 60-70 days before calving.

2.4 Hygiene of milking utensils

All milking utensils should be of uniform size. They should have small mouths to avoid external contamination. They should be made of a non-rusting and non-absorbent material such as aluminium or galvanized iron. Stainless steel would be ideal, but for the cost considerations. The use of vessels such as empty dalda tins, pesticide/insecticide containers, teapots and such should be avoided. The utensils should be free from dents, cracks and crevices. The utensils should be scrubbed and cleaned before and after each milking. The detergents and chemicals used should be non-injurious to health, and non-abrasive to hands. At farm level, use of washing soda coupled with exposure to sunlight or rinsing with scalding water or use of detergents-cum-disinfectants such as iodophors is recommended. The cleaned vessels should be placed inverted for complete drainage of water after milking, so as to avoid contamination from bacteria of the air, insects,
rodents, mosquitoes, reptiles etc. In villages where milk collection is carried out by co-operative societies, the use of community milking byres/parlours with facility to clean and disinfect udders/teats as well as milking equipments under the supervision of the society officials is recommended. Milk should immediately be transferred from the barn to the milk room.

### 2.5 Hygiene of milking environment

The places, where housing, feeding and milking of the animals are done, need special care in order to minimize contamination of the milk. In the animal house system, the animals are housed during winter and milked in the same building. This system has been practiced in temperate countries for many years, the extent of its adoption varying in different countries according to climatic conditions. The animal house is a specialized building, which should be carefully designed and constructed so as to provide comfortable and healthy housing for the cows and at the same time to enable them to be milked in clean conditions. The major points to be considered are siting, planning and layout, walls and floors of the housing and ease to clean them, stall divisions, adequate water supply, lighting and proper ventilation, drainage facilities, dung disposal, isolation boxes for sick animals.

### 3 Straining of milk

A clean muslin cloth should be tied on the mouth of the milk-collecting vessel to strain off all extraneous matter. Although straining would not remove microorganisms, it will expel all particulate matter, thus improving the aesthetic appeal of milk.

### 4 Cooling of milk

The strained milk should preferably be chilled immediately to 4°C to prevent the proliferation of microorganisms. In places where milk is stored in cans before transportation, bulk can coolers are the best options. Some of the other cooling options practiced may be air-cooling, water-cooling, ice cooling and mechanical cooling. The cooling aids usually used are household refrigeration, direct expansion surface cooler, expansion bulk tank, ice bank and chilled water.

### 5 Transportation of milk

The basic system of milk transport in India comprises the transport of milk from the farm to the collection center (in small vessels or in cans), from the collection center to the chilling center (in cans or small tankers) and from the chilling center to the processing plant (in insulated road tankers). The quality of milk will deteriorate during transit if the surfaces that are in contact with the milk are not sufficiently clean and the milk is at too high a temperature.

#### 5.1 Preventive measures

All the measures recommended for clean milk production at the farm should be strictly adhered to, so that the initial quality of milk is good. Milk should be held for minimum time at the farm at ambient temperatures. In general, transport of uncooled milk can be justified only if great care has been taken in its production (number of organisms below 100,000/ml) and if the milk is processed or chilled to a low temperature not more than 3 h after its production. The collection centre should be equipped with a basic cooling system (in-can chiller). For larger quantities of milk, a surface cooler or plate chiller with a tank storage system is recommended, especially if the holding period between reception and transport to the dairy is long. The milk should be chilled to below...
4ºC at the chilling centre. At the dairy, the temperature of the milk should not exceed 4ºC when it is received in road tankers. Cleaning and sterilization of all equipment used, whether small containers, cans or road tankers, should be carried out immediately after emptying. The tankers are usually cleaned in processing dairies using manual method or CIP.

6 CLEANING AND STERILISATION OF MILKING EQUIPMENT

In the production of clean milk, the cleanliness and sterility of the equipment is of prime importance. Cleaning and sterilization are complementary processes, as neither alone will achieve the desired results. These can be separate processes or can be combined as in the case of chemical sterilisation. The term ‘cleansing’ is frequently used to indicate cleaning combined with (or followed by) sterilization and satisfies the condition that all equipment surfaces are free of milk residues as well as bacteria. All cleaning procedure comprise of 1) a pre-rinse with tepid water to remove all extraneous soil and wet the surface, 2) removal of soil from the surface by solution, emulsification, saponification or mechanical action or a combination of these, 3) dispersion of the undissolved soiling matter, 4) removal of the detergent solution along with the suspended and dissolved soil, and 5) final rinsing to remove the last trace of detergent.

6.1 Detergents

Detergents help to free the surface of the milking equipment from fat and milk residues. The type and strength of detergents used depends on the method of washing. Detergents in general are not disinfectants. However, strong alkaline detergents, if used hot are bactericidal. When alkaline detergents are used for hand washing, the concentration should not be more than the equivalent of 0.25% sodium carbonate. This is not applicable in circulation cleaning or CIP.

6.2 Sterilisation by heat

Heat may be applied to equipment surfaces on the farm in the form of steam, boiling water or hot water. When heat sterilization is applied to manual washing, as in most Indian conditions, cleaning and sterilization are separate processes. A scheme for cleansing milking equipment is given below.

6.2.1 Cold water rinse: The outside dirt and residual milk from the surfaces should be removed by a cold/lukewarm water rinse. This should be done immediately after the vessels are emptied, because if the milk solids are allowed to dry on the surface, it will be extremely difficult to remove them by rinsing.

6.2.2 Hot detergent wash: The hot detergent wash is best done in a wash trough. The temperature of the detergent solution should be about 46ºC, so as to be comfortable on the hands. The quantity of detergent used will depend on its type. The amount of detergent used should approximately equal 115 g of soda ash or 230 g of washing soda per 45 l of water. If the concentration of alkali is stronger than this, it will lead to gradual defatting of the skin of the hands. The milking equipment should be brushed in the hot detergent with suitable brushes to remove the surface residues.

6.2.3 Final clean rinse: The final traces of detergent should be removed by a rinse of clean water. If the water is hard, it is advisable to use hot water, as a cold rinse will leave a deposit on the utensils.

6.2.4 Steam sterilisation: The efficiency of steam in destroying microorganisms is greater than that of scalding/hot water. However, under Indian conditions, the latter is more practical. In large organized farms where milking machines are used, the use of
steam is more convenient. Moist heat a few degrees below boiling point (~ 96°C) for about 10 min is sufficient to kill all microorganisms other than the most resistant spores.

6.2.5 **Hot water sterilisation:** Boiling or scalding water may be used in small farms, where the number of equipment to be sterilized is too small to warrant the installation of a boiler. As with steam, scalding water is used after the cleaning process. Temperature should be as near the boiling point as possible (never below 85°C). The utensils should be immersed for 1 min, but where this is not possible, boiling water should be poured over the milk-contact surfaces till they are too hot to touch.

6.3 **Sterilisation by chemicals**

Sterilisation of farm equipments with the use of chemicals is preferred to the use of steam, as it does not involve the heavy capital expenditure of installing a boiler. Whereas steam sterilisation is governed only by time and temperature, chemical sterilisation is dependent on several factors such as 1) the strength of the disinfectant solution, 2) contact time, 3) temperature, 4) speed of action of the disinfectant and its specificity against various types of microorganisms, 5) ability of the disinfectant to wet and cover the surface and also to penetrate any deposit on the surface and 6) type of surface.

The common groups of chemical sanitisers that are used are hypochlorites (ca and sodium), organic chlorine-containing chemicals (chloramines, dichlorodimethyl hydrantoin, trichloroisocyanuric acid), quarternary ammonium compounds and iodine compounds (iodophor).

7 **FEEDS AND MILK CONTAMINATION**

Clean milk production must also ensure that feedstuffs offered to animals are not a potential source of contamination, which is passed on to milk, thereby putting human lives in danger. Some of these aspects, which have drawn attention in recent times, are described hereunder.

7.1 **Feeds and mammary infections**

Feeding does have an impact on mastitis. Proper nutrition can decrease new mammary infection rates by improving the animal’s immunity. The immune system of the animal combats disease by antigen/antibody reactions and/or the ability of white blood cells (somatic cells) to kill bacteria. Key micronutrients (added in relatively small amounts per day) that can improve immune response are selenium, zinc, copper, vitamin A and vitamin E. Studies have shown that proper amounts of vitamin E and selenium during lactation and dry period results in a 42 per cent reduction in mammary infections, and 68 per cent reduction in high somatic cell counts.

7.2 **Protein feed ingredients of animal origin**

Protein feed ingredients made from animal tissues are prohibited for consumption of dairy animals. FDA approved, in August 1997, rules preventing the establishment and spread of Bovine Spongiform Encephalopathy (BSE). The disease, known as ‘Mad Cow Disease’ has been found in European cattle herds and according to recent newspaper reports are relevant to India as well. The rule bans most types of protein made from mammalian tissue, like meat and bone meal made from cattle by-products. Cattle may become infected with BSE when they eat contaminated protein products made from rendered diseased animals. Feed manufacturers, protein blenders, and rendering companies are required to label any feeds or feed ingredients containing prohibited
material with the warning statement, "Do not feed to cattle or other ruminants." The rule has several provisions that apply to dairy producers:

7.3 **Aflatoxin in animal feeds**

Aflatoxin are a group of toxicants formed by moulds in improperly stored nuts, grains etc. By limiting the levels of aflatoxins in animal feeds, the levels in the milk and milk products can be minimised. The recommended action levels for aflatoxins as per FDA guidelines should not be more than 20 ppb for corn, peanuts, cottonseed meal, and other animal feeds and feed ingredients intended for dairy animals, for animal species or uses not specified above or when the intended use is not known.

8 **ANTIBIOTIC, DRUG & PESTICIDE RESIDUES IN MILK**

The usefulness of antibiotics and drugs against mastitis and other diseases in animals have rendered them almost indispensable in veterinary medicine. The administration of these substances, however, results in the secretion of their residues into milk. Similarly, the use of pesticides to control any pest, including unwanted species of plants or animals during the production, storage, transport, distribution and processing of food, agricultural commodities and animal feeds leads to the retention of these products or their derivatives in the product. Such residues pose serious threat to public health by entering into the milk when these materials containing pesticides are used as cattle feed. The consumption of such contaminated milk has physiological and technological implications. Adequate measures should be taken to prevent minimum secretion of these residues in milk.

9 **CONCLUSION**

The post-WTO scenario suggests that for sustainability, Indian dairy industry will have to step forward in the area of hygiene and cleanliness in order to improve the quality of milk. The foremost measure to be adopted at the grassroots level is the education of farmers on health and hygiene of animals, precautions to be exercised in the use of veterinary drugs and medicines and the significance of high levels of antibiotics and their residues in milk. Farmers will have to be urged not to use milk of sick animals. Adequate initiatives to produce fodder and feed free from pesticides, aflatoxins and heavy metals will have to be taken. In order to tackle quality-related problems, modernisation of the domestic supply chain is very essential. In this context, there is an urgent need to create and provide infra-structural facilities at all stages of milk handling. These may range from chilling facilities at village level, adequate and accurate testing facilities with trained manpower for routine testing as well as sophisticated techniques and maintenance of cold chains, considering the tropical climate of the country.

10 **REFERENCES**

DEALING WITH SANITATION STANDARDS AND REGULATIONS: LEGAL ASPECTS

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¹ General Manager, ² Bacteriologist, ³ Trainee Student
Model Dairy Plant, NDRI, Karnal

1. INTRODUCTION

Over the past several years, there has been significant change in consumer perception on quality and food safety. Consumers are demanding healthy, nutritious and cost-effective products processed under controlled hygienic conditions. In anticipation of consumer demands on food safety, food sanitary standards at national and international levels are under constant review.

With the expanding significance of global food trade, the need for a more universal food code will be paramount in the near future. The Food and Agriculture Organization (FAO) and the World Health Organization (WHO) have set up a Codex Alimentarius Commission (CAC) and subsidiary bodies that present a unique opportunity for all countries to join the international community in formulating food standards and working towards their global implementation. Development of the dairy portion of the codex is in process and will be of significance in governing the hygienic processing practices and recommendations relating to compliance with dairy product standards that can be adopted globally.

In order to meet International Sanitation Standards and Regulations, establishment of food hygiene during the entire chain from production to processing is essential for the Indian dairy industry. India being a tropical country with wide climate variations besides poor organizational and infrastructure facilities, this is a big challenge. Preparations are already underway at various levels to strengthen the national food control system in order to keep pace with the global movement on “Food Safety”.

2. CURRENT STRATEGIES FOR ACHIEVING EFFECTIVE SANITATION DURING FOOD PROCESSING

At the farm level Good Agricultural Practices (GAP) and Good Veterinary and Animal Husbandry Practices minimize contaminants residues such as pesticides, drugs etc. Good hygiene practices (GHP) minimize physical and microbiological contaminants and in combination with Good Manufacturing Practices (GMP) prevent contaminants at the processing site. There is a continuum of effective controls needed not only by producers and manufacturers but also by distributors, transporters, consumers and competent authorities in order to produce a safe and suitable food product under controlled sanitary conditions.

Sanitation areas and their standards at food processing sites fall under the following seven heads: 1) condition and cleanliness of food contact surfaces, 2) protection of food, food packaging material and food contact surfaces from adulteration, 3) prevention of cross contamination, 4) safety of process water, 5) ingredients/packaging material, 6) no evidence of pest in the food plant and 7) control of employee health conditions and hygiene.

Implementing General Principles of Food Hygiene enhances effectiveness of the sanitation programme during food processing. This involves 1) plant establishment, 2) process control, 3) prevention of cross contamination, 4) adoption of Sanitation
Standards Operating Procedures (SSOPs) and 5) providing effective training to the personnel. Some of these are highlighted below:

2.1 Implementing SSOP for effective sanitation of food contact surfaces

Cleaning and sanitation are fundamental to the success of any dairy plant. However, dairy companies are placing even greater emphasis on sanitation throughout the entire process including receiving, processing and packaging. Codex recommends dairy plants to develop their own SSOPs and verify the adequacy of cleaning. Written SSOPs their periodic revision sanitation maintenance schedule should be in place for food areas and food contact surfaces (equipment, utensils, overhead structures, floors, walls, ceilings, drains, lifting devices, refrigeration unit and anything else impacting on safety of dairy foods.

2.2 Safety management system for effective process sanitation

Incorporation of the Hazard Analysis Critical Control Point (HACCP) system helps in identifying the potential hazards in the process operations based on viability/proliferation of the contaminants and their control measures. It determines the critical control points, defines critical limits and their monitoring and thus guards the food against any food safety hazards. The use of HACCP was given on international dimension by CAC on food hygiene as an annexure to the Codex “Recommended International Code of Practice: General Principles of Food Hygiene”. Revised guidelines for the application of HACCP System (ALINORM 03/13A, Appendix II) have been endorsed by CAC in its 26th session held during 30th June-7th July’2003 at Rome to make HACCP more flexible to small and/or less developed business.

2.3 Implementation of CAC hygiene code for effective sanitation during production and processing of milk and milk products.

Codex Committee on Food Hygiene (CCFH) is elaborating the code on General Principles of Food Hygiene. The draft code of “Hygiene practices for Milk and Milk Products” was documented at the 35th session of the CCFH held from 27th Jan’2002 to 1st Feb’2003 at Orlando, Florida (USA). It is currently at step 5 of the procedure for its final approval by CAC. This code is a complete document on hygienic conditions required during the entire food chain. The application of these codes will improve the sanitary quality of dairy food, raw materials/ingredients in terms of prevention from adulteration of food contact surfaces, prevention of cross contamination, control of process operation, control of employee health and exclusion of pest etc. The codex is flexible enough to be applicable to different milk production systems including smallholder dairying system prevalent in our country.

2.4 Training of personnel on sanitation and legal standards

Personnel involved in the entire food chain should be trained as necessary and have appropriate skills. It is important to recognize the need for, and facilitate short term and long-term focus on education and training for all sectors so that those who are involved in food chain can effectively carry out their responsibilities of ensuring the safety of food. The education and training throughout the food chain assumes a greater significance when harmonization with codex is taken up as a policy issue in making national food safety regulations.
3. MEETING GLOBAL FOOD SAFETY/SANITARY REQUIREMENTS: LEGAL ASPECTS

With the expanding significance of global trade after the establishment of WTO, a free trade in safe food across international borders was agreed. WTO paved the way for several multilateral agreements on trade, which include Technical barriers to trade (TBT) relating to all goods and Sanitary and Phytosanitary agreement (SPS) concerning agricultural products. The quality aspects of all primary products of plant and animal origin fall under SPS measures.

3.1 Agreement on SPS measures

In regard to food, the term Sanitary and Phytosanitary measure means any gauge applied to protect human and animal life or health within the territory of the member countries from risk arising from food additives, contaminants, toxins or disease causing organisms in foods, beverages, or feed stuffs. For animal life and health, the SPS agreement recognizes the standards adopted and recommended by the International Office of Epizooites (OIE) and for plant life and health, those recommendations of the International Plant Protection Convention (IPPC). The organizations Codex, OIE and IPPC are known as three sisters. Only those measures that are necessary to send measurement must be based on scientific principles.

The SPS agreement specifically refer to standards, guidelines and recommendation of the CAC as the bench mark for dispute settlement as well as basis for harmonization of national food legislation. This was done to avoid the trade restriction arising due to Variation in the procedures of national food control systems involving monitoring and sampling, detection and analytical methods, certifications, import/export regulation, application of standards and food safety regulations. Therefore, while carrying out the process of harmonization, it is imperative that national legislations on food safety are based on sound science.

3.2 Establishment of CAC

Codex Alimentarius in Latin means Food Code. CAC is an international commission, a body of over 165 countries, constituted by FAO and WHO, whose objective is to protect the health of consumers and to ensure fair practices in food trade. The Codex Alimentarius is a collection of international standards for the safety and quality of food as well as codes of good manufacturing practices and other guidelines to protect the health of consumers and remove unfair practices in international trade and settling disputes in WTO. CAC brings together the collaboration of technical experts, scientists, governments, consumers and industry representatives to assist in developing standards for food manufacturing and trade.

3.3 Guidelines on the judgment of equivalence of sanitary measures

Sanitary measures that conform to the international standards (CAC) are presumed to be in conformance with the requirements of the SPS agreement. But, where the importing country measures differ from the exporting country’s measures, the latter may be determined to be equivalent if the exporting country can objectively demonstrate that its measures achieve the appropriate level of protection of the importing country. The Codex Committee on Food Inspection and Certification System (CCFICS) has proposed these guidelines to the CAC. Under the agreement, all measures are to be based on risk assessment (RA) of the risk to human health using internationally accepted risk assessment techniques. CAC has developed these procedures further for use by Codex member countries. Principal for risk analysis in the frame work of Codex include a
provision that requires that risk assessment should be based on data from different parts of the world including developing countries, based on realistic exposure scenarios, including susceptible and high risk population groups and taking into account acute, chronic and cumulative adverse health efforts.

4. GLOBALIZATION OF INDIAN FOOD SAFETY LAWS

India’s contribution in world food trade is relatively insignificant despite high foodstuff production of 500 million tons annually. One of the major factors for such low exports has been the food quality and food safety aspect. To ensure a strong presence in global markets, India needs to meet the challenges and keep pace with the development at international level market.

There are various bodies dealing with standards formulation activities. There are a number of food safety regulations (mandatory or voluntary) that are implemented by various Ministries/Departments within India. The review of multiple laws is necessary to have uniform and logical approach for regulating the quality of food and for harmonizing with the international regulations. Various ministries are taking the following actions.

4.1 Harmonization of BIS standards

BIS is the largest body for formulating standards for various food items. It is voluntary. The Indian standards IS:15000:1998 on Food Hygiene – HACCP system and guidelines for its application is equivalent to FAO/WHO, CAC document.

The Ministry of Civil Supplies and Consumer Affairs has brought out a paper for consideration of Committee of Secretaries (COS). The paper recommends that BIS should formulate standards for all food items in the country. This will be a major step towards harmonization of food laws and is still under consideration of COS for finalization.

4.2 Harmonization of PFA standards

The primary national public agency for India is Prevention of Food Adulteration Act 1954 and its amendment of 1955. It is mandatory. The Central Committee for Food Safety Standards (CCFSS) of the Director General of Health services, Ministry of Health and Family Welfare are responsible for its implementation. The task force constituted by the Prime Minister under the chairmanship of Shri Nuslsi Wadia has submitted its report which is under the consideration of the government. The task force has advocated promotion of food safety and quality and has further made the following suggestions:

- Food Regulation Authority (FRA) to be set up to formulate and update food standards for domestic and export market.
- FRA should replace the PFA to conform to international standards.

The task force has given ten specific recommendations which include standard methods of analysis, provision of adequate infrastructure/laboratories, harmonization of Indian standard with the quality norms of Codex and WTO and FRA governing body for expeditious decisions to replace the Central Committee on Food Standards (CCFS).

4.3 Essential commodities act

A number of quality control orders have been issued under Essential Commodities Act such as Milk & Milk Products Order (MMPO), Meat Product Order (MPO) and Vegetable Oils Control Order (VOCO). These orders are mandatory and are primarily meant for regulating the hygienic conditions. The Government of India’s latest amendment of MMPO (March’2002) from the Department of Animal Husbandry and
Dairying (Ministry of Agriculture), in its fifth schedule now includes Sanitary/Hygiene measures for Quality and Safety of food which shall be applicable even for the business handling <10,000 l of milk per day. These so many orders that need to be included in a single order, which may later be named the Food Products Order (FPO).

4.4 Harmonization of Export Inspection and Certification System

In the area of export inspection and certification systems, a decision has already been taken to take into account international guidelines (ISO-17020)- “The general criteria for the operation of various types of bodies performing inspection” as well as Codex standard. Laboratories to provide back up to certification are also being strengthened in terms of equipment, manpower, and system. In addition recognition and networking of laboratories in the country both for domestic testing as well as for imports/exports is being done. Establishment of Export Inspection Council (EIC), as the official certifying body of the government of India has already been designated as competent authority by the European commission for marine products, and basmati rice and is awaiting recognition for egg products and milk products.

4.5 Codex Contact Point in India

The Codex Contact Point in India is the Director General of Health Services (DGHS) in the Ministry of Health and Family Welfare. However, the Department of Food Processing Industries is closely associated with the activities of Codex Alimentarius. The department had made provision of Rs. 100.00 Lakh in the budget of 2000-2001 for creating the database, technical examination of various standards in association with experts and coordination as well as participation in international Codex meetings.

5. THE HINDRANCES IN HARMONIZATION

On several aspects, our present dairy standards do not fully comply with the codex guidelines/international standards. For instance, the MRL of lead in butter was 0.05 ppm as endorsed by the Codex Committee on Food Additives and Contaminants (CCFAC) in the 24th session of CAC at Geneva in July 2001. Indian delegations objections to this MRL and the request to revert it to 0.5 ppm was considered. Currently at its 26th session held at Rome the CAC has revoked the MRL of 0.005 ppm for lead in butter, as proposed by CCFAC. Another instance is the maximum permissible Aflatoxin level of 30 ppb as specified by PFA for all articles of food while it is individually specified for Aflatoxin B<sub>1</sub>, and M<sub>1</sub> as follows :

<table>
<thead>
<tr>
<th></th>
<th>MRL μg/Kg (ppb)</th>
<th>EU</th>
<th>USA</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aflatoxin B&lt;sub&gt;1&lt;/sub&gt;, Animal Feed</td>
<td>5</td>
<td>20</td>
<td></td>
</tr>
<tr>
<td>Aflatoxin M&lt;sub&gt;1&lt;/sub&gt;, Milk</td>
<td>0.05</td>
<td>0.5</td>
<td></td>
</tr>
</tbody>
</table>

Such discrepancies ask for India’s more active participation in Codex Committee with a clear view of India’s position. The next session of the Codex Committee on Pesticide Residues (CCPR) being held at New Delhi in April 2004 is an opportune time for India to raise its concerns and inhibitions on the related issues.

6. CONCLUSIONS

Adoption of sanitary measures such as GMP, GHP, SSOP and the HACCP system, as advocated by CAC, would minimize the entry of contaminants (microbiological, chemical, physical) during food processing. The international food standards/guidelines/codes related to food hygiene and sanitation formulated by the
codex are accepted by the WTO, as the reference points for the global food trade. In due course of time, most of the national food standards, if not all, are likely to be harmonized with those of codex and the food industry would be required to comply with those standards even for foods produced for domestic consumption. Obviously this applies to the dairy industry as well.

India has recognized the need for an adequate homework and national consensus on issues related to harmonization of food hygiene/sanitation/safety laws with international laws. India is working to strengthen its national food control system and an FAO project for the same is under way with DGHS. Provision of infrastructure, modernization of food analytical laboratories, the setting up of a universal food regulating authority in place of multiple food laws, stringent enforcement of food safety laws and inspection procedures and above all a mindset towards “clean and safe food” throughout the food chain, shall comfortably accommodate India in the global food trade.

7. REFERENCES


Laws Relating to Food Processing Industries. A Publication of Ministry of Food Processing Industries.


1.0 INTRODUCTION

Cleaning and sanitization are complimentary processes. While cleaning refers to removal of soil from the surface of the equipment, sanitization implies to the destruction of all pathogenic and almost all non-pathogenic organisms. Either of the processes alone will not achieve the desired result, which is to leave the surface as free as possible from soil and viable organisms. In actual practice cleaning and sanitization overlap to some extent, as during cleaning a high proportion of bacteria are destroyed and others get removed in the detergent solution. Faulty cleaning and sanitization can have serious consequences, as milk is a perfect nutrient in which bacteria can multiply. Cleaning operation requires labour; also indiscriminate use of cleaning compounds results in wastage without improvement in cleaning. An understanding of the cleaning methods is therefore, necessary for improving product quality while effecting cost saving.

2.0 SOIL FORMATION

Soil formation is basically an exothermic reaction that occurs spontaneously due to mechanisms such as mechanical trapping, electrostatic attraction, and hydrogen bond attraction, deposits resulting from mixture of mineral constituent precipitated from hard water and heated product residues that adhere tenaciously to the equipment. Mechanical entrapment is generally of minor significance, may be important in case of cervices, joints and porous surfaces. The relative significance of other forces depends on the nature of surface to be cleaned and the nature of soil to be cleaned.

2.1 Constituents of dairy soil

Dairy soil primarily consists of milk or milk product residues, which may be more or less modified by processing treatment or by interaction with water or cleaning materials previously used, or by dust, dirt or other foreign matter. The accumulated dried soil consists largely of fat, protein (precipitated, coagulated and baked-on by heat), insoluble calcium salts from water and washing detergent and bacteria. It has approximately 2.7 to 8.7 % moisture, 3.6 to 18.0 % fat, 4.5 to 44 % protein and 42-67.0 % ash.

2.2 Distribution of constituents in dairy soil

The continuous phase of the dairy soil consists of insoluble protein, with inclusion of low melting fat globules, soluble lactose crystals and flocks of insoluble calcium phosphate.

3.0 MECHANISM OF CLEANING

Cleaning is the reversal of soiling process requiring a supply of energy usually supplied in the form of mechanical and or heat energy. Essentially, water does most of the cleaning. Cleaning compound or detergents reduces the energy required for soil removal. Process. Detergent has been defined as “an substance that either alone or in a
mixture, reduces the work requirement of a cleaning process’ (Bourne, 1961). Cleaning mechanism consists of followings:

1. **Wetting** of soiled surface i.e. bringing the clearing solution into intimate contact with the soil to be removed. For this the solution should have adequate wetting and penetrating properties.

2. **Displacement** of the soil from the surface by solution, emulsification, saponification, peptization and / or mechanical action.

3. **Dispersion** of soil removed from the surface in the solution by dispersion, deflocculation or emulsification.

4. **Rinsing** to prevent redeposition of the dispersed soil on the cleaned surface.

### 4.0 CLEANING STEPS

Cleaning systems should be straightforward and foolproof. Improper cleaning and sanitization protocols result in high cost, product spoilage, equipment damage and some times even hospitalization of employee. Great care must therefore; be taken in the initial cleaning program design to ensure that all equipment is safely and effectively cleaned. All good cleaning protocols should involve at least four steps: pre-rinse, wash, post-wash and sanitization. Eliminating any of these steps may inevitably increase the cost of cleaning and result in ineffective cleaning of the equipment. The purpose of each cleaning step is shown in Table 1.

#### Table 1. Cleaning Steps

<table>
<thead>
<tr>
<th>Step</th>
<th>Purpose</th>
</tr>
</thead>
</table>
| **1. Pre-rinse** | 1. Remove visible soil  
                      2. Melt fats  
                      3. Prevent protein adherence  
                      4. Prevent thermal shock |
| **2. Wash**    | 1. Remove remaining soil  
                      2. Chemicals lift biofilms that bind to equipment surfaces |
| **3. Post-rinse** | 1. Removes suspended soils and chemical residues  
                          2. Prepare surface for sanitization |
| **4. Sanitizing** | 1. Kills bacteria that remain on equipment surface  
                                   2. Must contact surfaces for at least 1 min |

### 5.0 CLEANING METHODS

Cleaning methods can broadly be classified as 1) Manual cleaning, 2) Mechanical cleaning and 3) In-place cleaning.

#### 5.1 Manual Cleaning

This requires scrubbing the food particles off the equipment. Very mild acid or neutral cleansers are used because they are less corrosive to human skin. To allow safe handling by workers, the water temperature must be maintained between 44 and 50°C. Manual cleaning is time consuming, but it requires less capital investment.

#### 5.2 Mechanical Cleaning

**5.2.1 High-pressure low volume:** High-pressure sprays are used with mild non-foaming cleansers. Once manual rinse is completed, high-pressure sprays are used to wash, rinse and sanitize the equipment. The water is applied in a low volume at a high pressure of about 1000 psi.
5.2.2 Air blowers (high pressure) and vacuum: In dusty environments, high-pressure air blowers are used to blow down dust from high and difficult-to-reach places and then the entire area is vacuumed using a central vacuum system that filters and then exhausts to the outside.

5.3 Cleaning In-place

5.3.1 Two stage cleaning: The conventional (manual) method of cleaning is time consuming, expensive, labor intensive and often unsatisfactory in terms of bacteriological cleanliness. In the technique known as CIP (Cleaning -in- Place) the rinse water and detergent solution(s) etc. are circulated through tanks, process lines, piping etc. without dismantling the equipment. The success of CIP procedures depends on various factors such as
   a) Proper engineering and installation
   b) Temperature of the cleaning solution
   c) Adequate velocity of the cleaning solution
   d) Use of detergents designed especially for recirculation cleaning and
   e) Sufficient cleaning time

5.3.2 Single Stage Cleaning: Conventionally the dairy equipments are cleaned (CIP) in two stages, caustic cleaning followed by acid cleaning. Often one more caustic cleaning is done to remove residual acid. Thus, it becomes a 5 to 7 step CIP cleaning process (pre-rinse, caustic, rinse, acid clean, rinse, weak alkali and final rinse). It also takes more total cycle time of 80-100 mins. Single stage cleaning on the other hand, is essentially a 3 step cleaning process (pre-rinse, cleaning and rinse) using lesser time, water and energy. Also studies conducted on comparison between cleaning and sanitization performance by dual and single stage technique revealed single stage cleaning to be more efficient.

6 NEWER APPROACHES

6.1 Foam/Gel Cleaning

Cleaning of vertical surfaces (by CIP) has been a problem because of very less contact time between detergent and the soiled surface. Also some equipment is very large and difficult to assess manually. Foam or gel cleaning technique is relatively new. It typically consists of:
   a) Generating foam/gel and spraying it with very low pressure
   b) Longer contact and
   c) Rinsing of foam/gel.

The foam/gel cleaning technology involves development of foam/gel application equipment and development of optimum product suitable for its application. Lever Industrials of Hindustan Lever has developed this technology and has implemented in many countries (Godbole, 1996).

6.2 The Dry Ice Blasting Process

Dry ice blasting is a relatively new cleaning process using solid CO₂ pellets known as dry ice. The pellets sublime or convert directly from a solid blast pellet to CO₂ gas leaving no residue. This process is environment friendly and is extensively used in USA. Contract cleaning services using solid-carbon technique is also available (info@rsg-technologies.com).

The process involves propelling dry ice particles from a blasting gun at a hyper-velocity to impact and clean a surface. The particles are accelerated by compressed air, similar to other blasting systems. The micro-thermal shock (caused by the dry ice
temperature of \(-79^\circ C\), the kinetic energy of dry ice pellets and the air pressure break the bond between the coating and the substrate. The dry ice sublimates to \(\text{CO}_2\) gas and expands to about 400 times its original volume. The coating then pops off from inside out and the air stream removing it from the surface yet creating no secondary waste stream. Dry ice blasting is claimed to reduce cleaning time, manual labor, reduce downtime through CIP. The method also claims to clean ovens without its pre-cooling and thus reducing its cleaning time by 150% or more.

7. FACTORS AFFECTING CLEANING

Many variables work together to provide an effective cleaning program. The variables that must be given due consideration while developing a cleaning program are listed below.

7.1 Solution Temperature

Table 2. Effect of Solution Temperature on Cleaning

<table>
<thead>
<tr>
<th>Temperature</th>
<th>Effect</th>
</tr>
</thead>
<tbody>
<tr>
<td>Minimum temperature</td>
<td>• Melt and suspend fats and oils</td>
</tr>
<tr>
<td></td>
<td>• Ensure minimum chemical activity</td>
</tr>
<tr>
<td>Maximum temperature</td>
<td>• Some chemicals are ineffective at high temperatures</td>
</tr>
<tr>
<td></td>
<td>• Chemicals may be much more corrosive (chlorine)</td>
</tr>
<tr>
<td></td>
<td>• Equipment may not be able to withstand high temperature stress</td>
</tr>
<tr>
<td>Final temperature</td>
<td>• Should cool equipment</td>
</tr>
</tbody>
</table>

7.2 Duration of Application

a. All treatments must have a minimum contact time.

b. Maximum contact times apply to highly corrosive chemicals.

7.3 Mechanical Action

a. Equipment surfaces must be adequately scrubbed by mechanical action.

b. Clean in place cleaning systems require minimum flow rates.

7.4 Chemical Concentration

The correct type and concentration of chemical must be used. Improper use can be a) ineffective, b) harmful to equipment and c) dangerous to the personnel.

7.5 Soil Solubility

a. Specific soil is resistant to certain chemicals

b. Select chemicals to dissolve soil typical of operation.

Table 3. Soil Characteristics

<table>
<thead>
<tr>
<th>Soil Component</th>
<th>How To Remove</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sugars</td>
<td>Water</td>
</tr>
<tr>
<td>Fat</td>
<td>Surface-active solutions</td>
</tr>
<tr>
<td>Protein</td>
<td>Alkaline solutions</td>
</tr>
<tr>
<td>Mineral salts</td>
<td>Acid solutions</td>
</tr>
</tbody>
</table>
7.6 Water Hardness
   a. Interferes with cleaners and sanitizers
   b. Equipment subject to staining and film build-up
   c. Controlled by additives.

7.7 Other Water Impurities
   a. Can cause difficult stains, films or corrosion;
   b. Controlled by additives.

8. SANITIZATION
   Process of cleaning is not complete unless the cleaned surface is sanitized. Presence of soil on the surface of the equipment reduces sanitizer efficiency. Sanitizers are designed to kill bacteria and other microorganisms that remain on the equipment surface. Details of sanitization process have been discussed elsewhere in this compendium.

9. REFERENCES
   Anon. 1994. Revolutionary Cleaning Technology. Dairy Foods 95 (9) 110-111
1 INTRODUCTION

In a food processing plant, an important routine operation is the cleaning and sanitization of all food contact surfaces. The effectiveness of this operation largely determines the number and types of bacteria entering into the food products. Cleaning and sanitization are complementary processes; neither alone will achieve the desired end-result, which is to leave the contact surface as free as possible from food residues and from microorganisms to a level considered safe from public health viewpoint in terms of the destruction of pathogens. Cleaning and sterilization can be separate processes or they can be combined, as for example with some methods for chemical sterilization. The term ‘cleaned’ is frequently used to indicate that equipment has been cleaned and sterilized. In dairy practice it is rare that both conditions are completely satisfied. Milk-contact surfaces are seldom completely free of bacteria.

2 USE OF DETERGENTS AND SANITIZERS

Detergents are necessary for cleaning, but the type of detergent used and its concentration will depend on the method employed. For example, washing can be done by hand or mechanically when alkaline detergents are used for hand washing the concentration should not be more than the equivalent of 0.25% sodium carbonate, otherwise the solution will be too alkaline for hands. Detergents help to free the surface of utensils from fat and milk residues, but do not destroy microorganisms. However, strong alkaline detergents, especially if used hot, are bactericidal.

The word sanitary is derived from the Latin word ‘sanitas’ that means health. So sanitary refers to anything that pertains to health or preservation of health and in sanitary means injuries to health or that are unhealthful. Sanitization is the process of reducing microbial contamination of the food contact surface to a level considered safe from public health viewpoints. It conveys the idea of disinfection without any residue harmful to subsequent users of the article or product as well as elimination of any contamination, which might be aesthetically objectionable. Sanitization plays an important role in food industry as microorganisms cause spoilage of food and transmit diseases through infected foods. It is particularly true in dairy industry where milk is liable to bacterial spoilage since it works as a rich medium for their growth and rapid multiplication.

3 ASSESSING THE CLEANLINESS AND STERILITY OF EQUIPMENTS

The extent of residual bacterial contamination on equipment in a dairy plant can be measured by 1) Swab Rinse Method, 2) Contact Agar Colony Count Method or the 3) Product Quality Measure Method.

3.1 Swab Rinse Method

a) Swab Method: Swab method is applied to a large or small areas on flat or carved surfaces while rinsing methods are used for bottles, cans and other utensils which
could be closed for rinsing. In these methods attempt is made to measure the actual number of microorganisms, which remain on the plant, and to demonstrate their growth by allowing the bacterial cell to form colonies. Swab/rinse and agar colony count methods are rather expensive than product quality measure method due to involving colony count. The following procedure is adopted for the swab test.

- Remove the pre-sterilized swab from the glass tube containing 25 ml. Or Ringer’s or phosphate buffer and with heavy pressure rub back and forth over the area surface are treated twice (where possible an area of 900 cm$^2$ shall be examined). The swab shall be rotated so that all parts of it make contact with the surface.
- Swab samples are to be tested immediately, if not they shall be placed in a refrigerator at 2 to 3°C and examined not later than 24 hours.
- Prepare 1 ml and 0.1 ml plates, using yeastrel milk agar or tryptone glucose agar and incubate at 37.0° ± 0.5°C for 48 hours and count the colonies
- The results shall be expressed as the colony count per 900 cm$^2$.
  \[(\text{colony count per ml x } 25 \times \text{ area factor, if not } 900 \text{ cm}^2)\]
- The following standards are suggested as a guide for grading.

<table>
<thead>
<tr>
<th>Colony count per 900 cm$^2$</th>
<th>Classification</th>
</tr>
</thead>
<tbody>
<tr>
<td>Not more than 5000</td>
<td>Satisfactory</td>
</tr>
<tr>
<td>Over 5000 to 25000</td>
<td>Fairly satisfactory</td>
</tr>
<tr>
<td>Over 25000</td>
<td>Unsatisfactory</td>
</tr>
</tbody>
</table>

b) Rinse Method: In this method any one container is rinsed under standard conditions. It is simpler than swab method. But it has the disadvantages that a larger volume of Ringer’s solution or phosphate buffer is required and the method can only be used where rinsing is feasible for containers, such as milk bottles and cans. This method gives information on the bacteriological condition of bottles or cans immediately after washing. The minimum number of bottles to be examined at each test shall be four selected at random. The following procedure is adopted for bottles.

- Add 20 ml of the sterile Ringer’s solution or the phosphate buffer to the bottle irrespective of thesis and close the bottle with the previously sterilized rubber bang.
- Hold the bottle horizontally in the hands and rotate gently 12 times in one direction so that the whole of the internal surface is thoroughly wetted.
- Allow the bottle to stand for not less than 15 and not more than 30 minutes and again gently rotate 12 times so that the whole of the internal surface is thoroughly wetted.
- Prepare 5 ml plates in duplicate using yeastrel milk agar or tryptone glucose agar and incubate at 37.0°± 0.5°C for 48 hours.
- Count the colonies and results are expressed as colony count per bottle. That is the sum of the counts on the two plates multiply by two
- One colony per milliliter of the capacity of the bottle is satisfactory and over one colony per milliliter is unsatisfactory.

The sterility of milk cans is assessed as follows:

- Cans are selected at random after washing and examined with an interval of not less than a half and not more than one hour.
- Pour 500 ml of the sterile solution over the inside of the lid into the can and replace the lid.
- Lay the can on its side and roll to and fro so that it makes 12 complete revolutions.
- Pour the solution direct from the can into a sterile container.
- Lid and can may be examined separately also.
- Test the samples immediately, if not then store in a refrigerator at 2°C to 3°C and examine not later than 24 hours.
- Mix the sample by inverting the container slowly three times.
- Prepare 1 ml and 0.1 ml plates, using yeastrel milk agar or tryptone glucose agar and incubate at 37°C± 0.5°C for 48 hours.
- Count the colonies and express the results as the colony count per can (colonies per milliliter or rinse x 500)
- Calculate the colony count per l capacity of the can.

<table>
<thead>
<tr>
<th>Grading (colony count per l capacity)</th>
<th>Classification (For dry or moist can)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Not more than 1000</td>
<td>Satisfactory</td>
</tr>
<tr>
<td>More than 1000 but less than 5000</td>
<td>Fairly satisfactory</td>
</tr>
<tr>
<td>Above 5000</td>
<td>Unsatisfactory</td>
</tr>
</tbody>
</table>

### 3.2 Contact Agar Colony Count Method

This method is very simple in operation and avoids requirements for dilution water, pipettes, petri-dishes, etc. and hence a large number of tests can be performed in a short time. The bottles are collected in the same manner as described for the rinse test. These are kept in an air-conditioned room or in a refrigerator for 10 to 15 minutes to cool the glass, which helps in formation of an even film of agar when bottle is spun. The test is carried out as follows.

- Pour 10 to 15 ml (depending upon the size of the bottle) of melted and cooled yeastrel milk agar or tryptone glucose extract agar into the bottle.
- Replace the rubber bung and spin it rapidly so that even film of agar is formed on the inner surface of the bottle.
- Incubate the bottle at 37°C± 0.5°C with the stopper downwards so that any condensate drains towards the stopper.
- Count in a bright light the number of colonies developed in the bottle.
- The results are recorded as the colony count per bottle.
- One colony per milliliter of the capacity of the bottle is satisfactory and over one colony per milliliter is unsatisfactory.

### 3.3 Product quality measure method

In this method product which passes through or over the equipment is measured for its bacteriological quality and especially for changes in quality. The sterility of pipeline lines, coolers and bottle fillers and judged by taking a sample or milk (A) with sterile pipette or dipper directly from pasteurizing vat just before starting the milk pump, and taking another sample (b) from the bottle-filler valves before bottling into sterile containers. The milk samples are tested for standard plate count and presence of coliform organism according to standard procedure.
Interpretation

- When standard plate counts of sample (b) exceed those of sample (a) by 100 percent plus 2000
- Positive coliform tests of sample (b) (Since samples from pasteurizer should normally be free from coliform bacteria)
1 INTRODUCTION

In Dairy and Food Industry, the maintenance of hygienic conditions is a prerequisite to the production of quality products. This is accomplished by the use of appropriate cleaning agents with or without sanitizers. Thus, the word ‘detergent’, as it applies to the dairy industry means a substance or formulation used for cleansing or removal of soil, dirt or foreign matter from a surface. For efficient cleaning of dairy and food equipments different types of detergents are being currently employed. However, reports indicate that most of the formulations tested do not give satisfactory results in removal of milk stones and have one limitation or the other.

One of the most difficult problems in dairy processing is the removal of proteinaceous milk stones formed during pasteurization and UHT sterilization of milk. Adoption of new processing technologies such as ultrafiltration (UF) and reverse osmosis (RO) offers new challenges to cleaning operations. The membranes employed in these operations are susceptible to fouling, leading to blockage of membranes pores. Synthetic detergent formulations are not efficient in handling these specific problems of the dairy and food industry. Furthermore, these detergents are corrosive, toxic and non-biodegradable and cause environmental contamination.

To counter these limitations, enzyme-based detergents are fast emerging as an alternative to synthetic detergents owing to their biodegradability, low toxicity, non-corrosiveness, environmental friendliness, enhanced cleaning properties, increased efficiency and stability in different formulations. They are therefore also being referred to as “green chemicals”. In this context, there is a need to use “biodetergent or biocleaners”, which offer a better option to the synthetic detergents with respect to their biodegradability, low toxicity, non-corrosiveness environmental-friendliness, enhanced cleaning properties and their increased efficiency and stability in different formulations. These detergent formulae contain either microorganisms or their metabolites. Of these, enzyme detergents are proving extremely useful because they 1) check environmental pollution, 2) are biodegradable, 3) have low toxicity, 4) are non-corrosive and 5) have enhanced cleaning properties.

2 ENZYME BASED DETERGENT FORMULATIONS

Presently, proteases, amylases, lipases and cellulases make up the major portion of the market for industrial enzymes in cleaning applications. Proteases, the first enzymes to be introduced into detergent formulation, are used to clean or remove protein-based residues like blood, egg and milk (casein and whey proteins). Amylases have been included in detergent formulations to remove starch based stains, such as gravy, pudding and potato. Lipases demonstrate their cleaning advantages and triglyceride based residues, such as margarine, milk fat and oil. Most recently, cellulases have been included for colour maintenance or restoration benefits on cotton fabrics. All of these enzymes are specific for a particular application, yet all are classified as hydrolyzing enzymes or hydrolases based on their mechanism of action (Table 1).
Table 1: Hydrolase enzymes and their substrate

<table>
<thead>
<tr>
<th>Sr. No.</th>
<th>Enzyme type</th>
<th>Substrate</th>
<th>Natural Source</th>
<th>Reaction Catalyzed</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Protease</td>
<td>Proteins, polypeptides</td>
<td>Proteinaceous food, milk, meat products and cheese</td>
<td>Hydrolysis of amide or peptide bond</td>
</tr>
<tr>
<td>2</td>
<td>Lipase</td>
<td>Tri, di, mono glycerides</td>
<td>Milk fat, natural animal &amp; plant fat</td>
<td>Ester bond hydrolysis</td>
</tr>
<tr>
<td>3</td>
<td>Amylase</td>
<td>Amylose, Amylopectin</td>
<td>Starch based soils flour, potato and gravy</td>
<td>Hydrolysis of 1, 4 glycosidic bond</td>
</tr>
<tr>
<td>4</td>
<td>Cellulase</td>
<td>Cellulose</td>
<td>Amorphous cellulose vegetable, fruit and grains or cereals</td>
<td>Hydrolysis of β 1, 4 glycosidic bonds.</td>
</tr>
</tbody>
</table>

2.1 **Historical development of biodetergents**

The original idea of using enzymes as biodetergent was first described by Dr. Otto Rohm. He patented the use of pancreatic enzymes in pre-soak detergent composition to improve their ability to remove proteinaceous stains and first enzymatic detergent, named “Burnus” was launched. However, it was not commercialised because enzyme could be made available by extraction of pancreatic glands in only limited amounts. Moreover, functional enzymes trypsin and chymotrypsin with pH optimum between 7-9 were sold only until 1940s. The first detergent containing a bacterial protease *BIO 40*, produced by Schnyder in Switzerland appeared on market in 1959, swiftly followed by very successful market in Netherlands. The enzymes used were alkaline serine protease from *Bacillus licheniformis*. Consequently, since 1971 application of amylases, lipases and cellulases also came to picture in detergent formulations.

2.2 **Proteases**

Protease enzymes were first hydrolases introduced into detergent formulations specifically for the degradation of protein-based stains. Proteases have been classified according to the nucleophile or reactive component found at their catalytic sites. There are now four broad categories of proteases: serine, sulphydral, metallo and aspartyl proteinases. Of all these classes of proteases, only the serine proteases are suited for inclusion in detergent formulations. The aspartyl proteinases function poorly or not at all in alkaline pH range of detergent formulation. The metallo proteases do not survive the builders present to reduce water hardness, and the sulphydral enzymes are generally too slow and are not compatible with oxidants, such as bleach.

The first enzymatic detergent contained enzymes from pig pancreatic glands. However, it was not very effective in cleaning purposes because it was not stable in high alkalinity of detergent formulation. Therefore, a large number of microorganisms, such as yeasts, fungi and bacteria were screened. Among bacteria, bacilli are superior to other genera for large-scale enzyme production in large fermentation vessels of certain technological advantages.

2.2.1 **Advantages of microbial proteases**

a. Cultivation time of microbial proteases is short as compared to other microorganisms, which reduces costs by keeping aeration time and agitation time brief
b. Desired proteases are secreted into fermentation broth and usually proteases are
pure. Other enzymes are secreted in only small amounts (or are digested by
protease: i.e. autopurification)
c. Cell mass can be easily removed by basic operations, such as centrifugation or
filtration, with filter presses or belt filters
d. *Bacillus* species produced proteases with sufficient stability in alkalinity of
detergent formulation
e. Enzymes are not inactivated by surfactants, oxidative (bleaching) agents and
elevated temperatures (to 90°C) normally higher temperature employed during CIP
in dairy and food industry

Several species of bacilli are used for production of enzymes. The first species to
be used was *Bacillus subtilis* for production of alkaline proteases in large amounts.
However, it has some disadvantages, such as it produces three enzymes; amylase, neutral
protease and alkaline protease and their purification are difficult. Another drawback of
*B. subtilis* is its filterability and biomass removal is difficult. Later on, other bacterial
species, such as *B. licheniformis* and other alkalophilic strains were used for protease
production (Table 2).

<table>
<thead>
<tr>
<th>Table 2 Commercially available proteases containing detergents</th>
</tr>
</thead>
<tbody>
<tr>
<td>Brand</td>
</tr>
<tr>
<td>Milezyme</td>
</tr>
<tr>
<td>Alcalase</td>
</tr>
<tr>
<td>Maxatase</td>
</tr>
<tr>
<td>Optimase</td>
</tr>
<tr>
<td>Savinase</td>
</tr>
<tr>
<td>Maxacal</td>
</tr>
<tr>
<td>Optionean</td>
</tr>
<tr>
<td>Kazusase</td>
</tr>
<tr>
<td>Purafect</td>
</tr>
<tr>
<td>Esperase</td>
</tr>
<tr>
<td>Blap</td>
</tr>
<tr>
<td>Maxapem</td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td>Durazym</td>
</tr>
</tbody>
</table>

* genetically modified

2.3 Lipases

Different greasy food stains, such as tomato based sauces, butter, dressings,
edible oils and chocolate, etc; cosmetic stains, animal and vegetable fat including milk
fat components of milk stones deposited on equipments of dairy and food industry are
not removed completely by the application of proteases in detergent formulations. The
introduction of lipase in detergent formulations is of more recent than introduction of
protease and amylase. Novo Nordisk launched the first lipase product in 1987. Lion
incorporated lipase from *Humicola lanuginose* – the trade name Lipolase in their HI Top
brand on the Japanese market. Subsequently, Genencor Inc. followed in 1993 with Lumafast (a cutinase from *Pseudomonas meddocina*) and Gist-Brocades in 1995 with Lipomax (lipase from *Pseudomonas alcaligenes*).

### 2.3.1 Mode of action:
Lipases are glycerol ester hydrolases capable of hydrolyzing the water-insoluble triglyceride components into more water-soluble products, such as mono and diglycerides, free fatty acids and glycerol. Fatty acid moiety of triacylglycerol can range from short-chain to long chain $C_{18}$ (stearic acid) or may be saturated or unsaturated fatty acid. Only those with shorter chain lengths are slightly soluble. Lipases show substrate specificity. Its activity is neglected towards monomeric, water-soluble form and is largely increased when substrate is in aggregated i.e. emulsified insoluble form. Because lipase is apparently active only at water-substrate interface, this phenomenon is referred to as interfacial activation. Mechanism of action of lipase involves: (i) Physical binding of enzyme to the surface (at lipid-water interface), leading to a confirmation change that make the active site accessible to substrate molecule and (ii) Enzymes form a complex with substrate molecule which results in carboxyl ester bond hydrolysis.

### 2.3.2 Limitation of lipases as detergent:
As lipases can hydrolyse fat and improve the cleaning efficiency. However lipase uses as a part of a detergent present some difficulties, such as (i) Lipase similar to proteins are adversely affected by extremes in temperature, pH ionic strength and matrix composition (ii) Temperature effects are extremely pronounced in lipase ability to hydrolyse fatty oils *in situ*. Its activity is higher at elevated temperature but remarkably reduced at low temperatures (20°C/10 min., granular detergent + lipolase) as the target sites are solids, reducing accessibility to lipase (iii) It shows complete removal after several washing cycles and is considered a major drawback (iv) It shows sensitivity towards the inhibition by various detergent ingredients e.g. a. Surfactants, non ionics and particularly anions, generally cause irreversible unfolding, denaturation and inactivation of enzymes b. Bleaching agents-capable of oxidizing amino acids, such as cysteine, methionine and aromatic ones, such as tryptophan, phenylalanine and tyrosine. The oxidized enzyme can be considered to be cropped with a reduced catalytic efficiency c. Binders- because of their ability to bind divalent cations, such as Ca$^{++}$ results in unfolding and irreversible inactivation of enzymes

Finally, the presence of protease in a detergent may cause proteolysis of other enzymes present.

### 2.3.3 Genetically modified lipases:
To counteract the above limitations, the properties of lipase are improved by genetic engineering. *Pseudomonas alcaligenes* lipase has been improved by inducing mutation at active site i.e. replacement of methionine at position 21 by leucine influences the cleaning performance. On inducing mutation, it has been found that mutant M21L would become active ingredient of new product Lipomax instead of wild type enzyme. The gene from lipase of *Humicola lanuginose* has been cloned into fungus *Aspergillus oryzae* because of good fermentation properties of this genus. The activity of enzyme is improved in terms of increased washing performance, increased cleaning in first wash cycle, and improved efficiency preferentially at lower temperature; broaden stain specificity and lower sensitivity towards inhibition by appropriate mutation (deletion or substitution) or transfer of gene from one organism to another.
Table 3. Main detergent lipases

<table>
<thead>
<tr>
<th>Brand Name</th>
<th>Origin</th>
<th>Genetically Modified</th>
<th>Producer</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lipolase</td>
<td><em>Humicola lanuginosa</em></td>
<td>Gene cloned in <em>Aspergillus oryzae</em></td>
<td>Nova Nordisk; USA</td>
</tr>
<tr>
<td>Lumafast</td>
<td><em>Pseudomonas glumal</em></td>
<td>Gene cloned in <em>Bacillus lentus</em></td>
<td>Genencor, California</td>
</tr>
<tr>
<td>Lipomax</td>
<td><em>Pseudomonas alcaligenes</em></td>
<td>Self Cloning</td>
<td>Gist-Brocades, The Netherlands</td>
</tr>
</tbody>
</table>

2.4 Starch

Starch is a major component of most of our daily food all over the world. Consequently, it is found on clothes or dishes in most stains generated during preparation or consumption of meals containing food ingredients, such as sauce, porridge, mashed potatoes or chocolate. This creates a need for effective removal of starch from clothes, dishes by detergent composition especially in automatic dishwashing. Phosphorylated starches are used as emulsifiers for preparation of salad dressings, ice cream, mustard, gravy, and similar food products. Therefore, residues removal is essential in food and dairy industry equipments after their manufacture as well as from textiles and clothes after its consumption by the consumers.

The starch degrading enzymes are $\alpha$-amylase, isoamylase, pullulanase, glucoamylase, etc. The $\alpha$-amylases are mainly used in detergents, although recently pullulanases or isoamylases are also prepared from *B. subtilis*, *B. amyloliquefaciens* and *B. licheniformis* and are available under different trade names (Table 4).

Table 4. Main detergent amylases

<table>
<thead>
<tr>
<th>Brand Name</th>
<th>Source</th>
<th>Producer Company</th>
</tr>
</thead>
<tbody>
<tr>
<td>Optiamyl</td>
<td><em>B. subtilis,</em> <em>B. Licheniformis,</em> heat stable amylase</td>
<td>Solvay enzymes, USA; Gist – brocades, The Netherlands</td>
</tr>
<tr>
<td>Maxamyl</td>
<td>---Do---</td>
<td>Solvay enzymes, USA.</td>
</tr>
<tr>
<td>Amylase Mt</td>
<td>---Do---</td>
<td>Novo Nordisk, USA</td>
</tr>
<tr>
<td>Thermamyl</td>
<td>---Do---</td>
<td>---Do---</td>
</tr>
<tr>
<td>Purafect Oxam</td>
<td>---Do---</td>
<td>Genencor, California</td>
</tr>
</tbody>
</table>

The activity of bacterial $\alpha$-amylase strongly depends on the pH, temperature and the presence of calcium as a stabilizer. A certain level of Ca$^{++}$ ion is required to maintain the activity of alpha amylase. Ca$^{++}$ stabilizes the enzyme against denaturation and the attachment of proteases. The optimum activity lies in pH range 5-8 (Table 5).

These amylases may be combined with other enzymes to improve detergent properties and to harness maximum benefit or application in number of other fields especially for cleaning of dairy and food equipments.
Table 5. Optimum activity of amylases

<table>
<thead>
<tr>
<th>Enzyme</th>
<th>Source</th>
<th>pH Range</th>
<th>Opt. pH</th>
<th>Temp. Range (°C)</th>
<th>(inactivation temp.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bacterial α-amylase</td>
<td><em>B. subtilis</em> <em>B. Amyloliquefaciens</em></td>
<td>4.5 – 9.0</td>
<td>6.5 – 7.5</td>
<td>70-85</td>
<td>(95°C)</td>
</tr>
<tr>
<td>Thermostable α-amylase</td>
<td><em>B. Licheniformis</em></td>
<td>5.8 – 8.0</td>
<td>7.0</td>
<td>90-105</td>
<td>(120°C)</td>
</tr>
</tbody>
</table>

3. APPLICATIONS OF BIODETERGENTS IN MEMBRANE CLEANING

3.1 Membrane fouling during UF

The application of UF and RO membrane systems in the dairy, food, pharmaceutical and chemical industries are becoming indispensable. However, in dairy and food industries, these processes offer capability of concentrating and fractionating liquid foods like milk, whey, fruit juices and egg white, clarification and sterilization of fruit juices, wines, vinegar and beverages and whey desalting without thermal denaturation or degradation of heat-sensitive constituents like proteins or vitamins. As active membrane surface comes in contact with stock and even a small degree of adsorption causes pore blockage resulting in clogging of filters and the phenomenon is referred as membrane fouling, thereby cause a reduction in permeate flux rate and loss in product.

3.1.1 Common agents causing membrane fouling: The common agents involved in membrane fouling are mostly proteins, inorganic salts, such as Ca^{++} ion and fat residues. Whey proteins are smaller than casein micelles thus constitute main fouling agents. α-lactalbumin has strongest gel forming tendency than BSA and existed as granules while β-lactoglobulin is found to be major fouling agent as capable of forming strands or sheets. These whey proteins, α-lactalbumin and β-lactoglobulin formed 95 per cent of proteinaceous membrane deposits during UF of whole milk. During whey concentration, Ca also forms one of primary fouling agent as it exists in two forms, a permeable and impermeable fraction. The latter exist as colloidal phosphate and attached to β-lactoglobulin. When concentration of calcium phosphate in whey retentate exceeds its solubility index, it tends to crystallize forming deposits as specific membrane fouling agent, thereby reducing the flux.

3.1.2 Control of membrane fouling: Many pretreatments are often given to eliminate or reduce the chances of fouling of membranes. These are clarification, filtration, microfiltration, preheat treatment, alteration of pH and decalcification or chelation of calcium. In spite of all the precautions taken to prevent fouling, it can not be totally avoided, therefore recently it has been reported that application of biodetergents and biocleaners, especially enzyme detergents containing proteases can be used for effective cleaning of UF and RO membranes and to check the fouling of membranes so as to increase the life of these membranes as latter are very costly.

As usual cleaning in dairy and food industry involves use of strong acid and alkaline treatments with HNO_{3} or phosphoric acid and NaOH, respectively followed by flushing with water and sanitization. However, strong acids and alkalis can damage the membranes at higher temperature and pH condition and thereby shorts the life of
membranes. Therefore, enzyme detergents containing proteases as described earlier, such as Milezyme, Alcalase, Maxatase, Terg-A-Zyme along with protease, Optimase, Durazym and Maxapem are useful.

4. MILK-STONES FORMATION ON DAIRY EQUIPMENTS

For efficient cleaning of dairy equipments, different types of detergents are being currently employed. However, these do not give satisfactory results in removal of milk stones. Milk stones consist largely of calcium phosphate, precipitated and denatured milk proteins and insoluble calcium salts from hard water and washing solutions. Therefore efficient removal of milk stones from dairy equipments can be achieved by using biodetergents containing proteases, as denatured proteins are very difficult to remove even by using strong alkali solution practiced under normal CIP cleaning.

5. BIOFILM FORMATION ON DAIRY AND FOOD CONTACT SURFACES

In nature and food systems, microorganisms get attracted to solids surface conditioned with nutrients sufficient for their viability and growth. These microorganisms initially are deposited on the surfaces and later get attached, grow and actively multiply to form a colony of cells. These masses of cells further become large enough to entrap organic and inorganic debris, nutrients and other micro organisms leading to the formation of a microbial biofilm. In dairy and food processing equipments, when any food or milk residues remains, they deposit on the surface and then microorganisms start forming biofilms and even CIP procedures can not prevent the accumulation of micro organisms on equipment. Generally, an effective cleaning and sanitation programme, when included in the process from beginning, will inhibit both accumulation of particulates and bacterial cells on equipment surfaces and subsequent biofilm formation. However, removal of biofilm is very difficult and demanding task, a complete and cost-effective cleaning procedure should be developed.

5.1 Biodetergents and biocleaners in controlling biofilm

Biodetergent and biocleaners have proved effective in cleaning the extracellular polymers, which form the biofilm matrix and thus helps in removal of biofilms. The specific enzymes required vary according to the type of microflora making up the biofilm. In one study, a blend of enzyme mixture consisting of protease, α-amylase and β-glucanase was found effective in cleaning a simulated industrial biofilm. Workers of Genencor International, Inc., USA have developed enzymes called endoglycosidases, which deglycosylate biopolymers like glycoproteins, which are widely distributed in living organisms. They employed r-DNA technology to develop Endo-α-N-acetylglucosaminidase H (endo H) as cleaning agents. Endo H had a unique property to remove bacteria, such as staphylococci and E. coli from contact surfaces. Very recently, an enzymatic preparation comprising of exopolysaccharide-degrading enzymes, particularly cationic acid-degrading enzymes derived from a Streptomyces isolates was reported for the removal and prevention of biofilm formation. By using enzyme detergents such as biodetergents and biocleaners, we can prevent the biofilm formation on dairy and food industry equipments/processing lines.

6. CONCLUSION

As maintenance of hygienic conditions is a prerequisite to the production of quality products, use of synthetic detergents and cleaning agents does not solve the major problems of dairy and food industry, such as removal of proteinaceous milk stones after
CIP, membrane fouling in UF and biofilm formation on equipment surfaces. Latter is a more emerging problem now a day. Moreover, these synthetic detergents are non-biodegradable, corrosive and toxic also. Therefore, more emphasis should be given on the use of biodetergent and biocleaners, which are biodegradable, less toxic, non-corrosive, present no environmental pollution and having enhanced cleaning properties, have increased efficiency and stability. Therefore, these are referred as “green chemicals” and are becoming an ideal consumer choice.

Considering the Indian scenario, there is a need to increase production of these biodetergents and biocleaners in our country so that their import can be reduced. Also, there is need of awareness among people especially in dairy and food industry so that hygienic conditions in plant can be maintained leads to production of quality products.

7. REFERENCES


1. INTRODUCTION

The food industry is an important segment of industries in India and has its own peculiarities unlike other industries. Manufacturing a good food product is not enough. It must be free from harmful additives, microbes and remain so far a period it is intended to be consumed. Therefore, the methods employed in quality and food safety assurance programme within the food industry will vary considerably in accuracy and sophistication according to the type of process and size and nature of resources available. Since the international market has become demanding in terms of quality, safety and delivery, installation of Hazard Analysis Critical Control Points (HACCP) in food industry would provide a competitive edge to food supplies in the international market.

HACCP system, which identifies, evaluates, and controls hazards that are significant for food safety, can be applied throughout the food chain from the primary production to final consumption. It enhances food safety besides better use of resources and timely response to problems. This is the reason why HACCP system is now widely embraced by the food industries and by the government regulatory agencies around the world as a most cost-effective means of minimizing the occurrence of identifiable food borne biological, chemical and physical hazards and maximizing product safety. It is a system, which targets critical areas of processing and in doing so, reduces the risk of manufacturing and selling unsafe products.

The primary objective of a HACCP programme is to produce reliably safe food. This means a product, which is free of microbiological, chemical or physical hazards. Industry is fairly familiar with various microbiological, chemical and physical hazards and trying to avoid various common hazards. Despite familiarity and knowledge of food poisoning from microbiological and chemical causes, or injury from glass, wire and other dangerous physical objects, their control is difficult and occasionally they result in serious consumer safety exposures and expensive product recalls and retrievals. It is therefore necessary to have technical orientation on common microbiological, chemical and physical hazards that may cause serious problems in foods.

The Hazard analysis and Critical control Points (HACCP) is a science based system which systematically identifies specific hazards and provides measures for their control to ensure safety of food. It is a tool to assess hazards and establish control system that focuses on prevention rather than relying mainly on end product testing. A successful and effective implementation of the HACCP system requires the use of risk-based decision making in identifying significant hazards at different points in the food processing chain and establishing critical limits at specified critical points.

Application of HACCP system has signaled a shift in emphasis from resource intensive end-product inspection and testing to preventive control of hazards at all
stages of food production. The seven principles of HACCP enunciated in Codex Alimentarius Commission standard provide common denominator for food safety. The basic philosophy of HACCP is to ‘perceive and prevent’ the risk from occurring in the food system.

2. **SPECIAL NEEDS OF FOOD INDUSTRY**

There are two basic facets in food industry- one stressing on the quality concerns is normally effectively dealt under the Quality Management System (ISO 9001 and another stressing on health and safety concerns covered under HACCP systems. To achieve these objectives, it is necessary for the company to design and plan as relevant:

- a. Raw material specifications;
- b. Ingredients resourcing and control;
- c. Processing equipment and environment;
- d. Processing methods and control conditions;
- e. Intermediaries in specifications;
- f. Appropriate labeling specifications;
- g. Specifications of quality of products;
- h. Specifications for management & control systems;
- i. Specified distribution system and cycle; and
- j. Storage, handling and preparation instructions.

![Fig. 1 Life spectrum of food quality](image)

If the industries exercise proper care in the above aspects and adopt a management control system to ensure that capability, it is translated into sound food quality and safety system. Conformance with the strict product specifications is not easily obtainable in the manufacture of food, due to the nature of the natural variations of raw materials being used. Differences in raw materials may be due to climate, cultivations and rearing techniques, and non-uniformity within the species concerned. This poses an additional burden upon maintaining control over the system (See Fig. 1).

3. **VALUE OF SENSORY EVALUATION**

The consumer accepts food on the basis of certain characteristics, which he defines and perceives with his senses. These attributes are described in terms of sensations and referred to as sensory qualities (See Fig. 2). They include perceptions of:

- a. appearance factors such as color, size, shape and physical defects;
- b. kinesthetic factors like texture, viscosity, consistency, finger feel and mouthfeel;
- c. flavour factors, which include taste and odour.

HACCP systems takes cognizance of sensory perceptions while establishing critical limits and often includes measurements of temperature, time, moisture level, pH, Aw (Water Activity) and available chlorine, and sensory parameters such as visual appearance and texture.
Fig. 2. Continuum of sensory quality characteristics as perceived by human senses

To conduct tests that are based on sight, odour, taste and texture should combine the following elements:

a. Qualification, training and re-evaluation of testing personnel to ensure continuous competence,
b. Procedures to ensure long-term consistency and reliability,
c. Criteria on which judgments will be based to be clearly defined,
d. Consistency which can be facilitated by use of standard reference samples or the use of wall charts or photographs or other aids to demonstrate acceptance or rejection criteria,
e. Appropriate facilities to standardize temperature, humidity, light intensity and colour.

While designing sensory method it would be useful to take into account the above factors. Since the measurement of quality of food relies heavily on sensory evaluation methods, the final arbiter of quality is the consumer. No instrument has been developed to evaluate flavour. Yet it is essential for the monitoring of quality to know how consumers perceive a food item. Food is meant for eating and the controlled eating of food to validate its acceptability is an important aspect of quality assurance.

4. APPLICATION OF HACCP SYSTEM IN FOOD INDUSTRY

The application of food safety management system involves three distinct but interrelated phases namely prerequisites steps, preliminary steps and primary steps.

4.1 Prerequisites for implementing HACCP

4.1.1 Management commitment: The successful application of HACCP system depends entirely on the top management. Therefore it requires commitment and involvement of the top management at different stages of development and implementation of the system. This can come only if there is complete understanding of what HACCP actually is, what benefits it can offer to the industry, what is really involved and what resources will be required. The management should make its intent to quality and safety clear by defining its policy and should be responsible to:
Approve and drive food safety management programme,
Ensure that the programme continues to move forward and remains valid,
Appoint a management representative and HACCP team,
Ensure that adequate resources are made available to the HACCP Team,
Establish a progress monitoring and reporting procedure,
Ensure that the programme goals are set which are realistic and achievable,
Approve any changes to the food safety management programme.

4.1.2 Empowerment of employees: The awareness-training programme is an essential step in the journey of successful quality and food safety management programme. It is imperative to provide training through the hierarchy of the organization depending on the roles individuals play in the implementation of HACCP. The extent and depth of training varies with the degree of involvement of the personnel in pursuit of food safety in the organization.

An effective HACCP as a means of managing food safety requires the people responsible for it to be competent. The single most important element in setting up a HACCP System is training. Training not only provides the technical skills required in implementing HACCP but also helps in changing attitudes of people to appreciate the importance of food safety.

4.1.3 Facility specific requirements: In addition to management commitment and employee empowerment, the organizations must have the following in place representing International Code of Practice for General Principle of Food Hygiene enunciated by Codex Alimentarius Commission. 1) Design and Facilities, 2) Personal hygiene, 3) Supplier control, 4) Specifications, 5) Machinery and equipment maintenance, 6) Cleaning and sanitation, 7) Chemical control, 8) Receiving storage and shipping, 9) Product recall programme, 10) Pest control programme and 11) Calibration of measuring devices.

4.1.4 Compliance to food laws: It essential for the implementation of HACCP programmes to comply with the national food laws. Therefore for food industries in India it required that they should identify applicable provision of the Prevention of Food Adulteration Act and Rules.

5. PRELIMINARY STEPS

Step 1. Establishment of a multidisciplinary team
Development of HACCP based food safety management programme requires a multidisciplinary team with appropriate expertise in veterinary health, production, microbiology, toxicology, public health, food technology, health, chemistry and engineering according to the particular study. This cross-functional expertise is necessary to adequately analyze all physical, chemical and biological hazards through the food chain. If the
people drawn in the team are not specialists and are not properly trained and experienced, HACCP System is unlikely to be effective.

The team should have knowledge, experience and attributes to correctly:

a) identify potential food hazards,
b) evaluate the existing system and data in a logical manner,
c) assign levels of severity and risk to identified hazards,
d) analyze problems and recommend controls, criteria and procedures for monitoring and verification to bring lasting solutions to recurring problems,
e) recommend appropriate corrective actions when deviations occur.
f) communicate both within the team and with people across all levels of the dairy.
g) predict the success of the HACCP plan.

Step 2. Describe the product

The dairy product(s) description should include the major raw material, food ingredients, preservation and packing materials used and their impact on food safety. This can also include a brief description of how the process occurs and products are produced and stored. It would be useful if hazards that may exist either in ingredients or in packing material were identified. A description of the method of distribution includes type of transport and any special consideration to maintain product safety. For example Ice cream is described as a frozen ready to eat product containing both pasteurized and unpasteurized components. The skim milk powder, butter, sugar and water are pasteurized while the flavourings, nuts and chocolate are added without further heat processing. Air is also whipped into the product at freezing.

Step 3. Identify intended use

The intended use should be based on the expected uses of the product by the end user or consumer. It should be indicated how the product is to be used including if it is to be fully cooked before consumption, what preparations will be needed, what will be serving requirements, shelf life etc. If consumer has special consideration such as infant or geriatrics it should be made clear so that necessary emphasis may be given to safeguard their special interest. For instance ice cream is consumed without further processing by general population including high-risk groups but infant milk food is meant for infants and is given special consideration.

Step 4. Construct a process flow diagram

The HACCP team constructs a detailed process flow diagram for each product indicating critical steps of control. Each step within the specified area of operation is analyzed for the particular part of the operation under consideration to produce the flow diagram. When applying HACCP system to a given operation, consideration is given to steps preceding and following the specified operation. The process flow diagram is used as the basis of the hazard analysis and should therefore contain sufficient technical detail for the study to progress. Each step within the specified area of operation should be analyzed area of operation should be analyzed for the particular part of the operation under consideration to produce the flow diagram.
Step 5 On-site verification of process flow diagram

The HACCP team at site to confirm the processing operation against the flow diagram during all stages and hours of operation and amend the flow diagram where appropriate verifies the process flow diagram. This is partly in-office exercise and partly on-site activity. In-office exercise includes dissecting the process stage and discussing the implications of process parameters and then they verified at the site. Actually actually walking through the plant to check the accuracy and completeness and make sure that the steps listed on the diagram describe what really occurs in producing the product does the verification of the flow diagram at site.

This verification also includes plant layout verification as a bad layout may provide avenues for cross contamination from raw material to products, facilities to products and persons to product. This should also form part of on-site verification.

6. PRIMARY STEPS BASED ON HACCP PRINCIPLES

Principle 1. Conduct hazard analysis

When the process flow diagram is completed and verified, the HACCP team conducts a hazard analysis and lists all the biological, chemical and physical hazards that may be reasonably expected to occur at each step from primary production, processing, manufacture and distribution until the point of consumption. When conducting the hazard analysis, consideration must be given to the impact of raw materials, ingredients, manufacturing practices, role of manufacturing processes to control hazards, likely end-use of the product, consumer populations at risk and epidemiological evidence relative to food safety. The team should then identify in the HACCP plan which hazards are of such nature that their elimination or reduction to acceptable levels is essential to the production of safe food.
The team must then consider what preventative measures, if any, exist which can be applied for each hazard. Preventative measures are those actions and activities that are required to eliminate hazards or reduce their impact or occurrence to acceptable levels. More than one preventative measure may be required to control a specific hazard(s) and more than one hazard may be controlled by a specified preventative measure.

**Principle 2. Identify the critical control points**

A critical control point is a point/step/procedure where a food safety hazard can be prevented, eliminated or reduced to acceptable levels. The identification of a CCP in the HACCP system is facilitated by the application of a decision tree. All hazards that may be reasonably expected to occur, at each step, should be considered. If a hazard has been identified at a step where control is necessary for safety, and no preventative measure exists at that step, or any other, then the product or process should be modified at that step, or at any earlier or later stage, to include a preventative measure. Application of the decision tree determines whether the step is a CCP for the identified hazard.

**Principle 3. Establish critical limits for each CCP**

Since the critical control points define the boundaries between safe and unsafe products, it is vital that they are specified at the correct levels and validated at each criteria. The HACCP team should therefore fully understand the criteria governing safety at each CCP in order to set the appropriate critical limits. Critical limits must be specified for each preventative measure. In some cases more than one critical limit will be elaborated at a particular step. Criteria often used include measurements of temperature, time, moisture level, pH, and available chlorine, and sensory parameters such as visual appearance and texture.

**Principle 4. Establish a monitoring system for each CCP**

Monitoring is one of the most important aspects of the HACCP system. It is the scheduled measurement a CCP relative to its critical limits. The monitoring procedures must be able to detect loss of control at the CCP and provide information in time for corrective action to regain control of the process. A designated person with knowledge and authority to carry out corrective actions when indicated must evaluate data derived from monitoring. If monitoring is not continuous, then the frequency of monitoring must be sufficient to ensure that the CCP is under control. Most monitoring procedures for CCPs will need to be done rapidly because they relate to on-line processes and there will not be time for lengthy analytical testing. Physical and chemical measurements are often preferred to microbiological testing because they may be done rapidly and can often indicate the microbiological control of the product. All records and documents associated with monitoring CCPs must be signed by the person(s) doing the monitoring and by a responsible reviewing official(s) of the company.

**Principle 5. Establish corrective actions**

Specific corrective actions must be developed for each CCP in the HACCP system in order to deal with deviations when they occur. The actions must ensure that the CCP has been brought under control. Actions taken must also include proper disposition of the nonconforming product. Deviation and product disposition procedures must be documented in the HACCP record keeping. Corrective action should also occur when monitoring results indicate a trend towards loss of control at a CCP. Action should be taken to bring the process back into control before the deviation leads to a safety hazard.
Principle 6. Establish verification procedures

The HACCP system should include verification procedures to provide assurance that HACCP system is being complied with on day-to-day basis. This can be done most effectively by using audit method. Monitoring and auditing methods, procedures and tests, including random sampling and analysis, can be used to determine if the HACCP system is working correctly. The frequency of verification should be sufficient to confirm that the HACCP system is working effectively. Examples of verification activities include review of the HACCP system and its records, review of deviations and product dispositions, confirmation if caps are under control and validation of established critical limits.

Principle 7. Establish record keeping and documentation

Efficient and accurate record keeping is essential to the application of a HACCP system. Records need to be kept of all areas, which are critical to product safety to demonstrate that the HACCP system is in compliance with the documented system. Documentation of HACCP procedures at all steps should be included and assembled in a manual. Records are useful in providing a basis for analysis of trends as well as for internal investigation of any food safety incidents, which may occur. It is extremely useful to allocate a unique reference number to each HACCP record. The types of records that might be retained are a) HACCP plan, b) modification to HACCP plan, c) CCP monitoring, d) deviations and associated corrective action records, e) training records and f) audit records.

7. A MODEL HACCP SYSTEM

Figure 4 represents a model based on Codex Standard on HACCP.

8. SYNERZIGING WITH ISO 9001

The basic management principles being essentially similar the two systems, they should not be looked as two distinct systems demanding two set of documentation and operated separately in the same organization. The two systems should be integrated (See Fig.05) in one set of documented system. This will accrue a considerable amount of economy not only in documentation and implementation of the system but also in the day-to-day operation. The organizations do not have to face two sets of auditors and two sets of certification bodies, as these activities require time and manpower for the certification and auditing process.

9. CONCLUSIONS

The trade reforms initiated by the World Trade Organization (WTO) through Sanitary and Phytosanitary (SPS) Measures have already changed the business environment. There is an upsurge of activities in the food industry and in the governments to conform to international norms for facilitating international trade. The industries around the world have recognized food safety as *de rigueur* for long-term survival and for entry into competitive global markets.

Implementation of HACCP system has been slow but slowing picking the pace. More and more industries are adopting HACCP system for ensuring quality and food safety in their produce. A cursory glance at the certified companies reveals that most of them have integrated ISO 9000 and HACCP for management of quality and safety of their products to assure customers around the world.
The regulatory agencies lay more emphasis on safety while businesses emphasize on both quality and safety as component of reliable quality. HACCP adds reliability in the produce as it enough to produce good quality and safe food but also to maintain through its shelf life period.

**Structure of a HACCP-based Food Safety System**

*Prerequisite programme*

Fig. 4 Model based on Codex Standard on HACCP

10. REFERENCES


Fig. 5 An integrated model for ISO 9001 & HACCP Systems
1 INTRODUCTION

There are four types of hazards in food that can cause illness, injury and even death: biological, physical and chemical hazards and allergens. Biological hazards are living organisms including bacteria, parasites, viruses and moulds. Physical hazards include substances that can cause choking or internal injury such as glass, metal, wood chips and jewelry. Chemical hazards comprise cleaners, sanitizers, pesticides, paints and other chemicals that can make food dangerous to eat. Allergens are substances that can cause an allergic reaction and can include fish, shellfish, nuts, eggs, dairy products, sulfites, soy products, sesame seeds, wheat, and others.

Food borne disease, a biological hazard refers to illnesses acquired by the consumption of contaminated foods or beverages. More than 250 different food borne diseases have been identified, the majority of which are infections caused by bacteria, viruses and parasites that can be found in food. Food borne disease can also result from other contaminants including poisonous chemicals other harmful substances.

2 MAGNITUDE OF FOODBORNE ILLNESS

Foodborne diseases are a widespread and growing public health problem, both in developed and developing countries. The global incidence of foodborne disease is difficult to estimate, but it has been reported that in 2000 alone 2.1 million people died from diarrhoeal diseases. A great proportion of these cases can be attributed to contamination of food and drinking water.

In industrialized countries, the percentage of people suffering from foodborne diseases each year has been reported to be up to 30%. In the United States of America (USA), for example, around 76 million cases of foodborne diseases, resulting in 325,000 hospitalizations and 5,000 deaths, are estimated to occur each year. While less well documented, developing countries bear the brunt of the problem due to the presence of a wide range of foodborne diseases, including those caused by parasites. The high prevalence of diarrhoeal diseases in many developing countries suggests major underlying food safety problems.

While most foodborne diseases are sporadic and often not reported, foodborne disease outbreaks may take on massive proportions. For example, in 1994, an outbreak of salmonellosis due to contaminated ice cream occurred in the USA, affecting an estimated 224,000 persons. In 1988, an outbreak of hepatitis A, resulting from the consumption of contaminated clams, affected some 300,000 individuals in China.

3 MAJOR FOODBORNE DISEASES FROM MICROORGANISMS

3.1 E. coli Infection

*Escherichia coli* is a bacterium that is a common inhabitant of the gut of warm-blooded animals, including man. Most strains of *E. coli* are harmless, however, some strains, such as *E. coli* O157:H7, can cause severe foodborne disease and are referred to as enterohaemorrhagic *E. coli* (EHEC). This pathogen produces toxins, known as
verotoxins or Shiga-like toxins because of their similarity to the toxins produced by *Shigella dysenteriae*. The organism can grow from around 7-10°C to 50°C, with an optimum temperature of 37°C. Some EHEC can grow in acidic foods, down to a pH of 4.4, and in foods with a minimum water activity (Aw) of 0.95. It is destroyed by thorough cooking of foods until all parts reach a temperature of 70°C or higher. The designation "O157:H7" in the name of this bacterium refers to specific chemical compounds that are found on its surface that distinguishes it from other strains of *E. coli*.

Infection with *E. coli* serotype O157:H7 (*E. coli*) was first described in 1982. Subsequently, it has emerged rapidly as a major cause of bloody diarrhoea and acute renal failure. The infection is sometimes fatal, particularly in children. Outbreaks of infection, generally associated with beef, have been reported in Australia, Canada, Japan, United States, in various European countries, and in southern Africa. Outbreaks have also implicated alfalfa sprouts, unpasteurized fruit juice, lettuce, and game meat and cheese curd.

In 1996, an outbreak of *E. coli* O157:H7 in Japan affected over 6,300 school children and resulted in 2 deaths. This is the largest outbreak ever recorded for this pathogen.

### 3.2 Salmonellosis

Salmonellosis in humans is contracted mainly through the consumption of raw or undercooked contaminated food of animal origin (mainly meat, poultry, eggs and milk), although many other foods have been implicated in its transmission. The causative organisms pass through the food chain from primary production or through cross-contamination from food products in households or food-service establishments and institutions such as hospitals. In developed countries human-to-human transmission is uncommon but can occur, notably in institutions, for instance special-care baby units and residential homes for the elderly. Little is known about the epidemiology in developing countries but spread within hospitals and health centres has been reported. A total of 2213 different salmonella strains have been identified. Epidemiologically, they can be classified according to their adaptation to human and animal hosts:

- **Group 1**, e.g. *Salmonella typhi* and *S. paratyphi*, causes enteric fever only in humans and in higher primates.
- **Group 2** causes disease in certain animals: *S. dublin* in cattle, *S. cholerae-suis* in pigs, but only infrequently in humans. However, when these strains do cause disease in humans, it is often invasive and can be life-threatening.
- **Group 3** includes the remaining strains. Typically, such strains cause gastroenteritis, which is often mild and self-limiting but can be severe in the young, the elderly, and patients with weakened resistance against infectious diseases. This group features *S. enteriditis* and *S. typhimurium*, the two most important strains for salmonellosis (transmitted from animals to humans).

Every year, approximately 40,000 cases of salmonellosis are reported in the United States. Because many milder cases are not diagnosed or reported, the actual number of infections may be thirty or more times greater. Salmonellosis is more common in the summer than winter. Children are the most likely to get salmonellosis. Young children, the elderly, and the immunocompromised are the most likely to have severe infections. It is estimated that approximately 600 persons die each year with acute salmonellosis.
3.3 Campylobacteriosis

It is caused by certain species of Campylobacter bacteria and in some countries; the reported number of cases surpasses the incidence of salmonellosis. Foodborne cases are mainly caused by foods such as raw milk, raw or undercooked poultry and drinking water. Acute health effects of campylobacteriosis include severe abdominal pain, fever, nausea and diarrhoea. In two to ten per cent of cases the infection may lead to chronic health problems, including reactive arthritis and neurological disorders.

Campylobacter are mainly spiral-shaped, S-shaped or curved, rod-shaped bacteria. There are 16 species and six subspecies assigned to this genus, of which the most frequently reported in human disease are C. jejuni (subspecies jejuni) and C. coli. Other species C. laridis and C. upsaliensis are also regarded as primary pathogens, but are generally reported far less frequently in cases of human disease.

3.4 Brucellosis

Brucellosis is a zoonosis of both public health and economic significance in most developing countries. In many developed countries, the animal disease has been brought under control, which has led to a subsequent decrease in the number of human cases. The occurrence of the disease in humans is largely dependent on the animal reservoir. Where brucellosis exists in sheep and goats, it causes the greatest incidence of infection in humans.

Six species of Brucella are currently presently known, of which Brucella melitensis, B. suis and B. abortus have public health implications. B. melitensis occurs more frequently than the other types in the general population and it is the most pathogenic and invasive species of this genus, followed, in order, by B. suis and B. abortus.

Brucellosis is transmitted through contaminated and untreated milk and milk products and by direct contact with infected animals (cattle, sheep, goats, pigs, camels, buffaloes, wild ruminants and, very recently, seals), animal carcasses, and abortion materials. Worldwide, millions of individual are at risk, especially in developing countries where the infection in animals has not been brought under control, heat treatment procedures of milk (e.g. pasteurization) are not routinely applied, and food habits such as consumption of raw milk and poor hygienic conditions favour human infection. In such conditions transmission of the infection to humans may frequently occur. Although the disease in animals has been brought under control in several industrialised countries, it occurs sporadically in individuals who acquire the infection abroad or by ingestion of unsafe animal products and in occupationally exposed groups (e.g. farmers, veterinarians, laboratory and slaughterhouse workers).

Brucellosis in humans and animals is increasing in certain parts of the world, especially in developing areas of the Mediterranean Region, Middle East, western Asia and parts of Africa and Latin America. B. melitensis especially, being very pathogenic for human beings, constitutes a public health priority. Its recent emergence as a bovine pathogen in intensive dairy farms causes particular concern. A similar problem has also been reported where B. suis has become established in cattle.

3.5 Botulism

Human botulism is a serious but relatively rare disease. The disease is an intoxication caused by extremely potent toxins preformed in foods. The toxins are produced by the bacterium Clostridium botulinum. Person to person transmission of botulism does not occur. There are seven recognized types of botulism. Four of these
(types A, B, E and rarely F) cause human botulism. Types C, D and E cause illness in mammals, birds and fish. The sporulated form of the bacterium is commonly found in soils, aquatic sediments and fish. The spores are heat-resistant. Under anaerobic conditions, botulinum spores can germinate, and the bacterium grows and produces the toxin. Ingestion of the toxin present in improperly prepared food is dangerous and may be fatal. Botulism is mainly foodborne intoxication but it can also be transmitted through wound infections or intestinal infection in infants.

3.6 Typhoid Fever

Typhoid fever is caused by *S. typhi*, the typhoid bacillus. At present, there are 107 different strains of the bacteria. Typhoid fever is characterized by the sudden onset of sustained fever, severe headache, nausea, severe loss of appetite, constipation or sometimes diarrhoea. Severe forms have been described with mental dullness and meningitis. Paratyphoid fever can be caused by any of three variations or bioserotypes of *S. enteritidis Paratyphi* A, B and C. It is similar in its symptoms to typhoid fever, but tends to be milder, with a much lower case fatality rate.

Typhoid fever affects 17 million people worldwide every year, with approximately 600,000 deaths. The number of sporadic cases of typhoid fever has remained relatively constant in the industrialized world, and with the advent of proper sanitary facilities, has been virtually eliminated in many areas. Most cases in developed countries are imported from endemic countries. Strains resistant to chloramphenicol and other recommended antibiotics have become prevalent in several areas of the world. Multidrug resistant strains have been reported from Asia, the Middle East and Latin America.

Typhoid fever is transmitted by food and water contaminated by the faeces and urine of patients and carriers. Polluted water is the most common source of typhoid. In addition, shellfish taken from sewage-contaminated beds, vegetables fertilized by night soil and eaten raw, contaminated milk and milk products have been shown as a source of infection.

3.7 Shigellosis

Shigellosis is an infectious disease caused by a group of bacteria called *Shigella*. Most who are infected develop diarrhea, fever, and stomach cramps starting a day or two after they are exposed to the bacterium. The diarrhea is often bloody. Shigellosis usually resolves in 5 to 7 days. In some persons, especially young children and the elderly, the diarrhea can be so severe that the patient needs to be hospitalized. A severe infection with high fever may also be associated with seizures in children less than 2 years old. Some persons who are infected may have no symptoms at all, but may still pass the *Shigella* bacteria to others.

A Japanese scientist named Shiga, for whom they are named, discovered shigella over 100 years ago. There are several different kinds of *Shigella* bacteria. *Sh. sonnei*, also known as "Group D" *Shigella*, accounts for over two-thirds of the shigellosis in the United States. A second type, *Sh. flexneri*, or "group B" *Shigella*, accounts for almost all of the rest. Other types of *Shigella* are rare in this country, though they continue to be important causes of disease in the developing world. One type found in the developing world, *Sh. dysenteriae* type 1 causes deadly epidemics there.

Every year, about 18,000 cases of shigellosis are reported in the United States. Because many milder cases are not diagnosed or reported, the actual number of infections may be twenty times greater. Shigellosis is particularly common and causes recurrent problems in settings where hygiene is poor and can sometimes sweep through
entire communities. Shigellosis is more common in summer than winter. Children, especially toddlers aged 2 to 4, are the most likely to get shigellosis. Many cases are related to the spread of illness in child-care settings, and many more are the result of the spread of the illness in families with small children.

3.8 Listeriosis

*Listeria monocytogenes* is considered emerging because the role of food in its transmission has only recently been recognized. In pregnant women, infections with *L. monocytogenes* can cause abortion and stillbirth, and in infants and persons with a weakened immune system it may lead to septicemia (blood poisoning) and meningitis. The disease is most often associated with consumption of foods such as soft cheese and processed meat products that are kept refrigerated for a long time because the organism can grow at low temperatures. *Listeria* species are ubiquitous in the environment. *L. monocytogenes* is common in the intestinal tracts of animals and humans. In animals, the bacteria can be shed in the milk and in cattle; the bacteria can cause mastitis and abortion. Seven serotypes are associated with *L. monocytogenes* but only serotype 4b has been associated with food borne illness outbreaks. Outbreaks of listeriosis have been reported from many countries, including Australia, Switzerland, France and the United States. Two recent outbreaks of *L. monocytogenes* in France in 2000 and in the USA in 1999 were caused by contaminated pork tongue and hot dogs respectively.

3.9 Bovine Spongiform Encephalopathy

Bovine Spongiform Encephalopathy (BSE), a fatal, transmissible, neurodegenerative disease of cattle, was first discovered in the United Kingdom in 1985. The cause of the disease was traced to an agent related to scrapie in sheep, which contaminated recycled bovine carcasses used to make meat and bone meal additives for cattle feed. Recycling of the BSE agent led to a distributed common source epidemic of more than 180,000 diseased animals in the UK alone. The agent affects the brain and spinal cord of cattle and lesions are characterized by sponge-like changes visible in a microscope. At this time, 19 countries have reported endemic BSE cases and the disease is no longer confined to the European Community: a case of BSE has been reported in the cattle herd of Japan.

In human populations, exposure to the BSE agent (probably in contaminated bovine-based food products) has been strongly linked to the appearance in 1996 of a new transmissible spongiform encephalopathy of humans called variant Creutzfeldt-Jakob Disease (vCJD). As of January 2002, 119 people have developed vCJD, most are from the UK but five cases have been reported from France.

3.10 Avian Influenza

Type A influenza viruses can infect several animal species, including birds, pigs, horses, seals and whales. Influenza viruses that infect birds are called “avian influenza viruses.” Influenza A viruses can be divided into subtypes on the basis of their surface proteins — hemagglutinin(HA) and neuraminidase (NA). There are 15 known H subtypes. While all subtypes can be found in birds, only 3 subtypes of HA (H1, H2 and H3) and two subtypes of NA (N1 and N2) are known to have circulated widely in humans.

Avian influenza is an infectious disease of birds. Migratory waterfowl - most notably wild ducks - are the natural reservoir of avian influenza viruses, and these birds are also the most resistant to infection. Domestic poultry, including chickens and turkeys, are particularly susceptible to epidemics of rapidly fatal influenza. Avian influenza
viruses rarely affect humans and do not normally infect species other than birds and pigs. Its ability to cause severe disease in humans has now been documented on two occasions (Hong Kong SAR, 1997 and The Netherlands, 2003). Investigation of these outbreaks determined that close contact with live infected poultry was the source of human infection. Therefore, the practice of marketing of live poultry directly to consumers should be discouraged in areas currently experiencing influenza outbreaks among poultry.

4 WHY DO FOODBORNE DISEASES EMERGE?

New foodborne disease threats occur for a number of reasons. These include increase in international travel and trade, microbial adaptation and changes in the food production system, as well as human demographics and behaviour.

Globalization of the food supply: A large outbreak of cyclosporiasis occurred in North America in 1996-7 linked to contaminated raspberries imported from South America.

Inadvertent introduction of pathogens into new geographic areas: *Vibrio cholerae* was introduced into waters off the coast of southern United States when a cargo ship discharged contaminated ballast water in 1991. It is likely that a similar mechanism led to the introduction of cholera for the first time this century into South America in 1991.

Travelers, refugees, and immigrants exposed to unfamiliar foodborne hazards while abroad: International travelers may become infected by foodborne pathogens that are uncommon in their countries. It is estimated that about 90% of all cases of salmonellosis in Sweden are imported.

Changes in microorganisms: Changes in microbial populations can lead to the evolution of new pathogens, development of new virulent strains in old pathogens, development of antibiotic resistance that might make a disease more difficult to treat, or to changes in the ability to survive in adverse environmental conditions.

Change in the human population: The population of highly susceptible persons is expanding worldwide because of ageing, malnutrition, HIV infections and other underlying medical conditions. Age is an important factor in susceptibility to foodborne infections because those at the extremes of age have either not developed or has partially lost protection from infection. Particularly for the elderly, foodborne infections are likely to invade their blood stream and lead to severe illness with high mortality rates. People with a weakened immune system also become infected with foodborne pathogens at lower doses, which may not produce an adverse reaction in healthier persons. Seriously ill persons, suffering, for example, from cancer or AIDS, are more likely to succumb to infections with *Salmonella*, *Campylobacter*, *Listeria*, *Toxoplasma*, *Cryptosporidium*, and other foodborne pathogens. In developing countries reduced immunity due to poor nutritional status render people, particularly infants and children, more susceptible to foodborne infections.

Changes in lifestyle: Greater numbers of people go out and eat meals prepared in restaurants, canteens, fast food outlets, and by street food vendors. In many countries, the boom in food service establishments is not matched by effective food safety education and control. Unhygienic preparation of food provides ample opportunities for contamination, growth, or survival of foodborne pathogens.
5 FOOD SAFETY CONCERNS

Food safety programmes are increasingly focusing on a farm-to-table approach as an effective means of reducing foodborne hazards. This holistic approach to the control of food-related risks involves consideration of every step in the chain, from raw material to food consumption. Hazards can enter the food chain on the farm and can continue to be introduced or exacerbated at any point in the chain until the food reaches the consumer. There are a number of major concerns. In devising and developing an effective safety programme at national and international level.

5.1 GM Food

The safety of food derived from biotechnology needs to be carefully assessed. To provide the scientific basis for decisions regarding human health, new methods and policies to assess such food need to be developed and agreed upon internationally. The assessment should consider health benefits as well as possible negative health implications. Crops modified to resist pests, foods with allergens removed or food with an increase of essential nutrients are possible examples of the former, while antimicrobial markers in some genetically modified foods have been suggested to be an example of the latter. The weighing of potential risks and benefits is an important aspect of assessment of foods derived from biotechnology that has not received much attention in the past. Likewise, clear communication of the basis for safety assessment in this area is generally lacking at national and international levels.

5.2 New technologies

New technologies, such as genetic engineering, irradiation of food, and modified-atmosphere packaging, can improve food production and food safety. However, the potential risks associated with application should be objectively and rigorously assessed well before these technologies are widely introduced. The basis for risk assessment should be communicated effectively, so that the public can be involved at the early stages of the process. Assessment should be based on internationally agreed principles and should be integrated with consideration of other factors, such as health benefits, socioeconomic factors, ethical issues and environmental considerations.

5.3 Animal Husbandry Practices

If not properly monitored and assessed, changes in animal husbandry practices, including feeding, may have serious implications for food safety. For example, increased use of ruminant bone and meat meal as feed supplement for cattle appear to have played a role in the emergence of BSE. Adding low levels of antibiotics to animal feed in order to increase growth rate has raised concern about the transfer of antibiotic resistance to human pathogens from this practice.

5.4 Agricultural Practices

Modern intensive agricultural practices contribute to increasing the availability of affordable foodstuffs and the use of food additives can improve the quality, quantity and safety of the food supply. However, appropriate controls are necessary to ensure their proper and safe use along the entire food chain. Pre-market review and approval followed by continuous monitoring are necessary to ensure the safe use of pesticides, veterinary drugs and food additives.

5.5 Others

The integration and consolidation of agricultural and food industries and the globalization of the food trade are changing the patterns of food production and
distribution. These conditions are creating an environment in which both known and new foodborne diseases can become prevalent. Food and feed are distributed over far greater distances than before, creating the conditions necessary for widespread outbreaks of foodborne illness. Hence other challenges, which need to be addressed to help ensure food safety, include the globalization of trade in food, urbanization, changes in lifestyles, international travel, environmental pollution, deliberate contamination and natural and manmade disasters. The food production chain has become more complex, providing greater opportunities for contamination and growth of pathogens. Many outbreaks of foodborne diseases that were once contained within a small community may now take on global dimensions.

6 STRATEGIES

These strategies include the formation of "early warning" networks for distributing epidemiological information, the development and implementation of HACCP procedures, the development of strategies for eliminating microorganisms from food, and the enhancement of current pathogen detection methods. Such programmes have international agencies and government (Public health), Consumers (Ultimate beneficiary or victim, Industry (maintain customer confidence, reduce losses) as partners.

The application of HACCP and risk assessment concepts in recent years is leading to fundamental changes in the approach to food safety. Governments in a number of countries are now undertaking quantitative risk assessments for specific microbiological hazards in the food supply, with the intention that the outputs of these risk assessments will be used in the development of food safety measures at the national level. Internationally, FAO and WHO have embarked on a series of Joint Expert Meetings on Microbiological Risk Assessment (JEMRA) that represent an extensive and on-going scientific commitment to risk assessment. The Codex Committee on Food Hygiene (CCFH) is currently considering the preliminary results of risk assessments of Salmonella sp. in eggs and broiler chickens and *L. monocytogenes* in ready-to-eat (RTE) foods. In further addressing the requests of the committee, quantitative risk assessments on *Campylobacter* sp. in broiler chickens and *Vibrio* sp. in seafood are currently underway.

Microbiological risk assessment (MRA) is resource-intensive in terms of scientific input and time, and effective incorporation of MRA in the development of food safety standards requires systematic and transparent application of a framework for managing food-borne hazards. The provisions and obligations of the World Trade Organization (WTO) Agreement on the Application of Sanitary and Phytosanitary Measures (SPS) that apply to safety measures for foods in trade are an additional incentive for MRA to be used in a systematic and transparent manner.

Generic frameworks for managing food-borne risks have recently been described by FAO/WHO, Codex and national governments. The four components of such frameworks can be summarized as follows:

- **Preliminary risk management activities** comprise the initial process. It includes the establishment of a risk profile to facilitate consideration of the issue within a particular context, and provides as much information as possible to guide further action. As a result of this process, the risk manager may commission a risk assessment as an independent scientific process to inform decision-making.
- **Evaluation of risk management options** is the weighing of available options for managing a food safety issue in light of scientific information on risks and other
factors, and may include reaching a decision on an appropriate level of consumer protection. Optimization of food control measures in terms of their efficiency, effectiveness, technological feasibility and practicality at selected points throughout the food chain is an important goal. A cost-benefit analysis could be performed at this stage.

- **Implementation of the risk management decision** will usually involve regulatory food safety measures, which may include the use of HACCP. Flexibility in the choice of individual measures applied by industry is a desirable element, as long as the overall programme can be objectively shown to achieve the stated goals. Ongoing verification of the application of food safety measures is essential.

- **Monitoring and review** is the gathering and analysing of data so as to give an overview of food safety and consumer health. Monitoring of contaminants in food and foodborne disease surveillance should identify new food safety problems as they emerge. Where there is evidence that required public health goals are not being achieved, redesign of food safety measures will be needed.

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1. **INTRODUCTION**

Since the 1940s, antibiotics have been the cornerstones of infectious disease therapy. Their remarkable healing power invites widespread and often inappropriate use, which leads to antibiotic resistance and consequent treatment complications. Antibiotics are important class of compounds that represent a key component in the strategy used to control bacterial infections in both human and animals. The common cold and flu are generally caused by viruses and thus, antibiotics are ineffective. In 1950 antibiotics were discovered to enhance growth and feed efficiency of food animals. "Veterinary drug" by definition, is any substance applied or administered to any food producing animal, such cattle, poultry, fish or bees, whether used for therapeutic, prophylactic or diagnostic purposes or for modification of physiological functions or behavior (IDF, 1997).

Antibiotics are low to medium molecular weight (100-1500) compounds exhibiting a variety of chemical structures hence a diversity of chemical and biological properties. These may be obtained from synthetic, natural or semi synthetic sources and can be classified as per the microbial source, antimicrobial activity or chemical structure, the last being the most appropriate to elucidate their mode of action. However, the mechanism of action of some antibiotics is not yet fully understood and also some have more than one mode of action. Antibiotics used in animal husbandry can be divided into following seven chemical groups: 1) Amino glycosides (gentamycin, lincomycin, streptomycin), 2) β-lactam compounds (penicillins and cephalosporins), 3) macrolides (erythromycin, spiramycin), 4) peptides (avoparcin, bacitracin), 5) sulphonamides (sulfamethazine) 6) tetracyclines (chlortetracycline, oxytetracycline), 7) miscellaneous compounds (chloramphenicol).

2. **ENTRY OF ANTIBIOTICS INTO MILK AND MILK PRODUCTS**

Antibiotics are extensively used in dairy cattle management for preventing and curing diseases like mastitis and brucellosis, which are prevalent in the tropics. But indiscriminate use, lack of medication records, use of unapproved drugs and failure to observe withdrawal period in lactating animals cause substantial excretion of these residues into milk.

The passage of the drugs across the mammary barrier appears to be similar to that of drugs through other biological membranes. Most drugs are either weak acids or weak bases, existing both in ionized and non – ionized forms. Their transfer to milk depends upon the solubility, their chemical properties and the extent of any transport mechanism that may be present for some related material. The pH of ruminant milk is lower than that of blood, so drugs of an acid nature have a higher concentration in blood than in milk. The reverse is true with alkaline drugs (Larsen, 1985). Acidic or basic character of antibiotic plays an important role in the amount of excretion into milk. More the dosage longer will be excretion time.
Udder infections necessitate the application of antibiotics via teat canal directly into a quarter. This results in extremely high levels of contamination in milk. One study based on farmer opinion reported that 92% of antibiotic contamination of milk is due to the use of intramammary infusions for the treatment of mastitis (Booth, 1982). A single intramammary injection of 1 million units of penicillin G can yield at first milking a contamination level of 12 µg per ml of milk or greater depending on milk yield (Chesham and Taylor, 1992). Excretion of these residues in milk is intensified due to exceeding recommended doses and failure to observe withdrawal period. However their excretion also depends on many other factors such as type of antibiotics, dose administered, physiopathological condition of the udder, the carrier/vehicle employed in the preparation, the amount of milk drawn from the gland, the time interval between treatment and milking, absorbance of the udder tissue, milk yield and individual factors (Hamann et al, 1979). In some cases a little amount of drug may be excreted uncharged in urine or faeces as linked with bile. Environmental factors include the contamination of milk, after milking of treated animals, by rinsing the contaminated inner surface of the parts of a milking machine with milk from untreated animals during milking.

3. HEALTH AND ECONOMIC ASPECTS OF ANTIBIOTIC RESIDUES IN MILK

The presence of these residues in milk causes major problems to human health and to the dairy industry. Manifestations of these occur as 1) the possible appearance of allergic reaction in sensitized individuals (as with penicillin) such as dermatitis, shock etc. (Continued consumption may become dangerous. In insensitive consumers sensitization may occur interfering in subsequent chemotherapy resulting in early or late hypersensitivity) 2) toxicity such as aplasia of the bone marrow (with chloramphenicol), 3) effects on the human gut microbial population, the emergence and predominance of resistant bacteria (both pathogenic and nonpathogenic) within animals and the transfer of antibiotic resistance genes to human pathogens with more frequent consumption of residues. These resistant strains transfer into human food chain not only from meat but also from milk and milk products (Walton, 1989). Sulphonamides (i.e. sulfamethazine) are carcinogenic and toxic (Mollereau et al., 1987). It has been estimated that about 3.5% of people when given therapeutic doses of sulfonamides exhibit adverse reaction and up to 10% are allergic to penicillin or its metabolites (Latha, 1998). Some compounds such as nitrofurans are animal carcinogens and mutagens. However, public health risks of antibiotics and their metabolites in foods are difficult to define. Presence of excessive levels of residues in foods is illegal and many countries impose financial penalties on offenders (Prescott and Baggot, 1988).

Antibiotic residues in milk cause economical loss due to failure of starter culture in fermented dairy products. Even low levels of antibiotic cause different kind of defects in cheese like off flavor, uneven texture, uneven eye development, and lower flavor intensity in raw milk cheese. Antibiotics also inhibit lactic acid formation, decrease flavor development in yogurt and dahi (Ramakrishna et al., 1985; Mayra-Makinen, 1993). They may also lead to undesirable growth of antibiotic resistant coliforms and interfere with the phosphatase test. It also hinders export of dairy products by making them unable to meet the international standards.

4. MILK PROCESSING AND ANTIBIOTIC STABILITY

The amount of the residue, chemical nature of the residual antibiotic, composition of milk and milk products influence residue stability during processing treatments like
cooling, pasteurization, homogenization, boiling, sterilization and drying. Shahani (1958) found that at 71°C, longer time was required to totally inactivate penicillin-G (1705 min) than streptomycin (1320 min), chlortetracycline (280 min) or oxytetracycline (140 min). Antibiotics are more stable in milk than in water and buffer. Oxytetracycline was least stable and was completely inactivated in 30 min at 100°C. Pasteurization reduced penicillin by 7-8% in whole milk and 8-11% in skim milks; boiling for 120 min by about 19% in whole milk and by 24% in skim milk. However, streptomycin was not affected but sterilization was detrimental to both the antibiotics (Moats, 1988). Cooling (7-8°C) adversely affected penicillin and tetracycline slightly with no effect of chilling (3-4°C) or freezing (-10°C). Tetracycline potency was lost by 10% at 4°C in 7 days and by 18% at 25°C in 48 h (Podhorniak et al., 1999). Pasteurization decreased the recovery of sulfamethazine content in milk probably due to binding to protein or reducing sugar (Malik et al., 1994). On prolonged boiling for 120 min, 17.6% destruction of penicillin was noticed in buffalo milk and slightly higher rate of destruction was observed in cow milk, but boiling for 120 min could not inactivate the streptomycin (Kaul, 1982). However, sterilization showed almost similar effect on both the antibiotics. Diserens et al. (1995) reported that penicillin and sulfamethazine residues are not affected by spray drying. Skim milk with sulfamethazine 5.10 ppb when spray dried contains 4.9 ppb after spray drying on dry matter basis (Malik et al., 1994).

5. SAFETY REGULATIONS

The synonymous terms maximum residual limits (MRL) and tolerance or safe level of the 'marker residue' (e.g. the parent compound, its metabolites etc.) resulting from the use of a veterinary drug and are expressed in ppm, ppb or ppt levels. It is based on the acceptable daily intake (ADI) for that compound. Various committees recommend such MRLs and help in legislation. This may result in different recommendations for MRLs making legislation difficult internationally and setting the MRLs near the limits of analytical determination rather than based on toxicology or risk assessment.

A number of national and international organizations are involved in development of control mechanisms for the drugs used in animal production. These mechanisms include control of the distribution, use, determination of safe residue level and residue detection methods. In its sixteenth session in 1985, the Codex Alimentarius Commission (CAC) established the Codex Committee on Residues of Veterinary Drugs in Foods (CCRVDF). It is the body to establish worldwide MRLs of veterinary drugs. Prior to 1995, MRLs on the benzyl penicillin and oxytetracycline antibiotics had been adopted as Codex standards. In 1995, at the 21st session of CAC sulfadimidine including few hormones were adopted for Codex standards. European Community had established MRLs for some antibacterials in 1994. But it was decided for the harmonization of the European market, the EU would set MRLs for all drugs used in veterinary medicine by 1997. MRLs and safe tolerance levels of antimicrobials in milk provided by CAC, EU and FDA as of 1999 and PFA are listed in Table 1.

6. WITHDRAWAL TIME OF ANTIBIOTICS

The withdrawal time may be defined as the period following the last medication that is required to bring the concentration of the drug below a tolerable limit (Beukers, 1995). This varies widely because of large individual variation between animals due to variation in treatment and type of disease. Lehmann (1995) reported that dihydrostreptomycin sulphate was present in higher concentration in cow milk and took a longer time to be eliminated from milk supply of lactating cows given intrammary
Table 1. MRLs (Codex, EU) and tolerances (USA) of residues of antimicrobial drugs in milk (μg/kg) (May, 1999)

<table>
<thead>
<tr>
<th>Substance (-group)</th>
<th>MRL codex</th>
<th>MRL (EU)</th>
<th>USA</th>
<th>PFA</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>β- Lactams</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Penicillin</td>
<td>4</td>
<td>4</td>
<td>5</td>
<td>4</td>
</tr>
<tr>
<td>Ampicillin</td>
<td>-</td>
<td>4</td>
<td>10</td>
<td></td>
</tr>
<tr>
<td>Amoxicillin</td>
<td>-</td>
<td>4</td>
<td>10</td>
<td></td>
</tr>
<tr>
<td>Cloxacillin</td>
<td>-</td>
<td>30</td>
<td>10</td>
<td></td>
</tr>
<tr>
<td>Oxacillin</td>
<td>-</td>
<td>30</td>
<td>50</td>
<td></td>
</tr>
<tr>
<td>Ceftiofur</td>
<td>100</td>
<td>100</td>
<td>50</td>
<td></td>
</tr>
<tr>
<td>Cepahapirin</td>
<td>-</td>
<td>10</td>
<td>20</td>
<td></td>
</tr>
<tr>
<td><strong>Tetracyclines</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Chlortetracycline</td>
<td>100</td>
<td>100</td>
<td>300</td>
<td></td>
</tr>
<tr>
<td>Oxytetracycline</td>
<td>100</td>
<td>100</td>
<td>300</td>
<td>100</td>
</tr>
<tr>
<td>Tetracycline</td>
<td>100</td>
<td>100</td>
<td>300</td>
<td></td>
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<tr>
<td><strong>Sulfonamides</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sulfadimidine</td>
<td>25</td>
<td></td>
<td>10</td>
<td>25</td>
</tr>
<tr>
<td>Sulfadimethoxine</td>
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<td></td>
<td>10</td>
<td></td>
</tr>
<tr>
<td>Sulfamerazine</td>
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<td></td>
<td>10</td>
<td></td>
</tr>
<tr>
<td>Sulfathiazole</td>
<td></td>
<td></td>
<td>10</td>
<td></td>
</tr>
<tr>
<td><strong>Macrolides</strong></td>
<td></td>
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<td></td>
</tr>
<tr>
<td>Erythromycin</td>
<td>40</td>
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<td>50</td>
<td></td>
</tr>
<tr>
<td>Spiramycin</td>
<td>100</td>
<td>200</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tylosin</td>
<td>50</td>
<td>50</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Aminoglycosides</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Gentamicin</td>
<td>200</td>
<td>100</td>
<td>30</td>
<td>200</td>
</tr>
<tr>
<td>Neomycin</td>
<td>500</td>
<td>500</td>
<td>150</td>
<td></td>
</tr>
<tr>
<td>Spectinomycin</td>
<td>200</td>
<td>200</td>
<td>30</td>
<td></td>
</tr>
<tr>
<td>DH/Streptomycin</td>
<td>200</td>
<td>200</td>
<td>125</td>
<td>200</td>
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<tr>
<td><strong>Quinolones</strong></td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Enrolfloxacin</td>
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<tr>
<td>Marbofloxacin</td>
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<td>75</td>
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<td></td>
</tr>
<tr>
<td>Sulfadiazine</td>
<td></td>
<td></td>
<td>10</td>
<td></td>
</tr>
<tr>
<td><strong>Miscellaneous</strong></td>
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<td></td>
</tr>
<tr>
<td>Chloramphenicol</td>
<td>0</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Colistin</td>
<td>50</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lincomycin</td>
<td>150</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Novobiocin</td>
<td></td>
<td></td>
<td>100</td>
<td></td>
</tr>
<tr>
<td>Rifaximin</td>
<td>60</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Thiampiphencol</td>
<td>50</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Trimethoprim</td>
<td>50</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Adapted from: (Pederson and Suhren, 2000)

Penicillin-G and dihydrostreptomycin simultaneously. Roudaut and Moretaine (1995) determined sulphonamide residues in bovine milk followed by intravenous and intramammary injections. It was observed that the maximum concentration was reached at the first milking following the last injection and was higher after intravenous injection. The incurred studies of veterinary drugs including six β-lactams showed that β-lactam drugs cleared out at 48 hrs and 36 hrs from milk after intra-mammary and intramuscular injection, respectively. Sulphonamide residues were detected in milk to 7 days (10 ppb or more) and to 4 days to drop below 100 ppb. Tetracycline, oxytetracyclin and
chlortetracycline on an average took 3 days to drop below 100 ppb and to 5 days to clear the milk (below 20 ppb) (Zomer, 1995). Fletourius et al. (1990) reported that OTC persisted in milk for as long as 4 days. After intramuscular injection of a single dose of 5 mg of OTC/kg body weight. No penicillin residues were detected in milk from treated quarters after 24 hrs after three successive infusions of 1000 units of penicillin-G.

7. METHODS OF DETECTION

In order to monitor the antibiotic residues in milk and milk products there is a need to develop precise, accurate and sensitive analytical methods to determine these residues. Currently, the detection methods used are assays based on microbial growth inhibition, microbial receptors, enzymatic-colorimetric, receptor binding and spectrophotometric, chromatographic and immunoassays. These methods are either qualitative, quantitative, or semi - quantitative. However, they have one or more limitations in terms of specificity, precision, accuracy, sensitivity, cost and time. In contrast to microbiological methods, chromatographic approaches provide a rapid response and offer both high sensitivity and separation efficiency.

8. CONTROL OF ANTIBIOTIC RESIDUES IN MILK

After the 1980s, the FDA and dairy industry adopted a joint three point programme to a) re-evaluate antibiotic detection methods, b) implement a public awareness programme about the safety of milk supply, and c) develop a 10-point hazard analysis critical control point (HACCP) based animal drug education programme for dairy farmers (Adams, 1994). This has successfully decreased the number of residue positive milk samples.

An integrated approach involving all different methods and concerned parties including the producer, processor, food inspector and the consumer would be useful in eliminating residues from milk. Microbial inhibition tests are quite helpful for ex-farm milk. In addition to microbial testing, chemical methods also are useful (Honkanen-Buzalski and Reybroeck, 1997). Use of certain enzymes e.g. β-lactamases (like penicillinase) that may be destroyed by heat processing is one method (Korycka Dahl et al., 1985). A promising field of biotechnology is to develop and use antibiotic resistant lactic acid bacteria. However, this prospective aspect is also fraught with certain drawbacks. Only a few of the induced penicillin resistant strains of lactic streptococci e.g. L lactis, L lactis subsp. lactis (i.e. S. lactis subsp. diacetylactis) and L.lactis subsp. cremoris were able to retain acid forming and proteolytic activity with 30-50% suppression of diacetyl productivity. The former two organisms behaved normally in presence of streptomycin. Lactobacilli were more resistant than lactococci (Singh et al., 1990).

9. CONCLUSION

The use of antibiotics to control infection and promote growth is widespread in livestock production. It would be fair to say that consumers have few problems in principle with using veterinary chemicals for prevention or treatment of disease, assuming, of course, that the correct drugs and dosages are being used and the withholding periods observed. Consumers have demonstrated that they are prepared to pay for safety and for quality in food. They need to be reassured that they are getting exactly that.
10. REFERENCES


PESTICIDE RESIDUES IN FOOD PRODUCTS: CONSEQUENCES AND MANAGEMENT

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Dairy Chemistry Division

1. INTRODUCTION

Pesticides are key stone components of crop protection. The use of pesticides in food production has provided numerous benefits in terms of increasing production and quality. Since chemical control of pests is so successful, there has been an explosive expansion in the development of synthetic organic pesticides. As a result, consumers are exposed to pesticides posing serious threats to public health by entering into the food chain. Mainly through the crop fields the pesticides have entered into our food chain and are now omnipresent - in air, water, soil, vegetables, fruits, food grains, animal feeds, meat, milk and milk products. Thus consumers must be given appropriate information about pesticide residues in food to make their own risk assessment.

Synthetic organic insecticides including mainly, organochloro (OC), organophosphate (OP) and organocarbamate (OCm) pesticides exhibit a high degree of persistence in the environment as compared to the other classes of pesticides. The OC compounds are the most persistent and bio-accumulative while OP and OCm have acute toxicity and less persistence. More potent and less persistent OP compounds have advantage over OC that they are readily decomposed by physico-chemical and enzymatic processes in the animal body. Because of their high toxicity to higher animals and the irreversibility of their attack, risk factor is greater. OCms have a reversible mode of action. These are less persistent with a systemic action, less toxic than OP but have adequate potency against crop pests.

2. CONSUMPTION PATTERN OF PESTICIDES

In European countries, use of persistent OC pesticides has been banned for more than 20 years and less persistent OP and OCm pesticides have replaced these. In India also, during 1995-2000, the consumption pattern of pesticides have changed. The consumption of OC, OCm and synthetic pyrethroids has decreased from 40, 50 and 10 (1995-96) to 14.5, 4.5 and 5% (1999-2000) respectively, whereas the consumption of OP has increased tremendously from 30 to 74%. There is also a moderate use of natural pesticides (neem and its formulations), about 2%. Out of 57 insecticides registered for use in agriculture, the top 10, namely 8 OP (monocrotophos, malathion, methylparathion, phosphamidon, phorate, quinalphos, dimethoate, chlorpyriphos), 1 OCm (carbaryl) and 1 OC (endosulphan) account for 80 percent of total insecticides used (Agnihotri, 2000). Monocrotophos, a highly toxic insecticide has been banned in USA in 1988 but in India it is still a top selling pesticide.

3. STATUS OF PESTICIDE RESIDUES IN FOODS

It has been found that 60% of our food commodities were contaminated with pesticide residues and out of these 14% had pesticide residues above permitted maximum residue limit (MRL) values as compared to 21% contamination with only 2% above MRL on worldwide basis (Agnihotri, 1999). Table 1 enlists the MRL (ppm) of
pesticide residues in food products including milk and milk products by PFA, 2002 and for milk and milk products by Codex Alimentareus Commission (CAC) 1996 and 2003. The status of pesticide residues namely OC pesticide residues (OCPR), OP pesticide residues (OPPR) and Ocm pesticide residues (OCmPR) published by survey of European countries have shown that the contamination of foods including milk, in general, is very low in relation with the MRL (IDF 9101, 1990; Rathore et al., 1996a,b and Manes et al., 1996). In India, work has been done on the incidence of OC, OP and OCmPR in food products like vegetables, fruits, cereals, honey, meat products, feed concentrates, milk and milk products. In the two phases of analysis (1970-87 and 1988-03) of pesticide residues, the various food commodities have shown a decline in the level of OCPR. Due to change in consumption pattern of insecticide in India during 1995-2000, the presence of OPPR and OCmPR have been observed in most of the food commodities including milk (Table2). This is based upon several reports from India (PL480 report, 1983; Rathi et al. 1997; Agnihotri, 1999; Kathpal and Kumari, 2000; Singh and Dhaliwal, 2000; Mishra et al. 2001; Sharma et al. 2002 and Sharma, 2003). However, information on the levels of OPPR and OCmPR in milk is very limited.

Table1: MRL (ppm) of pesticide residues in food products including milk and milk products by PFA 2002 and for milk and milk products by CAC 1996, 2003

<table>
<thead>
<tr>
<th>Pesticide</th>
<th>Milk &amp; Milk Products</th>
<th>Food Grains</th>
<th>Fruits &amp; Vegetables</th>
<th>Meat &amp; Poultry</th>
</tr>
</thead>
<tbody>
<tr>
<td>Monocrotophos</td>
<td>0.002*, 0.02</td>
<td>0.025</td>
<td>1.0(F) 0.2 (V)</td>
<td>0.02</td>
</tr>
<tr>
<td>Dimethoate</td>
<td>---</td>
<td>2.0</td>
<td>---</td>
<td>---</td>
</tr>
<tr>
<td>Phosphamindone</td>
<td>---</td>
<td>0.05</td>
<td>0.2 (F&amp;V)</td>
<td>---</td>
</tr>
<tr>
<td>Carbaryl</td>
<td>0.05**, ---</td>
<td>1.5</td>
<td>---</td>
<td>5.0(V)</td>
</tr>
<tr>
<td>Methylparathion</td>
<td>---</td>
<td>---</td>
<td>0.2(F) 1.0(V)</td>
<td>---</td>
</tr>
<tr>
<td>Malathion</td>
<td>---</td>
<td>4.0</td>
<td>4.0(F) 3.0(V)</td>
<td>---</td>
</tr>
<tr>
<td>Endosulphan</td>
<td>0.004*, ---</td>
<td>---</td>
<td>2.0(F&amp;V)</td>
<td>0.2(Fish)</td>
</tr>
<tr>
<td>Quinalphos</td>
<td>---</td>
<td>0.01 (Rice)</td>
<td>---</td>
<td>0.01 (Fish)</td>
</tr>
<tr>
<td>Lindane</td>
<td>0.01*, 0.01(M)</td>
<td>0.1(Except Rice)</td>
<td>1.0 (F&amp;V)</td>
<td>2.0</td>
</tr>
<tr>
<td></td>
<td>0.2(MP)#</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Phorate</td>
<td>0.05*, 0.05#</td>
<td>0.05</td>
<td>0.05(F&amp;V)</td>
<td>0.05</td>
</tr>
<tr>
<td>Ethion</td>
<td>0.02*, 0.5 #</td>
<td>0.025</td>
<td>1.0 (V) 2.0 (F)</td>
<td>0.2 #</td>
</tr>
<tr>
<td>Chlorpyriphos</td>
<td>0.02**, 0.01#</td>
<td>0.05</td>
<td>0.2(V) 0.5 (F)</td>
<td>0.1#</td>
</tr>
<tr>
<td>DDT</td>
<td>0.05*, 1.25#</td>
<td>--</td>
<td>3.5 (F&amp;V)</td>
<td>7.0</td>
</tr>
</tbody>
</table>

# Fat Basis

4. CONSEQUENCES OF PESTICIDE CONTAMINATION

Pesticides are harmful if used injudiciously. Mode of action of various insecticides is very much similar in insects and mammals. OC pesticides exert their insecticidal activity by binding to the nerve membrane and interfering with the transmission of nervous impulses, possibly by upsetting the sodium or potassium balance across the nerve membrane. OP pesticides apparently inhibit the action of several enzymes, but the enzyme acetylcholinesterase has been reported to be the main victim. In the absence of effective acetylcholinesterase, the liberated acetylcholine accumulates and prevents smooth transmission of nervous impulses across the synaptic gap at the nerve
junction. This causes loss of muscular coordination, convulsions and ultimately death. Similarly Ocs also affect the activity of acetylcholinesterase and thereby preventing the effective transmission of nervous impulse. The toxicological effects of Ocs are vomiting, paraesthesia, disturbance of balance, damage to peripheral nerves, blindness, infant mortality and negative influence on reproduction activity and liver functioning. Similarly toxic effects of OPs and Ocs are acute intoxication, convulsions, respiratory failure, cardiac arrhythmias, long term central nervous system changes, mutagenicity, carcinogenicity and organospecific toxicity of heart, liver and kidney.

5. MANAGEMENT STRATEGIES

There is still a great need to adopt different useful strategies for controlling pesticide residues in the food chain. Some of these are listed below.

i) Time of spray: Crops should be sprayed much before harvesting.

ii) Processing of foods: Washing coupled with peeling and boiling wherever possible can help the consumer to minimize the exposure to pesticide residues (Kathpal and Kumari, 2000).

iii) Industrial effluent management: The dumping of industrial effluents in rivers, canals or any other water body should be prevented and properly managed.

iv) Business ethics: Agrochemical companies can play significant role in reducing the contamination of foods by giving full information about the use of particular pesticide such as dose rate, efficacy, MRL etc.

v) Use of biopesticides: Biopesticides are living organisms or a product derived from an animal or plant source and which kills the pesticides in order to sustain its growth cycle in environment. They are safer to human being and also do not leave any toxic residues in crops/environment and hence should be given due importance.

vi) Use of pest resistant varieties of seeds through genetic engineering: The identification and judicious exploitation of exotic gene that can provide insect resistance is the most significant near term contributions of genetic engineering to insect pest management. The most exotic insect resistance genes are insecticidal proteins, where the gene product itself provides the toxicity.

vii) Integrated Pest Management (IPM) Techniques: A number of international institutes, national Institutes, state agricultural universities, voluntary health organization keep on making sporadic efforts to organize training and demonstrations on safe use of less persistent and easily biodegradable synthetic pesticides. However, keeping in view the large number of users of pesticides, systematic and coordinated efforts are needed in this direction.

viii) Integrated Nutrient Management (INM) Techniques: After the IPM, INM (Integrated Nutrient Management) is further step to reduce the use of chemicals. INM is based on three principles i) assessment of the basic soil fertility and climate. ii) nature of the crop, not in isolation, but as a part of the cropping system and yield target. iii) at least 30% of the total nutrient level of NPK to be in organic form. Under conventional farming fertilizers, herbicides, insecticides and fungicides are applied at a uniform rate throughout the crop field. On the other hand, precision agriculture lays emphasis on judicious crop management at micro level where in only required amounts of inputs are applied.

ix) Organic farming: Organic farming is a route to meet the INM. Organic farming is a system in which the maintenance of soil fertility and the control of pests and diseases are achieved through the enhancement of biological processes and ecological interaction.
6. CONCLUSION

Changing status showing a decrease in the consumption of organochloro pesticides in India has brought out a definite changing status showing a decrease in the organochloro pesticide residues level in food products. The persistent organochloro pesticides have already been banned from the agriculture sector. However, a strict ban on their use is required to avoid their entry into the food chain. There is still a great need to adopt judicious use of less persistent and biodegradable synthetic pesticides and biopesticides. Safety and education must be encouraged in the rational use of pesticides. Adoption of useful strategies viz. Integrated pest management (IPM), integrated nutrient management (INM), good agricultural practices (GAP) and organic farming can help in controlling pesticide residues.

7. REFERENCES


Table 2. Pesticide residues (ppm) of major OC, OP, OCm in Indian food commodities during 1970 – 2003

<table>
<thead>
<tr>
<th>S. No</th>
<th>Food Commodity / Pesticide</th>
<th>OCPR</th>
<th>OPPR</th>
<th>OCMPR</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Vegetables (leafy and root tubers)</td>
<td>Tr-10.20</td>
<td>0.10-0.82</td>
<td>-</td>
</tr>
<tr>
<td>2</td>
<td>Fruits</td>
<td>Tr-4.4</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>3</td>
<td>Cereal (Wheat)</td>
<td>Tr-13.90</td>
<td>Try-5.43</td>
<td>0.02-11.92</td>
</tr>
<tr>
<td>4</td>
<td>Honey</td>
<td>Tr-0.850</td>
<td>ND-0.044</td>
<td>-</td>
</tr>
<tr>
<td>5</td>
<td>Meat Products</td>
<td>Tr-34.1</td>
<td>ND-1.18</td>
<td>-</td>
</tr>
<tr>
<td>6</td>
<td>Feed Concentrates</td>
<td>0.039-0.270</td>
<td>1999</td>
<td>2003</td>
</tr>
<tr>
<td></td>
<td></td>
<td>ND-2.27</td>
<td>ND-0.007</td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>Milk</td>
<td>ND-8.64</td>
<td>ND-0.065</td>
<td>1992-93</td>
</tr>
</tbody>
</table>
SPOILAGE ORGANISMS: 
BANES OF PROCESSING IN DAIRY INDUSTRY

Dr. R. K. Malik ¹ and Kunal Chaudhary ²
¹Principal Scientist, ²Research Scholar
Dairy Microbiology Division

1. INTRODUCTION

Being both highly perishable and nutritious, milk has since prehistoric times been subject to a variety of preservation treatments. Modern dairy processing utilizes pasteurization, heat sterilization, fermentation, dehydration, refrigeration, and freezing as preservation treatments. The result, when combined with component separation processes (i.e., churning, filtration, centrifugation, coagulation), is an assortment of dairy foods having vastly different tastes and textures and a complex variety of spoilage microflora. Spoilage of dairy foods is manifested as off flavors and odors and as changes in texture and appearance.

1.1 Milk

Milk is a good growth medium for many microorganisms because of its high water content, near neutral pH, and variety of available nutrients. Milk, however, is not an ideal growth medium since, for example, the addition of yeast extract or protein hydrolysate often increases growth rates. These components consist of lactose, fat, protein, minerals, and various non-protein nitrogenous compounds. Many microorganisms cannot utilize lactose and therefore, must rely on proteolysis or lipolysis to obtain carbon and energy. In addition, freshly collected raw milk contains various growth inhibitors that decrease in effectiveness with storage.

1.1.1 Carbon and nitrogen availability: Carbon sources in milk include lactose, protein, and fat. The citrate in milk can be utilized by many microorganisms but is not present in sufficient amounts to support significant growth. A sufficient amount of glucose is present in milk to allow initiation of growth by some microorganisms, but for fermentative microorganisms to continue growth they must have the appropriate sugar transport system and hydrolytic enzymes for lactose utilization. Although milk has a high fat content, few spoilage microorganisms utilize it as a carbon or energy source. This is because the fat is in the form of globules surrounded by a protective membrane composed of glycoproteins, lipoproteins, and phospholipids. Milk fat is available for microbial metabolism only if the globule membrane is physically damaged or enzymatically degraded (Alkanhal et al., 1985). Generally, milk will be spoiled by other mechanisms before this occurs. There are primarily two types of proteins in milk, caseins and whey proteins. Caseins are present in the form of highly hydrated micelles and are readily susceptible to proteolysis. Whey proteins (β-lacto globulin, α-lactalbumin, serum albumin, and immunoglobulins) remain soluble in the milk after precipitation of casein. They are less susceptible than caseins to microbial proteolysis. Milk contains non-protein nitrogenous compounds such as urea, peptides, and amino acids that are readily available for microbial utilization.

1.1.2 Natural inhibitors: The major microbial inhibitors in raw milk are lactoferrin and the lactoperoxidase system. Natural inhibitors of lesser importance include lysozyme, specific immunoglobulins, and folate and vitamin B₁₂ binding
systems. Lactoferrin, a glycoprotein, acts as an antimicrobial agent by binding iron. Psychrotrophic aerobes that commonly spoil refrigerated milk are inhibited by lactoferrin, but the presence of citrate in cow’s milk limits its effectiveness, as the citrate competes with lactoferrin for binding the iron (Batish et al., 1988).

1.2 Dairy products

Dairy products provide substantially different growth environments than fluid milk, because these products have nutrients removed or concentrated or have lower pH or water activity ($a_w$). Yogurt is essentially acidified milk, and therefore provides a nutrient-rich low-pH environment. Cheeses are less acidified than yogurt, but they have added salt and less water, resulting in lower $a_w$. In addition, the solid nature of cheeses limits mobility of spoilage microorganisms. Liquid milk concentrates such as evaporated skim milk do not have sufficiently low $a_w$ to inhibit spoilage and must be canned or refrigerated for preservation. Milk-derived powders have sufficiently low $a_w$ to completely inhibit microbial growth. Butter is a water-in-oil emulsion, so microorganisms are trapped within serum droplets. If butter is salted, the mean salt content of the water droplets will be 6 to 8%, sufficient to inhibit gram-negative spoilage organisms that could grow during refrigeration. However, individual droplets will have significantly higher or lower salt content if the salt is not uniformly distributed during manufacture. This can result in the growth of Psychrotrophic bacteria in droplets of low salt content. Unsalted butter is usually made from acidified cream and relies on low pH and refrigeration for preservation.

2. Spoilage Organisms of Milk and Milk Products

2.1 Psychrotrophic spoilage

There is often sufficient time between milk collection and consumption for psychrotrophic bacteria to grow. Pasteurized milk is expected to have a shelf life of 14 to 20 days, so contamination of the contents of a container with even one rapidly growing psychrotrophic microorganism can lead to spoilage. Psychrotrophic Bacteria in milk that spoil raw and pasteurized milk are primarily aerobic gram-negative rods in the family Pseudomonadaceae, with occasional representatives from the family Neisseriaceae and the genera Flavobacterium and Alcaligenes. It is typical that 65 to 70% of psychrotrophic isolates from raw milk are in the genus Pseudomonas (Garcia et al., 1989). Although representatives of other genera, including Bacillus, Micrococcus, Aerococcus, and Staphylococcus, and the family Enterobacteriaceae may be present in raw milk and may be psychrotrophic, they are usually outgrown by the gram-negative obligate aerobes (especially Pseudomonas spp.) when milk is held at its typical 3 to 7°C storage temperature. The psychrotrophic spoilage microflora of milk are generally proteolytic, with many isolates able to produce extracellular lipases, phospholipase, and other hydrolytic enzymes but unable to utilize lactose. The bacterium most often associated with flavor defects in refrigerated milk is Pseudomonas fluorescens, with Ps. fragi, Ps. putida, and Ps. lundensis (Ternstrom et al., 1993) also commonly encountered.

2.2 Proteases

2.2.1 Factors affecting protease production: P. fluorescens and other psychrotrophs that may be present in raw milk generally produce protease during the late exponential and stationary phases of growth (Griffiths et al., 1989), although there are reports of protease production throughout the growth phase (Malik et al., 1985). The effect of temperature on protease production does not parallel its effect on growth. The temperature for optimum production of protease by psychrotrophic Pseudomonas spp. is
lower than the temperature for optimum rate of growth. Relatively high amounts of protease are produced at temperatures as low as 5°C. The effect of calcium and iron ions on protease production by *Pseudomonas* spp. is relevant to dairy spoilage. Ionic calcium is required for protease synthesis.

### 2.2.2 Protease-induced product defects:
Proteases of psychrotrophic bacteria cause product defects either at the time they are produced in the product or as a result of enzyme surviving a heat process. Most investigators have observed that these proteases preferentially hydrolyze κ-casein. Degradation of casein in milk by enzymes produced by psychrotrophs result in the liberation of bitter peptides. Bitterness is a common off flavor in pasteurized milk that has been subject to post-pasteurization contamination with psychrotrophic bacteria. Continued proteolysis results in putrid off flavors associated with low molecular-weight degradation products such as ammonia, amines, and sulfides. Bitterness in UHT (commercially sterile) milk develops when sufficient psychrotrophic bacterial growth occurs in raw milk (estimated at $10^5$ to $10^7$ CFU/ml) to leave residual enzyme after heat treatment. Low-level protease activity in UHT milk can also result in coagulation or sediment formation. UHT milk appears to be more sensitive to protease-induced defects than raw milk, probably a result of either heat-induced change in casein micelle structure or heat inactivation of protease inhibitors (Reimerdes *et al.*, 1982).

### 2.4 Lipases

#### 2.4.1 Factors affecting lipase production:
Psychrotrophic *Ps. fluorescens* isolated from milk often produces extracellular lipase in addition to protease. Other commonly found lipase-producing psychrotrophs include *Ps. ftragi* and *Ps. aeruginosa*. Lipases of psychrotrophic pseudomonads, like proteases, are produced in the late log or stationary phase of growth. As with protease, optimal synthesis of lipase generally occurs below the optimum temperature for growth. Milk is an excellent medium for lipase production by pseudomonads. Although *Pseudomonas* spp. can utilize inorganic nitrogen, lipase production requires an organic nitrogen source. However, some amino acids repress lipase production, especially those that serve as nitrogen but not carbon sources.

#### 2.4.2 Lipase-induced product defects:
The triglycerides in raw milk are present in globules that are protected from enzymatic degradation by a membrane. Milk becomes susceptible to lipolysis if this membrane is disrupted by excessive shear force (from pumping, agitation, freezing, etc.). Raw milk contains a mammalian lipase (milk lipase) which will rapidly action the fat if the globule membrane is disrupted. Most cases of rancidity in raw and pasteurized milk are a result of this process, rather than from the growth of lipase-producing microorganisms. Phospholipase and protease produced by psychrotrophic bacteria can degrade the fat globule membrane, resulting in the enhancement of milk lipase activity (Alkanhal *et al.*, 1985). Milk lipase is heat labile, so most milk products will not have residual activity. The exceptions are some hard cheeses made from unheated milk or milk given a sub-pasteurization heat treatment.

### 2.5 Control of product defects associated with psychrotrophic bacteria

Preventing product defects that result from growth of psychrotrophic bacteria in raw milk involves limiting contamination levels, rapid cooling immediately after milking, and maintenance of cold storage temperatures. Limiting populations of bacteria primarily involves cleaning, sanitizing, and drying cow’s teats and udders before milking, and using cleaned and sanitized equipment. Removal of residual milk solids from milk corner surfaces is critical for psychrotrophs control. As previously indicated,
Psychrotrophic activity in milk is inhibited at 2°C, but freezing of milk causes disruption of the fat globule membrane, making it highly susceptible to lipolysis.

3. SPOILAGE BY FERMENTATIVE NON-SPORE FORMERS

3.1 Lactic acid bacteria

Spoilage of milk and dairy products resulting from growth of acid-producing fermentative bacteria occurs when storage temperatures are sufficiently high for these microorganisms to outgrow psychrotrophic bacteria, or when product composition is inhibitory to gram-negative aerobic organisms. Fermented dairy foods though manufactured using lactic acid bacteria, can be spoiled by the growth of "wild" strains that produce unwanted gas, off flavors, or appearance defects. Non-spore-forming bacteria responsible for fermentative spoilage of dairy products are mostly in either the lactic acid-producing or coliform groups. Genera of lactic acid bacteria involved in spoilage of milk and fermented products include Lactococcus, Lactobacillus, Leuconostoc, Enterococcus, Pediococcus, and Streptococcus (Chapman et al., 1990). Coliforms can spoil, milk, but this is seldom a problem since they are usually outgrown by either the lactic acid or psychrotrophic bacteria. Coliforms induced spoilage is more common with fermented products, especially certain cheese varieties. Members of the Enterobacter and Klebsiella genera are most often associated with coliforms spoilage, while Escherichia spp. only occasionally exhibit sufficient growth to produce a defect.

3.1.1 Defects of fluid milk products: The most common fermentative defect in fluid milk products is souring caused by the growth of lactic acid bacteria. Lactic acid by itself has a clean pleasant acid flavor and no odor. The unpleasant "sour" odor and taste of spoiled milk is a result of small amounts of acetic and propionic acids. A malty flavor results from growth of Lactococcus lactis subsp. lactis var. maltigenes. Most dairy associated species of lactic acid bacteria have strains that produce extracellular polymers which increase the viscosity of milk, causing the ropy defect (Corning, 1990). The defect in non-cultured fluid milk products is usually caused by growth of specific strains of lactococci.

3.1.2 Defects in cheeses: Some strains of lactic acid bacteria produce flavor and appearance defects in cheese. Lactobacilli are a normal part of the dominant microflora of aged cheddar cheese. If hetero-fermentative lactobacilli predominate, the cheese is prone to develop an "open" texture or fissures and off flavors as a result of gas production during aging (Lalaye et al., 1987). Gassy defects in aged cheddar cheese are more often associated with growth of lactobacilli than the growth of coliforms, yeasts, or spore formers. Lactobacillus brevis and Lb. casei subsp. pseudoplanatarum have been associated with gas production in retail mozzarella cheese. Lb. casei subsp. casei produces a soft body defect in mozzarella cheese. Some cheese varieties occasionally exhibit a pink discoloration. Pink spots in Swiss-type varieties result from the growth of pigmented strains of propionibacteria. Another common defect of aged Cheddar cheese is the appearance of white crystalline deposits on the surface. Although they do not affect flavor, these deposits reduce consumer acceptability. Fruity off flavor in cheddar cheese is usually not caused by growth of psychrotrophic bacteria, as it is in milk, but rather a result of growth of lactic acid bacteria (usually Lactococcus spp.) that produce esterase (Table 1).
Table 1. Some defects of cheese that result from microbial growth

<table>
<thead>
<tr>
<th>Defect</th>
<th>Microorganisms</th>
<th>Metabolic product</th>
</tr>
</thead>
<tbody>
<tr>
<td>Open texture, Fissure</td>
<td>Heterofermentative lactobacilli</td>
<td>CO₂</td>
</tr>
<tr>
<td>Early gas</td>
<td>Coliforms, Yeasts</td>
<td>Hydrogen, CO₂</td>
</tr>
<tr>
<td>Late gas</td>
<td><em>Clostridium</em> spp.</td>
<td>Hydrogen, CO₂</td>
</tr>
<tr>
<td>Rancid</td>
<td>Psychrotrophic bacteria</td>
<td>Free fatty acids</td>
</tr>
<tr>
<td>Fruity</td>
<td>Lactic Acid Bacteria</td>
<td>Ethyl esters</td>
</tr>
<tr>
<td>White crystalline surface</td>
<td><em>Lactobacillus</em> spp.</td>
<td>Excessive D-lactate</td>
</tr>
<tr>
<td>deposits</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pink discoloration</td>
<td><em>Lactobacillus delbrueckii</em> subsp.</td>
<td>High redox</td>
</tr>
<tr>
<td></td>
<td><em>bulgaricus</em></td>
<td>potential</td>
</tr>
</tbody>
</table>

3.2 Coliform bacteria

Growth of coliform bacteria usually occurs during the cheese manufacture process or during the first few days of storage and therefore is referred to as early gas (or early blowing) defect. In hard cheeses, such as cheddar, this defect occurs when slow lactic acid fermentation fails to rapidly lower pH, or when highly contaminated raw milk is used. Cheese varieties in which acid production is purposely delayed by washing the curds are highly susceptible to coliform growth. Soft, mold-ripened cheeses, such as Camembert, increase in pH during ripening, with a resulting susceptibility to coliform growth.

3.3 Control of defects caused by lactic acid and coliform bacteria

Defects in fluid milk caused by coliforms and lactic acid bacteria are controlled by good sanitation practices during milking, maintaining raw milk at temperatures below 7°C, pasteurization, and refrigeration of pasteurized products. Control of coliforms growth in cheese is achieved by using pasteurized milk, encouraging rapid fermentation of lactose, and good sanitation during manufacture.

4. SPORE-FORMING BACTERIA

Spoilage by spore-forming bacteria can occur in low-acid fluid milk products that are preserved by sub-sterilization heat treatments and packaged with little chance for re-contamination with vegetative cells. Products in this category include aseptically packaged milk, cream and sweetened and unsweetened concentrated canned milks. Non aseptic packaged refrigerated fluid milk may spoil owing to growth of psychrotrophic *Bacillus cereus* and *B. polymyxa* in the absence of more rapidly growing gram-negative psychrotrophs (Overcast *et al.*, 1974). Hard cheeses especially those with low interior salt concentrations, are also susceptible to spoilage by spore-forming bacteria. Spore-forming bacteria that spoil dairy products usually originate in the raw milk. Spore-forming bacteria in raw milk are predominantly *Bacillus* spp., with *B. licheniformis*, *B. cereus*, *B. subtilis*, and *B. megaterium* most commonly isolated.

4.1 Defects caused by spore-formers in dairy products

4.1.1 Defects in fluid milk products: Pasteurized milk packaged under conditions that limit recontamination can spoil owing to the growth of psychrotrophic *B. cereus* and is present in over 80% of raw milk samples. Germination of spores in raw milk occurs soon after pasteurization, indicating that they were heat activated. The defect produced by subsequent growth is described as sweet curdling, since it first appears as coagulation without significant acid or off flavor being formed. Psychrotrophic *Bacillus* sp. other
than *B. cereus* are also capable of spoiling heat-treated milk. Cromie et al. (1989) observed that psychrotrophic *Bacillus coagulans* was the predominant spoilage organism in aseptically packaged heat-treated milk. This microorganism produces acid from lactose, giving the milk a sour flavor. Most bacterial spores present in raw milk are moderately heat labile and are destroyed by UHT treatments.

4.1.2 Defects in canned condensed milk: Canned condensed milk may be either sweetened with sucrose and glucose to lower the *a*<sub>w</sub> or left unsweetened. The unsweetened product must be sterilized by heat treatment. "Sweet coagulation" is caused by growth of *Bacillus coagulans*, *B. stearothermophilus*, or *B. cereus*. This defect is similar to the sweet curdling defect caused by psychrotrophic *B. cereus* in pasteurized milk. Swelling or bursting of cans can be caused by growth of *Clostridium sporogenes*. "Flat sour" defect (acidification without gas production) can result from growth of *B. stearothermophilus*, *B. licheniformis*, *B. coagulans*, *B. macerans*, and *B. subtilis* (Overcast et al., 1974).

4.1.3 Defects in cheese: The major defect in cheese caused by spore-forming bacteria is gas formation, usually resulting from growth of *Clostridium tyrobutyricum* and occasionally from growth of *C. sporogenes* and *Clostridium butyricum*. This defect is often called "late blowing" or "late gas" because it occurs after the cheese has aged for several weeks. Emmental, Swiss, Gouda, and Edam cheeses are most often affected because of their relatively high pH and moisture content plus their low interior salt levels. The defect can also occur in cheddar and Italian cheeses. Processed cheeses are susceptible to late blowing because spores are not inactivated during heat processing. The number of spores in raw milk needed to cause a defect varies with size and shape of the cheese in addition to pH and moisture, because cheese size and shape determine the extent of salt penetration after brining. The number of spores required to cause late blowing in 9-kg wheels of rinsed Swiss cheese was estimated at > 100 per liter of raw milk (Dasgupta et al., 1989).

4.2 Control measures for spoilage caused by spore-formers

4.2.1 Control of spore-former-associated defects in fluid products: Methods for controlling growth of spore-formers in fluid products mainly involve the use of appropriate heat treatments. UHT treatments produce products microbiologically stable at room temperature. However, when sub-UHT heat treatments are more severe than that required for pasteurization, the shelf life of cream and milk can actually decrease, a phenomenon attributed to spore activation (Muir, 1989). Use of a double heat treatment, the first to activate spores and the second to destroy them, does not result in the expected increase in shelf life (Griffiths et al., 1990a). Adding hippuric acid, a naturally occurring germinant to raw milk, does not germinate sufficient spores before heat treatment to provide a consistent increase in shelf life (Griffiths et al., 1990b).

4.2.2 Control of spore-former-associated defects in cheese: Ideally, control of late blowing defect would occur at the farm by instituting feeding and management practices that would reduce the number of spores entering the milk supply (Herlin, 1993). In practice, this approach has not achieved the required results, so cheese manufacturers have tried to control the defect by removing spores from the milk at the plant or inhibiting their growth in the cheese. Numbers of bacterial spores can be reduced in milk by a centrifugation process known as bactofugation. Germination of spores in the cheese can be inhibited by addition of nitrate and/or lysozyme (Dasgupta et al., 1989). Nitrate as a cheese additive is prohibited in many countries, and lysozyme by itself does not provide complete protection. Bacteriocins produced by lactic acid bacteria may
provide a highly specific means of inhibiting anaerobic spore germination (Thualt et al., 1991).

5. YEASTS AND MOLDS

Growth of yeasts and molds is a common cause of the spoilage of fermented dairy products, because these microorganisms are able to grow well at low pH. Yeast spoilage is manifested as fruity or yeasty odor and/or gas formation. Cultured milks, such as yogurt and buttermilk, and fresh cheeses, such as cottage, normally contain fermentable levels of lactose and therefore, are prone to yeast spoilage. A "fermented/yeasty" flavor observed in cheddar cheese spoiled by growth of a Candida spp. was associated with elevated ethanol, ethyl lactate, and ethyl butyrate (Horwood et al., 1989). Yeast spoilage can also occur in dairy foods with low aw, such as sweetened condensed milk and butter. The most common yeasts present in dairy products are Kluyveromyces marxianus and Debaromyces hansenii (the teleomorph) and their asporogenous counterparts (the anamorph), Candida famata, C. kefyr and other Candida species (Fleet, 1990). Also prevalent are Rhodotorula mucilaginosae, Yarrowia lipolytica, and Torulopsis and Pichia sp. (Rohm et al., 1992). The most common molds found on cheese are Penicillium sp. (Bullerman et al., 1974).

5.1 Controlling mold spoilage

Yeasts and molds that spoil dairy products can usually be isolated in the processing plant on packaging equipment, in the air, in salt brine, on manufacturing equipment, and in the general environment (floors, walls, ventilation ducts, etc.). Successful control efforts must start with limiting exposure of pasteurized products to these sources. Mold spores do not survive pasteurization (Cromie et al., 1989). If the initial contamination level is limited, strategies to inhibit growth are more likely to succeed. These include packaging to reduce oxygen (and/or increase carbon di-oxide), cold storage, and the use of anti-mycotic chemicals such as sorbate, propionate, and natamycin (pimaracin). Added liquid smoke is also a potent mold inhibitor (Wendorff et al., 1993). None of these control measures is completely effective. Vacuum-packaged cheese is susceptible to thread mold defect, where the fungi grow in the wrinkles of the plastic film (Hocking et al., 1992). Some molds are resistant to anti-mycotic additives. Sorbate-resistant molds are commonly isolated from sorbate-treated cheese but not from untreated cheese (Liewen et al., 1989).

6. CONCLUSIONS

Considering the milk production of milk in India at 80 million ton, it has been estimated that about 10% of milk collected in summer month by the dairies is received in sour or unprocesseble state. This causes a huge economic loss besides causing shortage of milk. Effective control of these contaminants must begin on the farm and be followed through to the retail store. Clean equipment and packages, limited time of storage, low holding temperatures for milk and the finished cheese, effective laboratory control and attention to practices which will slow the outgrowth of spoilage organism will help the people of dairy industry to produce a product with good yield, good flavor, long shelf life, and high sales appeal. We use our knowledge of microbiology, biochemistry, engineering, sensory analysis, production management, personal management, sales and marketing. Nevertheless, they do provide us with opportunities to use these educational disciplines and to meet together at times like this where we can share with each other those findings and experiences that many people have contributed.
7. REFERENCES


1. INTRODUCTION

The overall objective of food manufacturers and caterers is to provide the consumer with safe wholesome products with desirable sensory attribution in a cost effective manner. Milk and milk products, because of their high nutritional value and lack of natural preservatives, are highly susceptible to spoilage and can support health threatening microorganisms such as *Salmonella*, *E. coli*, *Listeria*, *Campylobacter*, *Staphylococcus aureus* and Tuberculoses bacteria. Not only the presence of pathogenic organisms and their toxic metabolites, but also the other spoilage microbial species and non-microbial substances may cause adverse effects on food quality and safety during primary production, collection, chilling, transportation, processing, packaging and distribution. Dairy products are frequently involved in a number of food-borne illnesses all over the world. More then 200 food-borne illnesses have been recognized, and most of them for diagnosis require very specific laboratory facilities and standard laboratory practices.

2. FOOD BORNE DISEASES: IMPACT

Food borne illnesses are a major cause of gastro-intestinal illness worldwide. The reported cases of such illness are believed to represent only a small fraction of the people who are actually till after eating contaminates food. It may however, be stated that the impact of morbidity and mortality from food borne diseases is quite substantial. Expressed in monetary terms, the costs of human illness, value of lives shortened through death, lost productivity to society, pressure and constraints on medical care and public health systems, recalls and destruction of foods, loss of sales and legal settlements will cost billion-dollar expenditure.

The main types of problems that lead to food borne illness are associated with
- ethnic food, and the way they are handled and stored
- food, that are easily contaminated consequent to atmospheric exposure
- limited treatment to remove or destroy the organisms, i.e. not cooked or lightly treated foods
- ready-to-eat-foods, those have frequently been handled during processing and may be warmed before consumption
- foods sold by street vendors, sweet meat sellers and restaurants and
- globalization of food supplies

3. SAFETY RISKS

Safety risks from foods are usually associated with the following situations:
- Frequent travelers
- Persons in developing countries
- Very young, elderly, ill and immuno-compromised people
- Those largely dependent on imported or exotic foods
Changes in processing and packaging, biotechnology and molecular implication

Emerging infections diseases and low level of knowledge about their containment.

The factors contributing to emergence and adaptation of pathogens may be classified as:

- Biological (changes in genotype leading to enhanced, survival, resistance or virulence)
- Environmental
- Food-related
- Consumer-associated

4. DAIRY INDUSTRY IN INDIA

The Indian dairy industry produces nearly 88 million tons of milk annually. Besides fluid milk, products like cream, butter ghee, traditional milk products, milk sweets, milk powders, infant food, cheese, ice cream, dahi and other fermented products are produced. Dairy industry in India is a significant part of the food processing industry and the total agricultural system. Dairy product, contribute substantially to the health of primarily vegetarian population. Share of dairy industry to GDP is also important. Milk production systems in India are classified as backyard, smallholder, erved-urban and commercial.

5. SANITATION IN DAIRY INDUSTRY

The present status of sanitation during milk production is far from satisfactory. The training needs of the milk producers are high to update awareness of sanitation during milking and handling of milk. Concerted efforts have to be made to introduce the concept of clean milk production in the villages and on the farms.

Sanitation in dairy industry is normally assessed on the basis of biological, chemical or physical standards of cleanliness. The acceptability of a food is determined by the tolerances established for various contaminants in these three categories. Physical cleanliness has been relied upon to a great extent for evaluating sanitation, and dairy industry has made food progress in the control of foreign matter such as dirt, insects, rodents, hairs, feed residues and unwanted debries in milk. Consumers are new demanding the introduction of microbiological quality standards. The regulatory agencies are also putting stress on this aspect. The microbiological standards are being formulated for a number of dairy products. The adoption of sanitary practices in handling and processing of milk and milk products is especially critical. Many principles of sanitation, in-place-cleaning, sanitary design of buildings and equipment have promoted the establishment of large dairies. The introduction of Good Manufacturing Practices (GMP) in dairy industry emphasis the use of microbiological criteria for evaluating the overall sanitation practices of a dairy plant.

It would seem logical that the establishment of specific standards or GMP for dairy industry would go far in preventing the distribution of potentially hazardous products or contaminated goods prepared under less satisfactory conditions.

6. GMP RELATED REGULATIONS

The product-wise set of standards for GMP is written under “umbrella” regulations. For example, such universal requirements as screens on windows, clean equipment and other basic sanitation rules would keep reappearing in each individual set
of regulations. Safe food production is facilitated by the adoption of prevention measures such as the use of safe raw materials, application of GMP and HACCP procedures and measures of interventions. CCP are those which present risks of contaminations as a result of microbial multiplication during manufacture storage, shipment, distribution and consumption. HACCP principles are now incorporated into the guidelines for GMP by various agencies. Detailed criteria have been established in areas like factory layout building design, equipment and utensils, sanitary facilities and controls, sanitary operation, quality of raw materials, manufacturing processes and controls and personnel hygiene.

7. **BENEFITS OF GMP**

GMP regulations—whether general or specific—should result in a number of benefits, such as (a) both large and small plants will have a definite inspection report from the regulatory authority with statements what the agency believes is necessary to comply with plant sanitation requirements (b) the observations will help firms in setting up their own sanitation programme as well as measuring the conformity with required, sanitary practices (c) compliance with GMP has a preventive effect, since it will minimize the distribution of potentially hazardous or contaminated products, and (d) the consumers will have further assurance that the food they are getting is safe and wholesome. Under the provisions of GMP as related to sanitation in doing processing, it is stated that (a) a food is illegal if it is filthy, putrid or decomposed, (b) a food is illegal if it is prepared, packed or held under unsanitary conditions whereby it may have become contaminated with filth.

The dairy plants will have available the knowledge of experts who helped to establish the GMP regulations. The industry will have the specifications for suitable buildings, equipment and record-keeping, etc. that will be covered in the general and in the specific regulations.

On the contrary, some people hold the view that the industry is already over regulated and GMP will be additional burden. Another observation is that the GMP will be so complicated that many companies, particularly smaller ones will be unable to comply and will be forced out of business. These dangers will hold no water in the wake of WTO Agreements and Open Competitive enacts. Dairy products have to compete with the global trading countries within and outside. Improvements in quality competitiveness are needed.

8. **GUIDELINES FOR REGULATING GMP**

Many companies in the United States of America have expressed satisfaction that the Food and Drug Administration, has for the first time, put in writing the minimum requirements for a satisfactory sanitation programme for food plants. For years, these companies have recognized the advantages of GMP. The programmes for various firms in the dairy industry may vary in detail, but all contain certain essential items, which include:

- guidelines governing the general environment in which products are manufactured and held, including factors such as storage temperatures
- isolation of raw products from processed or cooked product
- sanitary practices and facilities for personnel
- detailed instructions in written form on how and when to clean the equipment and
• instructions on how to manufacture the product, along with microbiological standards for specific raw products and for finished products.

Training programmes on sanitation practices for all classes of employees in these programmes, it is important to educate the management of the importance of sanitation and even more important in contact with the personnel when actually handle and work with food-products.

9. GOOD PLANT HYGIENE

It is necessary to observe good housekeeping practices, involving such things as rodents, insects and birds. Failure to maintain hygienic practices may attract adverse actions against the plant personal hygiene of employees should take into account the subclinical infections or boils and sores and the wearing of uniforms and where they should be worn. Another requirement is that personnel wear hairnets, headbands, caps or other effective hair restraints. The human being is the weakest factor in the entire sanitation programme. The practice of sanitation should be regarded as a continuing way of life and not just a sporadic event.

The criteria and methodology chosen for assessing good manufacturing practices must be carefully evaluated as to their soundness, validity and the ultimate objective of the tests and not used just to impress the public. The microbiological criteria used in the evaluation of good manufacturing practices should reflect the presence or absence of potential health hazards. A regular review of cleaning and sanitizing methods should be made especially with regard to strength and contact times. Cleaning data should be maintained and verified.

10. PREVENTION OF PATHOGENS ENTRY INTO PLANT ENVIRONMENT

Good raw milk management practices will help in reducing the microbial load. Cooling of milk on the farm should be properly controlled as pick up times may vary. While applying GMP to the handling and transportation of raw milk, the “cow to consumers” concept should be kept in mind. Dairy Cattle are the reservoir for *E. coli*, which get transmitted to dairy plant through milk tankers and drivers. Guidelines have been given to prevent entry of pathogens into the plant environment in many textbooks and monographs.

11. SAFE HANDLING OF DAIRY PRODUCTS

There are ways in which risks can be minimized through proper handling that will reduce the changes of pathogens coming in contact with foods. It may be kept in mind that the goal of “absence of any risk” is unattainable. The mandated HACCP will be the norm for all countries to reduce the impact of food borne illness. The majority of outbreaks from dairy products can be attributed to post processing contamination. Virtually every country regulates dairy-Products. Initiated by the International Dairy Federation (IDF), the Codex Alimentarius Commission, implements the Joint FAO/WHO Food Standards Programme. The Codex Committee on Milk and Milk Products (CCMMP) has provided a code of principles for the handling of milk and milk products. IDF has also published a bulletin outlining recommendation for the hygienic manufacture of milk and milk based products. In India, the Export Inspection Council (EICI) BIS, PFA and the revised Milk and Milk Products Order have specified the sanitary and regulatory aspects as applied to milk products. Animal healthcare services
provided by the governments and industry are important factors in producing safe milk and milk products.

12. TECHNOLOGIES FOR CONTROLLING FOODBORNE MICROBES

1. Thermal inactivation
2. Control with cold temperatures
3. Inactivation by irradiation
4. Microwave inactivation of pathogens
5. Control with chemicals
6. By MAP packaging, use of edible films
7. With CO₂ under elevated pressure
8. By low pressure and ambient pressure gauge
9. By applying naturally occurring antimicrobial systems including bacteriolytic enzymes
10. Application of bacteriocins in food preservation
11. Formulation of low-acid food, for Botulinum safety
12. Inactivation by high intensity pulsed electric field
13. Magnetic fields as a potential non-thermal technology for the inactivation of microorganisms
14. Microbial inactivation by high pressure
15. Ohmic heating
16. Microbial control by HACCP system
17. Hurdle technology

13. DESIGN OF PROCESS PLANTS

The equipment design for milk products must take care of the following criteria

- Meet the sanitary and safety requirements including risk elimination
- Meet the legal requirements (3A standards BIS, Pressure Vessel (Act, etc.)
- Fabricated to be 100% cleanable and preclude contamination during processing
- Free from imperfections such as pits, folds, crevices, dead ends
- Ensure self draining characteristics accessibility for cleaning and inspection
- Provision for sampling of products
- Sealed and self lubricating bearings
- Motors and other moving parts fully enclosed, explosion and splash proof

14. EFFECTIVE MAINTENANCE

High exporting dairy countries follow well-established and effective maintenance programmes even during shutdown. Regardless of where the product is going to end up, either exported or marketed locally, the same maintenance standards should apply. There are internationally acceptable for preventive and repairs standards, but they are cost dependent. The equipment and vessels during the production season are subjected to continued filling and washing with liquids of varied temperatures resulting the stainless steel to expand and control frequently and causing the surface to corrode, followed by appearance of pin holes pits and cracks. The cleaning solutions are unable to penetrate the pinholes and clean out the residual product within. Bacteria sorrowing in these pinholes can extenuate the incoming product. It is, therefore, most important that these defects are identified annually and the interior surface of the vessels is returned to an acceptable hygienic surface which is washable and sanitizable.
15. REPROCESSING OF RETURNED PRODUCTS

All returned product should be treated as a raw product and processed at temperatures above the required minimum. External carton contamination should be carefully avoided, and reclaimed product isolated from all other plant operations. Reuse of outdated product, and reuse of temperature-abused product or product from leaking containers are high-risk operations. Never mix reprocessed product into freshly prepared commodity.

16. CONCLUSION

The current good manufacturing practices for the dairy industry to a great extent depend on the commitment of management and technical staff by the adoption of standard guidelines relating to quality management, personnel, training, documentation, premises, equipment, manufacture, good laboratory, practices, use of updated technologies, packaging, infestation control, ware housing, storage and transportation. Total quality concept is heavily influenced by sanitation and safety requirements from raw material procurement to finish products supply to consumers. The investments made in GMP will bring much high profitability to the dairy industry. Freedom from contaminants additives, adulterants, etc. will loose the business interests and success of the industry. A good regulatory authority needs to be in place to administer GMP.

17. REFERENCES

1. INTRODUCTION

Laboratory practices are developed after the evaluation of protocols in terms of drawbacks, advantages, cost, reproducibility, simplicity, interferences by other substances, applicability to pure analyte vis a vis its estimation in biological / complex materials, safety, its use in field conditions, acceptance by law enforcing authority, validation by other users, yield and availability of lab facilities. Laboratory practices are also developed for recording of data, safe handling of chemicals, appropriate and correct use of equipments and their maintenance and avoiding exposure to hazards including chemical, radiation, biological, gaseous, noise etc. A set of guidelines is followed for maximizing productivity and minimizing possibility of accidental exposure to hazards.

2. SAFE LABORATORY PRACTICES AND TIPS

Worker must have sound theoretical knowledge of possible hazards in environment of his work place. This helps in realization of benefits of safe working, extent of loss (both life had property) in unsafe handling and designing safe laboratory practices. Safe laboratory practices for working in general research laboratory, radioactive laboratory, organic chemistry laboratory, pathogen laboratory, molecular biology laboratory and hybridoma / cell culture laboratory may differ and these are to be understood by the worker otherwise productivity is likely to be compromised. The following general safety measures are recommended.

- Worker must know the location and operation of fire extinguishers.
- Wherever required, worker must wear goggles to protect eye.
- Wear lab coat to protect clothes. Acids can make holes in cotton clothes. Organic solvents such as acetone, ethyl acetate can dissolve nylon and rayon clothes. Long hairs should be tied back to keep them from coming in contact with laboratory chemicals and flame.
- Avoid inhaling and never taste any chemical in laboratory.
- In case of serious cut, stop blood flow using direct pressure and clean towel.
- Never carry out unauthorized experiments. Come to the laboratory prepared.
- Always remember that hot glassware looks same as cold glassware. Instead of mouth suction for pipetting, use auto dispensers. If auto dispensers are not available, plug the pipette with cotton for measuring strong acid, base and other reactive solvents.
- Never force glass tubing through a rubber stopper. If glass tubing is to be inserted into rubber stopper, be sure to lubricate both the stopper and tubing with glycerol or soapy water.
- Water can cause death of reaction in many organic chemistry experiments. Many workers make mistake of beginning each lab experiment by washing their glasswares. Soon they realize that enormous time is wasted in drying glasswares. Clean glassware at the end of experiment so that it has time to dry for the next experiment.

- Certain experiments are conducted in steps. When sufficient time is available between steps, utilize this time for preparation for next step.

- Always label the reagents and solvents.

- Cooling water always enter the bottom of the condenser and flows out from the top.

- Always stop distillations before the boiling flask goes dry. Residues concentrated to dryness during distillation may be unstable and explode. This is particularly important with ethers and some alcohols, which can form organic peroxides.

- Glass joints that come in contact with strong bases (NaOH or KOH) need to be greased. Failure to clean them promptly after use will result in permanent sealing of the glass surfaces. Teflon stopcocks are never greased.

- Never leave a reaction unattended.

- When performing extractions, save both layers (organic and water) until one becomes sure of presence of desired product in particular layer. In case one fails to remember which layer is aqueous, identify by adding little water to both the layers.

- Exercise great care in handling volatile, flammable solvents such as ether, acetone and methanol. Never evaporate these solvents on hot plate in an open system. An efficient condenser system must be used.

- An open flame may be ignited only when no flammable solvents are in the vicinity.

- While handling pathogen, disease-causing microorganisms, care should be taken in their handling to protect worker and others from their exposure. After the experiments, pathogens must be killed by autoclaving and only then these should be disposed. Work on pathogens should be carried in authorized laboratories. Pathogen testing on animals should be carried out under control conditions. Culture collection centers must also adhere to the guidelines for handling of pathogens and distribute only to authorized persons. Worker must have sufficient background of microbiology. Pathogen handling in casual way can lead to serious implications not only to workers from lab but also entire environment and in that situation difficult to control it.

- Radioactive materials are also to be used by authorized workers. Worker must have sound knowledge of the subject. Radioactive materials have different half-lives and their energy levels are also different. Long half-lives radioactive materials are more harmful as compared to short half-lives. Similarly, radioactive materials with more energy levels radiations are more harmful as compared to low energy. Further, the quantities of radioactive materials used in experiments define the extent of precautions to be taken in its handling. Radiation affects DNA, the basic unit that stores genetic information. Laboratory must be regularly
monitored for any spillover and in case of radioactive spillover, everyone in vicinity must be informed and such area cleaned. Every worker must wear lab coat and must use badge for checking extent of exposure. All containers must be legibly labeled that these contains radioactive materials. Approved guidelines must be followed in their disposal.

- In molecular biology lab, recombinant microorganisms, transgenic animals and transgenic crops are prepared. There is always a possibility that altered genetic material prepared by using genetic engineering can find entry to normal microorganisms, animals and crops. Even, possibility cannot be ruled out of the integration of this in to human genome. Therefore great care is required so that this material does not spread.

- In animal cell culture laboratory, if cell lines of human origin are used, all precautions for their containment must be taken. Mouth pipetting is not permitted. Accidental entry of these cell lines in humans will prove fetal. Before their disposal, all cells must be killed. If one is working with cell lines from other species, immune system of human can take care in some situations and but it is desirable to take all precautions.

3. DATA COLLECTION, RECORDING AND ANALYSIS

Data collection, recording and analysis are very important aspects for defining good laboratory practices. Every experiment must record purpose, procedure, data collection, calculations, and conclusions. Some useful hints are provided.

- Designing of experiments is very important. A carefully and well thought design can answer many questions and minimize errors. Considerable time should be devoted in designing the experiment and preferably be completed one day before actual experiment.

- All calculations for preparations of solutions are carefully checked. Purity of the chemicals should be checked and taken in to account into calculations.

- All data should be collected in sturdy laboratory notebook. Make a carbon copy of data and keep at distant location to take care of possible loss in case of fire.

- It is generally seen that procedure is modified on the day of experiment and such modification must be recorded.

- Prepare data tables ahead of time. Well-prepared data tables not only speed up the recording of data but also aid in report writing.

- All calculations must be recorded. This helps in finding calculation errors even after several months or years.

- Observations during experiments are to be seriously made. This can help in analysis of data in correct way.
FOULING, CLEANING AND SANITIZATION OF MEMBRANES

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1. INTRODUCTION

Fouling of membranes represents major problem area and calls for special knowledge of operating skills and cleaning procedures. Like all other industrial equipments, membrane filtration plants have to be cleaned at regular intervals. Today we have a variety of membranes available with differences in chemical and temperature resistance. The most important consideration in cleaning and maintenance is never to allow the feed constituents to dry out on the membrane surface. Shutting down the system during operation and leaving the treated fluid in contact with membranes for 1-2 min results in severe fouling (Renner and El-Salam, 1991). Cleaning of membranes has to be efficient, easy, fast with no risk to the membrane and the rest of the installation. Besides, it must completely meet the sanitary requirements. The cleaning reagents and operating parameters such as pressure, flow velocity and temperature, are dictated by the feed and the resulting fouling. Better understanding and controlling of these parameters can determine the performance and lifetime of the membrane. The prevalent method for achieving these objectives is to perform in-place cleaning procedure followed by a sanitary step. In most cases the cleaning of membrane filtration system can be accomplished by using cleaning agents recommended by the manufacturer. The advent of high resistant membranes has in many respects made cleaning easier than before.

2. FOULING OF MEMBRANES

Fouling is generally attributed to the accumulation of macromolecules such as protein, lipids, micro-organisms and/or inorganic salts, on the membrane surface and to the possible crystallization and precipitation of smaller solutes that are normally permeable such as sugar and salts, in membrane pores (Merin and Cheryan, 1985; Patel and Reuter, 1985). Adsorption of macromolecules on the membrane surface is dependent on solution properties (pH, ionic strength, and concentration of solutes) and surface characteristics (hydrophobicity and surface charge). The adsorption of individual whey proteins to a hydrophobic surface is higher than to a hydrophilic surface. This holds true for hydrophobic polysulphone and hydrophilic regenerated cellulose acetate membranes. Current R&D emphasis is focused on minimising fouling. Manufacturers of membranes have been constantly involved in developing membranes to minimise fouling effect. Further, the nature of the fouling will vary from one product to another, the type of membrane process (Microfiltration, ultrafiltration, nanofiltration or reverse osmosis) and the operating conditions (flow rate, pressure, temperature) maintained. However, All types of fouling causes permeate flux to decrease in the course of time, thus reducing the capacity of the plant. For maintaining the plant capacity, it is therefore important to keep the fouling at a minimum and cleaning frequency be suitably regulated (Glover, 1985; Patel et al., 1992). In some plants, the facility of back-flushing is available. Back-flushing is applying counter-pressure on filtrate or permeate side that pushes a controlled amount of filtrate back through the membrane thereby dislodging the deposited matter from the membrane. Short and frequent back pressure pulses, by constantly dislodging the deposited matter, maintain the filtrate flux at high value and enable a full exploitation...
of higher permeability of membranes. This technique is one of the key advantages of ceramic/mineral membranes.

3. CLEANING OF MEMBRANES

Cleaning is the treatment that regenerates the membrane permeability. It must be kept in mind that membranes represent a barrier for direct cleaning and disinfection on the permeate side and that membrane filtration equipment can only be cleaned by CIP. Efficiency of cleaning is usually measured by determining the recovered percentage of the original flux (not less than 95%). Therefore, selection of the cleaning agents and conditions is of great importance. They should meet the necessary efficiency and should not affect the membrane or equipments.

3.1 Physical aspects of membrane cleaning

Physical aspects of membrane cleaning concern membrane material, temperature, time, mechanical aspects and module design.

3.1.1 Membrane material: Today membranes are made of various polymers, typically, polysulphone, polyam ide, and cellulose acetate, each with typical resistance characteristics towards chemicals, temperature, and pressure. The alkali resistance and temperature resistance of cellulose acetate membrane are very poor. The types of acid and alkali detergents, compatible with different types of membranes, are given in Table 1 (Marshall and Daufin, 1996). Application of any chemical not approved by the membrane manufacturer may cause serious membrane damage.

<table>
<thead>
<tr>
<th>Processing Conditions</th>
<th>CA</th>
<th>TFC</th>
<th>PS</th>
<th>Mineral</th>
</tr>
</thead>
<tbody>
<tr>
<td>Membrane process</td>
<td>RO</td>
<td>RO</td>
<td>UF</td>
<td>UF/MF</td>
</tr>
<tr>
<td>Temperature (°C) range</td>
<td>0-30</td>
<td>30-60</td>
<td>30-60</td>
<td>Upto sterilization</td>
</tr>
<tr>
<td>pH range</td>
<td>3-8</td>
<td>3-11</td>
<td>2-12</td>
<td>All</td>
</tr>
<tr>
<td>Chemical resistance</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Caustic soda (0.3%)</td>
<td>0</td>
<td>**</td>
<td>***</td>
<td>***</td>
</tr>
<tr>
<td>Nitric acid (0.5%)</td>
<td>*</td>
<td>**</td>
<td>***</td>
<td>***</td>
</tr>
<tr>
<td>Chlorine (20 ppm)</td>
<td>**</td>
<td>0</td>
<td>**</td>
<td>**</td>
</tr>
<tr>
<td>Flux</td>
<td>*</td>
<td>**</td>
<td>***</td>
<td>***</td>
</tr>
</tbody>
</table>

CA: Cellulose acetate, TFC: Thin film composite, PS: Polysulphone

3.1.2 Temperature: An increased temperature is of basic influence for cleaning (improvement of diffusion, increase of chemical splitting of soil, increase of solubility of different substances) especially for removing fat residues. In membrane cleaning, the use of higher temperatures is very often not possible. Nearly all polymeric-membranes are sensitive to high temperature e.g. cellulose acetate –35°C. Higher temperature treatment above the limit can result in decomposition.

3.1.3 Mechanical aspects: Effectiveness of the removal of the deposited layer increases with increasing flow rate. Further, deposited layer is more easily removed at lower trans-membrane pressure. For MF plant, it is best to clean first with low pressure
to take away the loose soil on surface and then change to higher filtration capacity to clean the pores of membrane.

3.1.4 Module Design: The connection between module types and cleaning behaviour is complex. The flow is influenced by the design as well as by the type of support and spacer material. Tubular membranes are normally in stainless steel, polysulfone or PVC housings. Here the detergent must only be compatible with the membrane. In plate and frame systems as well as in spiral wound membranes the detergent comes into close contact with the often-sensitive adhesive and the spacer materials. This limits the use of many classical cleaning compounds, especially surfactants.

3.2 Chemical aspects of membrane cleaning

3.2.1 Water Quality: Water is the most important cleaning agent and the one used in largest quantities. Consequently, the quality of the water used is of utmost importance in order to avoid unwanted deposits originating from the water on the membranes. Specifically important is the content of deposit forming components such as iron, manganese and silicates and of course the water used for cleaning must be of good bacteriological standard. Silicates can only be removed with hydrofluoric acid, the use of which destroys most membranes. Chlorine is used in some areas for treating potable water. Usually traces of chlorine are present in this water source. Although most of the commercial membranes available in the market withstand the presence of chlorine, some are affected especially those made from cellulose acetate, and polyamide. As a guideline for water quality, the following may be used

- Total hardness: 3.57 m Mol or 357 ppm CaCO₃ (max)
- Total bacteria: 1000 per ml (max)
- Coliform count: < 1 per ml

If the iron content is < 0.5 ppm & manganese < 0.2 ppm, the silicate content must be < 5 ppm. If the iron and manganese content is 10 times less than described, the silicate content can be up to 40 ppm.

3.2.2 Soil composition:

3.2.2.1 Fat: Removal of fat is more difficult on hydrophobic surfaces like organic polymers than on stainless steel or glass. Organic polymers includes PVC, PE, Acrylic. This is because of hydrophobic character of the fat molecules, which absorb at the membrane surface. For fat removal surfactants are used, which are able to emulsify the fat and they have to be compatible with the membrane, the spacer and the support.

3.2.2.2 Proteins: Alkaline detergents remove proteins best. The higher is the pH, the faster is the protein hydrolysis and better the solubility. Additional to the alkalinity, there is a need for dispersants, emulsifiers, soil carrying agents, stabilizers for hardness salts, buffering systems and available chlorine or oxygen or cleaning boosters. Enzymatic cleaners are usually employed if the pH limitation is at or below 10 or if a high level of soil is present. They are usually necessary where proteins are concentrated to a very high solid content.

3.2.3 Cleaning agents

Cleaning agents used in cleaning can be classified into three categories

3.2.3.1 Strong alkalis and acid: Usually sodium hydroxide and nitric/phosphoric acids are most simple agents to be used for cleaning of membrane plants as a common practice in dairy factories. Alkali affects the solubilization of proteins in the foulant deposits,
while the acids mainly affect solubilization of minerals. However, the severity of these harsh chemicals is found to decrease membrane lifespan in long term.

3.2.3.2 *Proteolytic enzyme:* These assure solubilization of protein aggregates and deposits, through effective hydrolysis of these deposits and formation of soluble degradation products. The enzyme detergent preparations presently marketed for cleaning of membrane systems are Terg-a-zyme (Alconox, Inc, New York, USA) and Ultrasil 53 (Hemkel KgaA, Dusseldorf, Germany) (Ganesh Kumar *et al.*, 1998). The new generation of membrane cleaning protocols more and more includes the use of enzyme cleaners as an option, which has the advantage of being gentler to the membranes. Hence, they are believed to lengthen membrane lifespan.

3.2.3.3 *Detergents:* These can remove both protein aggregates and lipids present in the deposits by forming detergent-protein complexes and emulsifying the lipid materials.

Table 2. Recommended Cleaning Solutions and sanitizers for polysulphone and polyamide membranes

<table>
<thead>
<tr>
<th>Cleaning solutions</th>
<th>Bacteriostats</th>
<th>Sterilizing solutions</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.1-0.4 N sodium hydroxide</td>
<td>0.2% sodium azide</td>
<td>Recirculate:</td>
</tr>
<tr>
<td>1-2 M sodium chloride</td>
<td>0.01% sodium thimerosal</td>
<td>Formaldehyde, 0.5%</td>
</tr>
<tr>
<td>&lt;200 ppm sodium hypochlorite</td>
<td>0.5% formaldehyde</td>
<td>Sodium hypochlorite (200 ppm maximum)</td>
</tr>
<tr>
<td>0.1% laboratory detergent</td>
<td></td>
<td></td>
</tr>
<tr>
<td>6 M urea</td>
<td></td>
<td></td>
</tr>
<tr>
<td>0.05-1% Micro</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**For protein solutions**
- 1% pepsin
- 1% trypsin
- 0.1-1% lab detergent (Alconox, Sparkleen, Tide, etc.)

**For Removal of Metal Ions**
- 0.1 N hydrochloric acid

3.2.4 **Sanitizers:** The more common disinfection used are Water at 80° C (where membrane tolerance allows), Hydrogen peroxides and Formaldehyde. The membrane stability limits the use of several sanitizers. The use of products based on available chlorine is possible on many organic polymer membranes, but often decreases the lifetime of the membrane. For this reason, chlorine-based sanitizers should be used with caution. Peracetic acid based products seem to be the ideal sanitizer. These products are compatible with nearly all membranes and have several advantages, being fast reactive, having good rinsability and being capable of passing through RO membranes enabling sanitation of the permeate side. For more sensitive membranes, sanitizers based on sodium metabisulfite should be used. Products based on this compound are not oxidizing. However, one big disadvantage is the very long reaction time.

4. **ROUTINE CLEANING AND MAINTENANCE OF MEMBRANES**

Several different parameters influence the choice of the right cleaning product as well as the right cleaning process (Krauck, 1996). Generally, antifoaming agents, perfume oils, pigments, silicates and some surfactants can lead to irreversible fouling.
Also because of the specific membrane characteristics (Porous surface, low chemical resistance, low thermal resistance and high costs), the cleaning process and the proper choice of cleaners has to be adhered to. Henkel-Ecolab has developed a special range of cleaning products (P3-ultracil) for membrane cleaning. The following general procedure can be adopted for routine CIP cleaning of a membrane with proper adjustment of the operating parameters, temperature and pressure (Dharam Pal, 1993, Makadiz, et al., 1999). After the processing is complete, the first step of the cleaning cycle is to flush out the feed stream from the whole plant by rinsing with water, preferably at the same temperature as that of the product. Flushing is stopped when clear water starts coming out of the system. The importance of the rinsing step becomes apparent from the finding that up to 98% of the deposited layer can be removed during this step depending on the velocity of the rinsing water. Therefore, rinsing should be carried out at high shear stress and low trans-membrane pressure. Then a commercial detergent solution is circulated through the plant. It is important that chemical in powder form are dissolved in water before they are introduced into the system. It is always important to add the chemicals gradually to the balance tank, avoiding local over concentration of chemicals in the system. The cleaning is continued for a specified period of time under specified temperature and pressure conditions. Generally, the cleaning shall be performed under reduced pressure than for normal operations. Typical pressures for cleaning of RO-plants are 15-20 bar and for cleaning of UF-plants 0.8-1.8 bar.

Some products call for several independent cleaning steps, e.g. dairy products. To accomplish a satisfactory cleaning it may be necessary to apply different chemicals in succession. This may for instance involve an acid cleaning succeeded by an alkaline cleaning or vice versa. In such cases, it is objectionable to mix chemicals from one step with the chemicals left in the system from the preceding step. The addition of a sequestering agent, e.g. hexa-meta-phosphate to cleaning detergents is very beneficial. Each cleaning step has to be followed by water flushing to remove impurities and used chemicals, before new chemicals are put into the system (IDF, 1979; Glover, 1985). In case of CA membranes and excessive fouling of PS and TFC membranes, the use of a proteolytic enzyme is essential.

For the food, dairy, and biochemical applications, cleaning is succeeded by disinfection. When a plant is shutdown for more than approx. 40 hours, it should be preserved (stored) in a liquid chemical preventing growth of bacteria and fungi. The chemical is recirculated 5 minutes at room temperature, before the plant is stopped. Polymeric membranes are never allowed to remain dry. The preservatives used are:

<table>
<thead>
<tr>
<th>Chemical</th>
<th>Concentration</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sodium bisulphite</td>
<td>0.25 %</td>
</tr>
<tr>
<td>Formaldehyde</td>
<td>0.5 %</td>
</tr>
<tr>
<td>Propionic acid</td>
<td>1.0 %</td>
</tr>
</tbody>
</table>

Before start on product, the chemical is flushed out, and a one-step-cleaning is carried out.

5. REFERENCES


WASTE MANAGEMENT IN THE DAIRY SECTOR:
ECONOMIC AND ENVIRONMENTAL ISSUES

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Senior Scientist
Dairy Technology Division

1. INTRODUCTION

‘Let us not wash our profits down the drain!’ This slogan, adopted by an American ice cream company in its employee training programmes signals that an effective waste and water management plan can cut food processing costs. Improved waste monitoring could save food processing plants lakhs of rupees annually. The presence of milk and milk products in dairy processing waste streams has long been recognised as a problem for downstream treatment plants and receiving waters. Economically, these milk solids and chemicals are considered product losses that have been paid for once, and then paid for again as they are carried from a plant along with the waste water. A plant's waste load can be decreased substantially by controlling the amount of water used and reducing the amount of product lost into the sewer. Stopping pollution at its source is less expensive and more practical than a waste treatment programme at the end of processing operations. This lecture aims to suggest some holistic measures that can be effective in avoiding unnecessary economic losses and environmental issues.

2. WASTES DISCHARGED FROM DAIRY PLANTS

It is impending that in the manufacture of a product a certain amount of waste is generated. More than 90 percent of a dairy plant’s total waste load comes from milk components (lactose, proteins, and butterfat) that are lost and flow into floor drains during processing. The wastewater also may contain cleaning agents, lubricants, and solids removed from equipment and floors.

If the waste is a solid its disposal can be done either by burying or landfilling or burning. However, if it is a liquid waste the easiest way is to drain it into a river or lake. Over the years the discharge of wastes have increased and regulations have been imposed in various countries all over the world making it mandatory for industries to treat the waste before it is discharged into waterways to avoid pollution of water. India is no exception in this regard and an Act was passed in the Parliament in 1974 to prevent and control water pollution.

In India, improved facilities to farmers and wider use of mechanical refrigeration have made it possible to collect milk from a wide ranging network of collection points and to bring it to a large central processing plant for converting milk into products. This has resulted in greater concentration of waste. Most of the water consumed at dairy plants ultimately becomes effluent. This, being rich in nutrients may endanger aquatic life if let into rivers or lakes without treatment. Generally, rivers and lakes have a dissolved oxygen (DO) level of 7 PPM. If nutrient-rich waste is drained into such waterways, this level will fall as the microorganisms present in the waste or in the waterway use the DO to convert the organic matter into end products. The aquatic life is in danger below a DO level of 5 PPM. Hence it has become necessary for the dairy industry to treat its waste before it is discharged into rivers or lakes.
Waste load can be determined by a number of different measurements, including biological oxygen demand (BOD5), chemical oxygen demand (COD), total suspended solids (TSS), total Kjeldahl nitrogen (TKN) and fats, oils, and grease (FOG). Of these, the BOD5 is the most popular indicator used by regulators and sewer utilities. BOD5 is a measure of the amount of oxygen needed to degrade the organic matter under specific conditions measured at five days and is expressed in mg/l. At any given point in a food processing operation, the ratio between BOD5 and COD is reasonably consistent. However, it varies widely from product to product as illustrated in Table 1.

Dairy plant effluent is generally treated to some extent on site and then discharged to municipal sewerage systems, if available. Sometimes liquid waste is also used for irrigation purposes either as such or after little treatment. For some municipalities, dairy effluent can represent a significant load on sewage treatment plants. Milk losses in wastes can be as high as 3 to 4%, with the main source of loss being residues which remain on the internal surfaces of vessels and pipes, accidental spills during tanker emptying and overflowing vessels. The organic load discharged in the effluent stream varies depending on cleaning practices and whether batch or continuous processes are used, since batch processes require a greater frequency of cleaning.

Table 1. Typical values of BOD5 and COD for selected material

<table>
<thead>
<tr>
<th>Material</th>
<th>BOD5 (mg/l)</th>
<th>COD (mg/l)</th>
<th>BOD5/COD</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Pure dairy products:</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1. Milk</td>
<td>104,600</td>
<td>173,000</td>
<td>0.6</td>
</tr>
<tr>
<td>2. Ice cream (10% fat)</td>
<td>292,000</td>
<td>540,000</td>
<td>0.54</td>
</tr>
<tr>
<td>3. Whey (acid)</td>
<td>32,000</td>
<td>70,000</td>
<td>0.54</td>
</tr>
<tr>
<td><strong>Effluent from:</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1. Bakery products</td>
<td>3200</td>
<td>7000</td>
<td>0.46</td>
</tr>
<tr>
<td>2. Dairy processing</td>
<td>2700</td>
<td>4700</td>
<td>0.57</td>
</tr>
<tr>
<td>3. Jams and jellies</td>
<td>2400</td>
<td>4000</td>
<td>0.60</td>
</tr>
<tr>
<td>4. Meat packing</td>
<td>1433</td>
<td>2746</td>
<td>0.52</td>
</tr>
<tr>
<td>5. Meat specialties</td>
<td>530</td>
<td>900</td>
<td>0.59</td>
</tr>
<tr>
<td>6. Poultry processor</td>
<td>1306</td>
<td>1581</td>
<td>0.83</td>
</tr>
</tbody>
</table>

*Adapted from: Rausch and Powell (1997)*

3. **ECONOMICS OF EFFLUENT DISCHARGE**

One kg of pollutants, in the form of BOD5, is directly equivalent to nine kg of milk lost down the drain. Thus, if the BOD5 level in a plant's waste-water is known, this information can be used to get a reasonably accurate idea of the product (and money) lost down the drain. When the BOD5/COD ratio, the COD concentration in the waste and the volume of the waste stream are known, the volume of product lost can be estimated as shown in Table 2. Once the BOD5/COD ratio is established for a process stream, BOD5 is calculated using the measured COD value and the ratio.

4. **STRATEGIES**

Strategies for reducing the organic load of dairy effluents focus on minimizing the amount of product that is lost to the effluent stream. A plant's water use and the volume and strength of its waste stream are strong double-prong indicators of how efficiently the plant is operating.
Table 2. Worksheet for calculating yearly value of lost milk

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Example</th>
<th>Your plant</th>
</tr>
</thead>
<tbody>
<tr>
<td>COD (mg/l)</td>
<td>1500</td>
<td></td>
</tr>
<tr>
<td>$K_{\text{cod}}$</td>
<td>$5.13 \times 10^6$</td>
<td>$1500$</td>
</tr>
<tr>
<td>Waste water volume (WWV) (l/day)</td>
<td>300,000</td>
<td></td>
</tr>
<tr>
<td>Lost product = COD x $K_{\text{cod}}$ x WWV</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lost product (LP) (l/day)</td>
<td>2308.5</td>
<td></td>
</tr>
<tr>
<td>Product value (PV) (Rs/l)</td>
<td>15.00</td>
<td></td>
</tr>
<tr>
<td>Yearly loss = LP x PV x 365 *</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Yearly loss (YL) (Rs)</td>
<td>1,26,39,038</td>
<td></td>
</tr>
</tbody>
</table>

* For a BOD5/COD ratio of 0.57. This ratio should be determined for each plant by measurement at specific points in the plant
* For a plant running 365 days an in 24 h shift
† If the payment is done on weight basis, this will be calculated taking density into consideration.

Adapted from Rausch and Powell (1997)

Conducting surveys on water usage and product wastage represent the simplest and most reliable methods of waste management in a dairy. Water usage survey will involve 1) installing water meters throughout the plant and reading them daily, 2) listing all water uses and the amount used each day, 3) consulting the literature for guidance in estimating usage if boiler and condenser water are not metered, 4) balancing the amount of water used with the incoming water supply and 5) finding means to minimize water usage and wastage. Product wastage survey will comprise of 1) ensuring that vessels and pipes are drained completely 2) removing product residues before cleaning, 3) using level controls and automatic shut-off systems to avoid spills from vessels and tanker emptying, 4) collecting spills of solid materials (cheese curd and powders) for reprocessing or use as stock feed instead of washing them down the drain, 5) shoveling the wastes into containers before actual cleanup begins, 6) fitting drains with screens and/or traps to prevent solid materials entering the effluent system, 7) installing in-line optical sensors and diverters to distinguish between product and water and minimize losses of both, 8) using dry cleaning techniques where possible by scraping vessels before cleaning or pre-cleaning with air guns, 9) collecting solids from floors and equipment by sweeping and 10) not using hoses as brooms.

5. WASTE TREATMENT IN A DAIRY PROCESSING PLANT: AN INSIGHT INTO THE PROCESS

Food processors, such as dairy processing plants pretreat the processing wastes to reduce waste loads discharged to municipal treatment plants. The raw effluent bears oil and grease, high amount of suspended solids and bio-chemical oxygen demand. The conceptual approach of pre-treatment by the Activated Sludge Process (ASP) includes the removal of oil and grease, coarse and suspended particles, which can be settled and dissolved organic matter and finally, handling of sludge for disposal. The sludge can benefit farmers when used as a liming material or as a nutrient additive to fields. It contains microbial matter (rich in nitrogen and phosphorus), water and some minerals. These being usable plant nutrients can benefit agriculture instead of just being landfill waste.
Substantial amount of free oil and grease is removed by skimming operation in the grease trap. However, the core of this treatment system is the aerobic-biological reactor, which is designed on the basis of ASP. The principle of ASP is based on degradation of organic matter by the action of various microorganisms (MO) as depicted in the following equation.

\[
\text{Organics + MO + } O_2 + \text{Nutrients } \rightarrow \text{New cells + } CO_2 + NH_3 + \text{Energy.}
\]

This could be paraphrased as:

\[
\text{Waste + Sludge } \rightarrow \text{Surplus Sludge + End product}
\]

In this biological process, a part of the newly synthesized sludge undergoes oxidation called endogenous respiration.

\[
\text{Cells + Oxygen } \rightarrow \text{End products + Less cells}
\]

The efficiency of the system mainly depends upon the concentration of active microorganisms present to perform the assimilation of organic matter. The activated sludge consists of bacteria (putrefactive) and protozoa. The desirable environmental conditions like sufficient DO, substrate and nutrients are required for cell growth and energy for various metabolic functions. It is, essential that the biological floe should readily separate from the treated wastewater in the final clarifier. The concentration of microflora is maintained by routing the mixed liquor flowing from the aeration tank through a secondary clarifier and recycling most of the settled biological solids back to the aeration tank.

Table 3 delineates the characteristics of effluent before and after treatment at Mother Dairy, New Delhi.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Raw effluent</th>
<th>Treated effluent *</th>
</tr>
</thead>
<tbody>
<tr>
<td>BOD5 AT 20°C</td>
<td>1200 mg/litre</td>
<td>30 mg/l</td>
</tr>
<tr>
<td>COD</td>
<td>2500 mg/litre</td>
<td>250 mg/l</td>
</tr>
<tr>
<td>Oil &amp; Grease</td>
<td>150 mg/litre</td>
<td>10 mg/l</td>
</tr>
<tr>
<td>Total suspended solids</td>
<td>1000 mg/litre</td>
<td>50 mg/l</td>
</tr>
<tr>
<td>pH</td>
<td>7.0 - 8.0</td>
<td>6.5 to 9.0</td>
</tr>
<tr>
<td></td>
<td>sometimes alkaline</td>
<td></td>
</tr>
<tr>
<td>Temperature</td>
<td>Less than 40°C</td>
<td>Not exceeding 40°C</td>
</tr>
</tbody>
</table>

* Limits prescribed by the Central Board for the Prevention and control of Water Pollution

Adapted from [http://www.cleantechindia.com/eicnew/successstories](http://www.cleantechindia.com/eicnew/successstories)

6. CONCLUSION

In summary, below is a list of useful tips to reduce waste in a dairy facility.

- Establish waste load reduction goals for your plant.
- Establish waste reduction targets for all important processes and areas of the plant where waste can be monitored and controlled.
- Improve maintenance to prevent product leaks from valves, piping, and equipment.
- Reduce water use; remember that water used in a plant becomes wastewater that must be treated.
- Design and install lines that will allow proper draining of product, rather than relying on rinse water to remove product.
- Allow enough time for more viscous products to drain from lines and tanks.
• Inspect tanks and vats to verify they have completely drained before starting a clean-out procedure.
• Install automated diverters to monitor overflows and product losses in wastewater.
• Collect solids from floors and equipment by sweeping. Shovel the wastes into containers before actual cleanup begins. Do not use hoses as brooms.
• Adopt the attitude that waste load reduction is one of the most cost effective managerial decisions you can make.
• Orient employees toward preventing pollution, and train them how to do their jobs in a way that will reduce the discharge of wastes from your plant.

7. REFERENCES
http://es.epa.gov/techinfo/facts/
http://muextension.missouri.edu/explore/agguides/soils/g09332.htm
http://www.cleantechindia.com/eicnew/successstories
1. INTRODUCTION

Water is a basic renewable natural resource upon which the survival and well being of living organisms depend. Quantity, quality and availability of water are critical factors in supporting all living beings. Agriculture consumes 65–70% of the total fresh water resources worldwide (www.arc.gov). In the food industry, besides for growing of the raw products, water is used by for generating steam, cleaning, peeling, grading, and conveying products, as a heat exchange medium in heating and cooling operations, for cleaning plant and equipment, for condensing vapors, for fire protection, sanitizing, drinking, humidification, as an ingredient in the finished products and as a means of waste disposal (Kramer et al., 1966). Due to the globalization and implementation of WTO and ISO concepts the quality of raw as well as finished products has become very important. In the present scenario the management of water, both qualitatively and quantitatively is gaining importance. Therefore the supply of adequate quantity and safe quality of water is of vital importance to the food industry. Management of water in food industry consists of three components: i) quality at entry level, ii) water conservation, and iii) waste management.

2. PROCESS WATER

The food production and processing industries are concerned particularly with three broad aspects of water quality, namely its microbiological purity and safety, its chemical impurities that affect its suitability in processing and its contamination load after use. In general water entering a food processing plant should meet health standards for potable drinking water. In addition to the chemical limit for safety for potable water, this water must be free from contamination with sewage, pathogenic organisms of intestinal origin. The use of water in food industry falls into four main categories. These are water that is used for cooling or heating purposes, for hygiene (washing equipments and ingredients etc.), for conveyance of materials and as an ingredient. To attain the required quality, water is almost always treated, even if it is supplied by a municipal system. (Potter and Hotchkiss, 1995)

2.1 Water for boiler feed

Several different minerals may be present into the water supply depending upon the salts over or through which it flows. Dissolved salts of calcium and magnesium are of great importance with respect to the hardness of water. During heating of water in the boiler, two things may occur: i) the soluble salts of Ca and Mg are concentrated as steam evaporates and ii) these are converted into insoluble forms, which accumulate as suspended solids and sludge. The suspended solids cause scaling within the boiler and may be carried over in the steam, which would be strongly alkaline and corrosive to metals and which would cause clogging of strainers or fine nozzle openings and brittling of metals. Such contaminated steam could cause off-flavors in food where direct contact is made as well as etching and discoloration of metal containers. In Indian context the required standards for boiler water and feed water has been mentioned in IS: 10496 – 1983.
2.2 Cooling water

The quality of cooling water for tin or glass packed foods should also be checked for its microbial quality. In cooling the water must be low of bacterial count to avoid the hazard of spoilage (Potter and Hotchkiss, 1995). Water of improper chemical composition may cause corrosion, spotting or denting of metal containers or lids.

2.3 Product preparation

The appearance and texture of many fruits and vegetables can be affected by the pH and hardness of the water used in their preparation and processing. Ca and Mg will react with the pectic substances to form pectates, which cause hardening or toughening of the products. In some cases this may result in down grading of the product while for some products such as tomatoes this process may be of benefit. Conversely “Zero–soft” water may cause excessively soft texture and cloudy brines. Fe, Mn, Cu and nitrates may cause discoloration of food products, while other minerals may leave white deposits all of which adversely affect the appearance of the product. Pronounced effects of hardness of water on the product are during the blanching operation. In addition hardness may reduce the efficiency of soaps and other detergents used in cleaning or may interfere with the effectiveness of lye peeling. The desirable range of hardness of water will vary with the operating conditions and products being packed. The Indian standards for water quality tolerances for processed food industry are shown in Tables 1 and 1A.

3. TREATMENT OF WATER SUPPLIES

Food processors almost always treat at least some of the water used in the plants, even if they are supplied by a municipal system. This is due to the special requirements for use in boilers, cooling towers and similar equipment. Treatment may be done to control corrosion and formation of scale on equipment, to remove turbidity caused by solids, to eliminate staining, odor and flavor problems, and to assure safety for consumption-to name a few. Satisfactory procedure for one water supply may be inadequate for another. Designing a water treatment system for a food plant must be considered on an individual plant basis. The importance of adequately testing the water to be treated to determine the best methods for a given plant must be stressed.

3.1 Turbidity-solids Removal

Turbidity results from suspended particles in water. The particles may range in size from 100,000 millimicrons in diameter for fine sand to colloidal suspensions with particle sizes from 1 to 200 millimicrons. Silt with a particle diameter of about 10,000 millimicrons tends to settle out as sediment in quiescent after. To produce clear water, removal of particles in colloidal suspension is usually necessary. Since colloidal suspensions are relatively stable, a coagulant is used to cause aggregation of particles of sufficiently high density to promote settling out for clarification. Inorganic chemicals commonly used as coagulants are ferric sulfate, ferrous sulfate, and filter alum, sodium aluminate. Rapid settling increases the efficiency of clarification, which can often be improved with the addition of a filter aid. Filter aids are chemicals, which speed floc formation and settling.

3.2 Softening

Softening of water is done to remove the hardness of water due to minerals. Different methods for water softening are as:
Table 1. Indian standards for water quality tolerance limits

<table>
<thead>
<tr>
<th>S.No.</th>
<th>Characteristics</th>
<th>Tolerances</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td><strong>I. Bacteriological Tolerances</strong></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>Coliform bacteria, MPN index per 100 ml</td>
<td>&lt;1</td>
</tr>
<tr>
<td>2</td>
<td>Standard plate count, per ml (Max)</td>
<td>50*</td>
</tr>
<tr>
<td>3</td>
<td>Proteolytic and lipolytic organisms combined count per ml (Max)</td>
<td>5**</td>
</tr>
<tr>
<td></td>
<td><strong>II. Physical and Chemical tolerances</strong></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>Color (Hazen units), Max</td>
<td>20</td>
</tr>
<tr>
<td>2</td>
<td>Turbidity (units), Max</td>
<td>10</td>
</tr>
<tr>
<td>3</td>
<td>Odor</td>
<td>None</td>
</tr>
<tr>
<td>4</td>
<td>PH</td>
<td>6.5 to 9.2</td>
</tr>
<tr>
<td>5</td>
<td>Total solids, mg/l, Max</td>
<td>1000</td>
</tr>
<tr>
<td>6</td>
<td>Total hardness (as CaCO₃), mg/l, Max</td>
<td>600</td>
</tr>
<tr>
<td>7</td>
<td>Sulphate (as sac), mg/l, Max</td>
<td>200</td>
</tr>
<tr>
<td>8</td>
<td>Fluoride (as F), mg/l, Max</td>
<td>1.5</td>
</tr>
<tr>
<td>9</td>
<td>Chloride (as Cl), mg/l, Max</td>
<td>250</td>
</tr>
<tr>
<td>10</td>
<td>Cyanide (as Cn), mg/l, Max</td>
<td>0.01</td>
</tr>
<tr>
<td>11</td>
<td>Selenium (as Se), mg/l, Max</td>
<td>0.05</td>
</tr>
<tr>
<td>12</td>
<td>Iron (as Fe), mg/l, Max</td>
<td>0.3</td>
</tr>
<tr>
<td>13</td>
<td>Magnesium (as Mg), mg/l, Max</td>
<td>75.0</td>
</tr>
<tr>
<td>14</td>
<td>Manganese (as Mn), mg/l, Max</td>
<td>0.2</td>
</tr>
<tr>
<td>15</td>
<td>Copper (as Cu), mg/l, Max</td>
<td>1-0</td>
</tr>
<tr>
<td>16</td>
<td>Lead (as Pb), mg/l, Max</td>
<td>0.1</td>
</tr>
<tr>
<td>17</td>
<td>Chromium (as Cr⁶⁺), mg/l, Max</td>
<td>0.05</td>
</tr>
<tr>
<td>18</td>
<td>Zinc (as Zn), mg/l, Max</td>
<td>15.0</td>
</tr>
<tr>
<td>19</td>
<td>Arsenic (as As), mg/l, Max</td>
<td>0.2</td>
</tr>
<tr>
<td>20</td>
<td>Nitrate (as N), mg/l, Max</td>
<td>20</td>
</tr>
<tr>
<td>21</td>
<td>Phenolic substances (as CaHIOH), mg/l, Max</td>
<td>0.001</td>
</tr>
<tr>
<td>22</td>
<td>Cadmium (as Cd), mg/l, Max</td>
<td>0.01</td>
</tr>
<tr>
<td>23</td>
<td>Mercury (as Hg), mg/l, Max</td>
<td>0.001</td>
</tr>
<tr>
<td></td>
<td><strong>III. Radioactivity tolerances</strong></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>Alpha emitters, uc / ml, Max</td>
<td>10⁻⁹</td>
</tr>
<tr>
<td>2</td>
<td>Beta emitters, uc/ml, Max</td>
<td>10⁻⁸</td>
</tr>
</tbody>
</table>

*Not applicable in the case of cooling water and of hot water supplied in dairy industry
** Not applicable in the case of cooling water, hot water and for water used for general purposes in dairy industry

3.2.1 Cold lime method: Many municipal water treatment plants use the cold lime softening method. In this process, calcium oxide (CaO) is added to the hard water to form calcium hydroxide, which reacts with magnesium and calcium bicarbonates and free CO₂ to form insoluble calcium carbonate and magnesium hydroxide. Magnesium hydroxide is a good flocculating agent, which aids in precipitating the calcium carbonate particles. This treatment will usually result in water with about 70 to 85 ppm of calcium (4 to 5 grains per gal.) when discharged from the final filtration unit. Sand and gravel filters are commonly used for removing the precipitated salts by the cold lime softening method.
### 3.2.2 Base exchange softening method:
Most food plants will find the base exchange process to be a more practical and controllable method for softening water for cleaning and other uses. The materials used in the ion exchange are natural or synthetic zeolites, which often are hydrous silicate or styrene base resins. In the sodium cation exchange, sodium from the zeolite or resin displaces an equivalent quantity of calcium and magnesium in the water as it passes through the bed. Some exchange of other cations occurs also including iron, manganese, copper and aluminum. In recent years the technology of ion exchange has advanced considerably and several excellent resins have been developed. For softening commonly used resins are of a sulfonated styrene divinyl benzene structure (Rohm and Haas Co. 1967).

### 3.2.3 Demineralizing (deionizing) water supplies:
Although softening water with a sodium cycle ion exchanger is most commonly found in processing plants, there is also need for demineralized (deionized) water for special purposes, such as use in the beverage industry. Several variations may be found in demineralization systems depending on the analysis of the untreated water and the desired purity of the treated water. Systems for demineralizing water are basically of two types, multi-bed and mixed-bed. Mixed-bed units offer the advantage of less space required, and they will also produce high quality water. Multi-bed and mixed-bed ion exchangers are sometimes sequenced into a system to produce very high quality demineralized water.

### 3.2.4 Filtration:
Filtering is almost invariably included in a water treatment system. In many cases, water is filtered before softening or demineralizing. Depending upon the system and quality of water desired, the final step may be filtration. Large water treatment plants for municipalities will often use gravity type filters. However, food-processing plants will usually find the enclosed pressure type filters more satisfactory. Water may be passed through a series of filters each with a different filter media to achieve a special purpose. For removal of particulate matter sand and gravel filter is effective. Where low silica is desired, nonsiliceous anthracite is used instead of sand. Food plants will find activated carbon filters useful for improving the taste and odor of certain water supplies. These filters absorb phenols, chlorine and similar compounds. Filters with highly activated carbon require a special tank lining to protect the vessel from galvanic corrosion. Filter media are available for removing iron and manganese from water or to raise the pH of acidic water by removing carbon dioxide. The oxidizing filter medium, which removes iron and manganese, does so by forming an insoluble

---

**TABLE 1A. Additional tolerances for specific operations**

<table>
<thead>
<tr>
<th>S.No</th>
<th>Characteristics</th>
<th>Tolerances</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Cooling</td>
</tr>
<tr>
<td></td>
<td></td>
<td>30*</td>
</tr>
<tr>
<td>2</td>
<td>Iron (as Fe), mg/l, Max</td>
<td>--</td>
</tr>
<tr>
<td>3</td>
<td>Manganese (as Mn), mg/l, max</td>
<td>---</td>
</tr>
<tr>
<td>4</td>
<td>Slime forming organisms</td>
<td>Absent</td>
</tr>
</tbody>
</table>

* For waters which are recirculated and used. In once through and run to waste systems, carbonate hardness should be absent. The Langelier index is of value in finding out the suitability of the water for cooling and determining the degree of treatment required, but in applying it, it should be kept in mind that the free carbon dioxide content of the make-up water is practically all lost in the first pass.

** Especially if used for washing with soap or other alkaline detergents.
precipitate, which collects on the bed. The precipitates are removed by periodic backwashing. Frequent regeneration of the bed with a solution of potassium permanganate restores the oxidizing capability for iron and manganese removal. A unit utilizing a rotary aerator and a bed of high luster anthracite coal as the filter media has the advantage of not requiring chemical treatment for regeneration. The unit appears useful for treating water with a high iron content and relatively low cost operation. Regular backwashing to expand the bed and remove the ferric precipitate is important as in any filter.

3.2.5 **Reverse Osmosis systems:** The technology of reverse osmosis (R.O.) is advancing rapidly. Reverse osmosis separates one component of a solution from another by placing the solution under pressure against a semi permeable membrane. Typically the pores of the semi permeable membranes used in reverse osmosis are 5 to 20 Angstrom units (5 to 20 x 10^-8 cm) in diameter. (Osmonics, Inc. 1976). A number of membranes have been developed, and cellulose acetate is on which is commonly used. Reverse osmosis is a method of purifying water to a high degree, especially when used in conjunction with a prefilter and an ion exchanger. Some advantages cited for reverse osmosis water purification are: chemicals are unnecessary, membrane life is normally 1 to 3 years, low maintenance requirements, pressure is the only energy requirement, and membranes can be tailored for specific separations or where very high quality water is required.

3.3 **Chlorination of water supplies**

Adding small amounts of chlorine to water supplies acts as a safeguard against water-borne diseases. Food processing plants have increasingly been chlorinating water for plant use to improve sanitation. Chlorine may be added to water systems in food plants as a gas or as solutions of chlorine compounds, which are mainly, hypochlorites of sodium or calcium. Some plant operators have found chlorine dioxide to be very satisfactory where considerable organic matter is present, such as in recycled water systems. Table 3 shows the chlorine dosage rates commonly used.

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Dosage rate (ppm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Water for:</td>
<td></td>
</tr>
<tr>
<td>Cooling</td>
<td>3–5</td>
</tr>
<tr>
<td>Chilling</td>
<td>20</td>
</tr>
<tr>
<td>Wash down</td>
<td>50</td>
</tr>
<tr>
<td>Well</td>
<td>1–5</td>
</tr>
<tr>
<td>Surface</td>
<td>1-10</td>
</tr>
</tbody>
</table>

4. **WASTE WATER**

Since food plant waste waters may contain such varied materials as meat and bone scrap, animal or fish entrails and excreta, blood, dairy wastes, pulp and peels of vegetable origin, spent coffee grounds, distillery slop, soils and detergents from washings their composition and contamination loads will vary greatly. Nevertheless, food plant waste waters can be grouped somewhat according to the nature of their impurities and pollution potentials, and these of course determine what methods will be suitable for their treatment. It is convenient to consider wastewaters according to the physical, chemical, and biological natures of their impurities.
4.1 Physical nature of impurities

Materials in food waste waters will vary in size from coarse floating or sinking solids down to colloidal suspended matter. Beyond this size limit are substances in true solution. Water-insoluble liquids such as oils and certain solvents also will be present. Gross particulates generally must be removed before plant wastewaters are sent on to treatment plants or dumped.

4.2 Chemical nature of impurities

Colloidal and dissolved impurities in waste waters may be characterized in terms of organic and inorganic materials. Many vegetable wastes will be intermediate. Fruit wastes generally will be higher in carbohydrate materials and lower in nitrogenous constituents. This becomes significant in terms of the end products of microbial degradation of these wastes both in treatment plants and when discharged onto land or into bodies of water. Food plant wastes usually require neutralization by simple addition of acids or alkalies to within its pH range of 6 to 9 before they may be discharged to sewage treatment plants or natural waters. Food plant wastes may be more odorous. Offensive odors frequently will require additional treatment of these wastes; less odorous wastes of otherwise acceptable pollution load may be dumped.

4.3 Biological nature of impurities

Food plant wastes are largely organic in character and are decomposed in treatment plants and in nature by biological degradation. This degradation is mostly by aerobic microorganisms. These oxidations are incomplete and leave intermediate products such as alcohols, acids, amines, and ammonia. The intermediates generally are odorous and may be toxic to plant and fish life, and in any event will undergo further degradation in nature.

5. WASTE WATER TREATMENT

Food establishment owners, operators and supervisors must ensure that: i) Sewage and liquid waste generated in their facilities are properly disposed of in an approved sewage disposal system; ii) Equipment with drains are not directly connected to the sewer; iii) Food preparation sinks (also includes ware washing sinks when the health department allows such facilities to be used for food preparation) are not directly connected to the sewer; iv) Modifications and alterations are not made to equipment or drains to create direct connections; and v) Mobile food establishments, temporary food establishments, and vending machine operations have approved liquid waste disposal methods in accordance with the regulatory agencies. Primary and secondary treatments are chosen for removal of gross particulates, coagulable colloidal matter, and reduction of BOD sufficient for ultimate discharge onto land or into streams.

5.1 Primary treatment

Gross particulates generally are removed at the food processing plant by screening through vibrating sieves. Smaller particles may be removed by filtering or centrifuging. Minute particles may be allowed to settle or rise in large tanks. Scum and oil are readily skimmed from such tanks, and settled solids are concentrated for removal and subsequent treatment by pumping the supernatant liquid away. Colloidal materials commonly are coagulated or flocculated with the aid of alum, which promotes settling. These primary treatments may remove some 40% of the wastewater BOD and perhaps 75% of total solids, depending upon the nature of the waste.
5.2 **Secondary treatment**

Secondary treatment often is performed by large food plants in plant site facilities similar to those of municipal sewage installations. In other cases the partially treated wastewaters are sewered and discharged to the municipal stations. Secondary treatment commonly involves the use of trickling filters, activated sludge tanks, and ponds of various types.

**Table 4. Indian Standards for disposal of Industrial effluents**

<table>
<thead>
<tr>
<th>Characteristics</th>
<th>Into inland surface water</th>
<th>Into public sewer</th>
<th>On land for irrigation</th>
<th>Into marine coastal area</th>
</tr>
</thead>
<tbody>
<tr>
<td>BOD (5days at 20°C) mg/l, max</td>
<td>30</td>
<td>350</td>
<td>100</td>
<td>100</td>
</tr>
<tr>
<td>COD, mg/l, Max</td>
<td>250</td>
<td>-</td>
<td>-</td>
<td>250</td>
</tr>
<tr>
<td>Dissolved solids, mg/l, Max</td>
<td>2100</td>
<td>2100</td>
<td>2100</td>
<td>-</td>
</tr>
<tr>
<td>Suspended solids, mg/l, Max</td>
<td>100</td>
<td>600</td>
<td>200</td>
<td>100</td>
</tr>
<tr>
<td>Oil and grease, mg/l, Max</td>
<td>10</td>
<td>20</td>
<td>10</td>
<td>20</td>
</tr>
</tbody>
</table>

**Table 5: Volumes and composition of wastes from selected food processing operations**

<table>
<thead>
<tr>
<th>Commodity</th>
<th>Volume (l/unit)</th>
<th>BOD (mg/l)</th>
<th>Suspended solid (mg/l)</th>
<th>Solid (mg/l)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fruit Products (1)</td>
<td>90 – 450</td>
<td>1000 – 5000</td>
<td>100 – 2000</td>
<td></td>
</tr>
<tr>
<td>Meat Packing (2)</td>
<td>9000 – 36, 300</td>
<td>600 – 1600</td>
<td>400 – 720</td>
<td></td>
</tr>
<tr>
<td>Milk Processing (3)</td>
<td>12 – 23</td>
<td>20 – 650</td>
<td>30 – 360</td>
<td></td>
</tr>
<tr>
<td>Potato chips (2)</td>
<td>18,000</td>
<td>730 – 1800</td>
<td>800 – 2000</td>
<td></td>
</tr>
<tr>
<td>Veg. Products (4)</td>
<td>90 – 1260</td>
<td>500 – 11,000</td>
<td>30 – 4000</td>
<td></td>
</tr>
<tr>
<td>Poultry Packing (5)</td>
<td>6.8</td>
<td>725 – 1150</td>
<td>770 - 1750</td>
<td></td>
</tr>
</tbody>
</table>

1) per case of product (data from apples, apricot and citrus), 2) per ton of product, 3) per l of milk, 4) per case of product, 5) per chicken.

*Source: Fellows, 2002*

6. **WATER CONSERVATION**

Optimizing facility water use means more than conducting an in-plant study and preparing a report. Water efficiency measures must be viewed holistically within a business’ strategic planning. A successful program must prioritize needs, set well-informed goals, establish current performance minimums, and carefully plan a course for action. Consider these principles when establishing water efficiency initiatives.

7. **CONCLUSION**

Water quality is a need of the hour. Food industry is a water intensive industry and requires management of water both quantitatively and qualitatively. Sound Principles of Water Management are reducing losses (e.g. fixing leaking hose nozzles), reducing overall water use (e.g. shutting off process water when not in use), employing water reuse practices (e.g. reusing wash water), equipment changes as permanent fixtures
to achieve water efficiency, changing employee behaviors (such as an operating procedure may be viewed as a quick and inexpensive way to achieve similar savings without up-front capital expense), self-assessment and processing rinsing and cleaning modifications. In reality, both the technical and human side of water management issues must be addressed. Consistent training and awareness in combination with proper tools and equipment will achieve more permanent water savings.

8. REFERENCES


Methods of sampling and test for industrial effluents. IS: 2488 ( Part I – 5 ).


Quality tolerance for water for processed food industry. 1981. IS: 4251.


Specifications for feed water, boiler water and condensate for high-pressure boilers. 1983. IS: 10496.


1. INTRODUCTION

Sanitation is a measure that is undertaken to protect health. It is an important part of safe operation for a plant. There have been some interesting developments in the area recently. Actually sanitizing is the treatment of a surface that has been previously cleaned to reduce the number of disease causing microorganisms to safe levels. The selection of a sanitizer depends on the type of equipment to be sanitized, the hardness of water, the effectiveness of sanitizers under site conditions and cost. Thorough cleaning is essential before using sanitizers. Sanitizers are less effective when food particles or dirt are present on equipment surfaces.

In recent years a great challenge to sanitation is the development of resistance by some organisms to the sanitizers like QACs, iodine compounds. Thus those sanitizers that kill and then rapidly disappear seem to create less opportunity for resistance to develop. Conventionally, heat and chemicals are used. Heat has several advantages over chemical sanitizing agents because it is non-corrosive, non selective to microbial groups and leave no residues. Heat sanitization in manual ware washing operation involves immersing cleaned equipment and utensils for at least 30 seconds in hot water that is maintained at 77 °C or above. The temperature of utensil surface is most important to ensure proper destruction of microorganisms. Irreversible heat sensitive labels can measure the temperature at the utensil surface or tapes that are attached directly to equipments and utensils by self-adhesive. The silver–labels will turn black when required sanitization temperature is reached. A T-stick can be used to measure the sanitizing temperature in dishwashing machine.

Typical chemical sanitizers are oxidizers such as chlorine compounds, peroxycacids and ozone. Chlorine based sanitizers are the most commonly used sanitizers in food plants. They are effective against all bacteria due to the formation of hypochlorous acid by the chlorine compounds such as hypochlorites, chloramine and gaseous chlorine. The free chlorine (hypochlorous acid) in water determines rate of killing of bacteria and large amount of organic matter will reduce the germicidal activity of chlorine solutions. Their effectiveness weakens as microorganisms are destroyed. Other factors such as temperature, pH of solution, exposure time and concentration of sanitizer also affect the effectiveness of sanitizer. Therefore alternatives to hypochlorites are available for produce water sanitation. Chlorine dioxide is less sensitive to pH and organic matter and is active at low concentration. Chlorine dioxide is formed by reacting chlorine gas (Cl₂) or hypochloric acid (HCl) with sodium chlorite (NaClO₂). Chlorine dioxide generating system are more expensive than hypochlorite, though stabilized liquid formulations are now available that are cheaper and easier to use than previous systems. Sodium hypobromite is also available in place of sodium hypochlorite but not for water sanitation.
**Peroxyacetic acid** mixed with sodium hydroxide is available for use in wash water sanitation. They act over a broad range of pH and are less sensitive to organic matter than sodium hypochlorite. **UV** systems are available for water sterilization as well as product surface. **UV** leaves no residue and is not affected by water chemistry. It is only surface active and so require clear surface to be effective.

2. **NEW DEVELOPMENT IN SANITATION**

A cleaning and sanitizing regimen may involve several steps such as rinsing, washing with alkali, water, acid, water and sanitizing. Neutral detergents may be used in some applications. Written Sanitation Standard Operating Procedures (SSOP) are mandated by Federal Regulation wherever Hazard Analysis Critical Control Point (HACCP) plans are required for all food industries and therefore all these plants need SSOP as well. An SSOP documents the chemicals, concentration, application methods and timing for every part of plant. Since soils, equipment design and specific microflora vary from plant to plant, preparing a cleaning and sanitation plant, choosing chemicals and writing SSOPs may require outside expert assistance (such as Ecolab Inc., St. Paul Minn).

Ecolab has several proprietary chemicals based on peroxyacetic acid, which breakdown to acetic acid, octanoic acid and water including Tsunami 100, Tsunami 200, Vortexxx, Inspexxx 100 and Inspexxx 200. Tsunami products are intended for microbial control in flumes and wash water, where fruits and vegetables are directly contacted. **Vortexxx** is aimed at yeast and molds and bacteria on equipment surface in beverage, food, meat and poultry processing. **Quadexxx** system is computer-controlled formulation and dispensing apparatus. The web - based technology keep track of amounts used, help prevent over or under use, and can inform management that cleaning procedures are in fact being followed.

3. **OZONE**

Ozone is also approved for use as a water-sanitizing agent but it may be difficult to maintain a consistent dosage since it breaks down to oxygen very rapidly. Ozone is a strong oxidizer but since it is applied at much lower doses than chlorine is not as aggressive as chlorine in causing corrosion. Ozone has been found to be equivalent in antimicrobial kill rates to 200 times the concentration of chlorine. Ozone generators are available now. Two companies DEL and Novazone are promoting the use of ozone as a sanitizer for food contact surfaces and direct food rinsing. **DEL** is emphasizing surface sanitation with its packaged, portable wash systems. **Novazone** uses thermoelectric cooling in its generator rather than air or water-cooling. DEL uses a built in oxygen concentrator, while Novazone uses air or oxygen concentration with less Nitric acid, a potential by-product that can cause corrosion in the generators.

Any Ozone system uses electricity to generate the feed gas and the ozone. The ozone is used as a gas or is contacted with water for application. Del.'s packaged systems do not release ozone gas, and there is neither harmful residue nor contaminating flavor. Another application is to release gaseous ozone in cold storage rooms and to control molds and eliminates ethylene used to accelerate ripening in fruits and vegetables.
4. ELECTROLYZED WATER

The concept is to generate on demand, ready to use, cleaning and sanitizing solutions. Water electrolyzer is a device which generates an alkaline sodium hydroxide solution and an acidic hypochlorous solution by electrolyzing salt in water and separating the solutions through a membrane. The acidic hypochlorous solution is at least 80 times more effective as sanitizer than the same parts per million hypochlorite ions found in the bleach. EO water has a strong bactericidal effect on *Listeria monocytogenes*, *E.coli* O157-H7, *Salmonella enteritidis*, *Campylobacter jejuni* and *Bacillus cereus* because it contains hypochlorous acid (10-90mg/L) and has high oxidation-reduction potential. Electrolyzed water continues to gain acceptance in US and Japan.

5. COLOR-CODED EQUIPMENT

One of the chronic issues in a food plant is preventing cross contamination by the miss use of tools, such as brushes, shovels and containers. To avoid this problem a clever solution with simple but powerful concept is suggested that is using brushes, shovels and scrapers of different colors. Plants establish their own codes dictating which color tool is used for which purpose. In some plants one color may be restricted to edible materials while other color is used for inedible waste. Normally, one color is reserved for use on floor but not for food.

6. ANTIMICROBIAL COATING FOR STEEL

A novel approach to sanitizing surface is to coat them with an antimicrobial substance such as inorganic antimicrobial compound called AgION, a zeolite containing silver ions. The zeolite is suspended in an epoxy coating. The coating is applied to sheet steel on a coil coating line, which can coat miles of steel at a time. The coating is cured and then the coil is slit and cut to produce standard size steel blanks and used to fabricate insulated panel, food service equipment, air handling system and ductwork. The zeolite coating has the added benefit on stainless steel of reducing the impacts of fingerprints. Effective application for the coated thin sheet is push plates on rest room doors, spots that are not often become contaminated and may not be routinely included in cleaning and sanitation.

7. VAPOR PHASE HYDROGEN PEROXIDE (VPHP)

Hydrogen peroxide is widely used biocide in the food industry because of its rapid antimicrobial efficacy and because it breaks down into environmentally innocuous residue (water and oxygen). Liquid hydrogen peroxide solutions have been used for a variety of applications including sanitization of general food surfaces, food contact surfaces, packaging materials and equipments. Hydrogen peroxide has broad-spectrum antimicrobial efficacy to its activity as a powerful oxidizing agent that is known to damage cellular proteins, lipids and nucleic acids. Liquid hydrogen peroxide solution has some disadvantages like repeated use at high concentration damage the surface and fogging is difficult to control.

Therefore, a recent development is the use of vapor phase hydrogen peroxide (VPHP). It has been widely used in pharmaceuticals filling lines, sterility testing environment, seal able enclosures, production room and lyophilize. Vapor is antimicrobial at relatively low concentration (0.1-2mg/L at 25° C). Atmosphere and
vacuum methods of application are used. The most widely used system is the VHP-1000 Biodecontamination series. In this VPHP is produced by vaporization of 35% liquid hydrogen peroxide for sterilization for desired exposure time. VPHP may be used as an alternative to manual and liquid based decontamination methods for room, enclosed areas and food contact equipment in the food industry.

8. NEW CIP AND WASHING EQUIPMENT

Multi tank CIP system, COP system and tunnel washer are used. One unique feature is an educator driven system for once through chemical use, which eliminates need for a return pump and makes a good starter system for firm replacing manual cleaning with automation.

9. CONCLUSION

Cleaning and sanitation may rely on some sophisticated chemistry, but they are only as good as the humans who execute the procedures. Specially coated steel takes some of the human element away, but food contact surfaces will still need to be cleaned often by a person with a hose and a brush. Protection of the worker as well as the consumer is critical, especially with chemicals, which can be toxic. An additional complication is the sad fact that sanitation is often a low -paid position relegated to the late shift, with little supervision. Tools that document usage and control formulas help compensate for what may be low skill levels.

10. REFERENCES

1. MEMBRANE CLEANING AND SANITATION

All membrane-cleaning procedures involve the following operations and depend upon their successful completion in order to return the membranes to a productive state.

a. Flushes
b. Detergent steps
c. Preservative steps
d. Sanitizing steps

The flushes are essential steps in the cleaning procedure and should not be regarded as intervals between cleaning / sanitizing steps. Flushes should be conducted at the process temperature or slightly above and usually at minimum trans membrane pressure and maximum cross flow velocity. The initial or product flush functions to remove product from the unit and also to remove all loose soil so that the detergent steps will attack only the soil that is difficult to remove. The rough rule of thumb is that the pH of the flush water exiting both the concentrate and permeates sides of the unit should be the same as that of the water entering the unit. Experience shows that the permeate system in most membrane units is much more difficult to flush than the concentrate side and thus the flush volume should be based on the amount of water needed to clear both sides of the unit from process fluid. For best results flushes must never be recirculated but run directly to drain.

Detergent steps are usually specialized to the major fouling characteristics of the soil and the character of the feed stream. In whey and milk processing it is conventional to use both acid and alkaline steps since major soil components in this case are expected to include both minerals and organic matter. It is conventional the use the following orders for these process.

<table>
<thead>
<tr>
<th>Whey</th>
<th>Milk</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Acid Step</td>
<td>1. Alkaline Step</td>
</tr>
<tr>
<td>2. Alkaline Step</td>
<td>2. Alkaline or Acid Step</td>
</tr>
</tbody>
</table>

In case where cleaning difficulties are to be expected one uses a three-step procedure.

Extended Cleaning (Whey or Milk)

Alkaline Step
Acid Step
Alkaline Step

For acidic soils such as those encountered in vinegar or juice processing one will usually use one or two alkaline steps and introduce an acid step only as needed. Usually the acid step is used once a week or even less frequently on soils arising from such process feed streams.
The frequency of cleaning is usually determined by experience and may vary from every 8-10 hours to every 36-48 hours. However, most units in the food processing industry are currently cleaned at daily intervals.

After cleaning comes either the sanitizing or the preservative step. In those cases where there is no down time interval between the end of the cleaning cycle and the resumption of processing the preservative cycle can be omitted. Membrane units unlike most other food processing equipment are usually left full of water and offer a pleasant warm environment that will support microbiological growth unless some type of preservative agent or agents is introduced into the system. The preservative agent that is used must be able to penetrate to the permeate system and this is an exacting requirement in the case of RO. In most cases pore sizes in UF are not small enough to seriously hinder passage of the agent to the preservative system.

The sanitizing step is usually carried out after the preservative solution is flushed out of the system. Sanitation is carried out with an approved/legal sanitizing agent (chlorine, iodine etc.) or techniques such as hot water. In each case it is essential that the sanitizing step be carried out properly – concentrations in the case of chemical sanitizing should be checked to ensure that they do not drop out of the effective range. In the case of hot water sanitizing the water temperature should be checked both at the entry and exit points of the unit. Large membrane units are good radiators and it is not uncommon to see a 10°F difference between the front and back end of the unit. Immediately after the completion of the sanitizing step processing should be resumed.

2. **MEMBRANE DETERGENTS**

Membrane detergents must be compatible with the membrane, compatible with the other components of the membrane system and also be capable of cleaning the system. These requirements have tested the ingenuity of cleaning companies and will continue to do so in the future.

RO membranes have widely varying sensitivities to temperature, pH and oxidizing agents. The thin film RO membranes introduced in the last few years are also sensitive to surface-active agents and this limits the components of cleaning solutions. The membrane substrate (support material), the adhesives used in spiral wound modules and plastic components such as pressure vessels, permeate hoses and plastic spacer plates can also limit the surface active agents, the cleaning solution pH or the temperature.

UF and MF membranes face the same types of limitations and here one must be even more familiar with the membrane and equipment limitations since there are a much wider number of membrane materials and membrane unit configurations in these two fields. Recently ceramic membranes have also been introduced and these have their own limitations in terms of the types of chemicals and environmental factors, which can be used.

Field experience has shown that membranes sensitive to pH are best cleaned with compounds that have buffer systems covering the pH range desired. Experience has shown that operating personnel cannot always be depended upon the monitor and adjusts pH. Experience also shows that all membrane detergents should content the lowest possible amount of insoluble material. This is particularly true in the case of MF membranes where this insoluble material can lodge in pores and affect future operation in the membranes. In those cases where enzyme detergent are used one should be aware of differences in enzyme activity in commercial detergents. In those cases where the cleaning solution base is made up from 50% NaOH one should be aware that
specifications for this material can vary and that the past history of storage can add to the amount of insoluble material that is in this chemical. The 50% caustic should be clear and colorless without a layer of scum floating on the surface of the material. At the minimum the physical appearance of the material should be checked upon receipt at the plant. Other bulk chemicals should be checked in the same way upon arrival at the plant.

During cleaning – cleaning solution parameters such as pH, temperature, appearance and concentration should be checked by appropriate means. One should not assume that soil loads are constant in a unit from day to day. Records of cleaning and operation should be maintained and monitored for variance of cleaning solution parameters and for declines in unit productivity. The most difficult type of cleaning failure to detect is the slow decline in unit productivity due to slight deficiencies in either cleaning or sanitizing.

3. WATER

Water is a good solvent, a good cleaner all by itself. For cleaning therefore we should strive to use good quality water in order to achieve the best results. Especially in membrane cleaning the quality of water is important. Whatever may be in the water could be filtered, concentrates and would deposit on the membrane surface, clogging it and thereby defeating the whole purpose of cleaning.

The pH of water should be 6-7.5, especially when cleaning Cellulose Acetate membranes, which are sensitive to higher pH values. The water should not contain any “chlorine” as even low concentrations may, over the long periods of time of contact, endanger the membranes. This is particularly true for polyamide or thin film composite membranes, which are susceptible to oxidizers. There should not be any considerable amounts of solids as they will be filtered out and soil the membranes.

The same is true for the bacteriological status. It is not necessary to sterilize the water before, besides sterilization only kills, it does not remove the microorganisms themselves. Bad water can lead to bacteriological fouling if left standing for a while on membranes. There are bacteria, which might attack the membrane and digest it, in the case of natural derivatives (CA).

Metal ions, such as high amounts of iron or manganese are detrimental. Their effect is compounded when higher levels of silicate are present. The membranes might start to become brownish, blackish, and fluxes go down because of the silicate film that is deposited on the surface; whereas, iron and manganese might still be removable with certain chemical agents and or acids (membrane specs permitting), silicates are almost impossible to remove. Hydrofluoric acid usually does it, but you might as well throw the membrane out. Operation succeeded, patient died!

High salt content of the chloride type is not recommended either. This is less for the benefit of the membranes, than for the supporting pipings, tanks etc. The combination of chlorides with acids causes pitting corrosion and should be avoided.

Water hardness can be a big problem. Many plants use water softeners, ion exchangers, permeate water off their RO plant or boiler water for cleaning. The recommended water is the permeate water. Any water other than permeate may cause irreversible fouling. Check all water supplies.

4. CHEMISTRY

For membrane cleaning there are basically three types of cleaning agents. These are:
4.1 Alkaline cleaners

Most cleaning can be done with a good alkaline product. Most types of soil that we encounter require – or are best removed with – alkalinity. Protein, most any kind of protein, is more easily removed at high pH values. At these pH values the protein also is slowly hydrolyzed, making it more soluble. As neutral values are approached, the solubility decreases, and at pH 4-5 many proteins can even be precipitated, they become quite insoluble and difficult to remove.

Under normal conditions of cleaning (time, temperature and alkalinity usually encountered), not much hydrolysis (called saponification, the making of soap) occurs. The higher the alkalinity, the higher the temperature, the more fat will be hydrolyzed, leading to salts of fatty acids. If calcium ions are around and not enough chelating power is in the cleaner (case of commodity caustic), then calcium soaps, insoluble deposits will form which can clog up filters and also membranes. This should be avoided.

Alkalinity based on caustic alone, pH, is not sufficient. It is difficult to control the pH as no buffer system is there nor detergency. There simply is no soil carrying capacity present. Builders are needed! Sodium or potassium silicate, a favorite builder substance is not suitable on membranes. Silicates do not rinse very well, and precipitate easily, especially when pH drops into the acid range.

Sodium carbonate, Soda ash or phosphates are good builders and buffer system, however care must be taken to use well soluble material. Do not use the granular type, which might dissolve too slowly and get into the membrane system where it might physically damage the surface by scratching it.

The curve of protein solubility suggests that the higher the pH the better the cleaning. We also know that in most cases we simply cannot use pH values of 13 or more, seldom more than 12.5 due to the restriction of the membrane. Built products have an enormous advantage over straight caustic. With the inclusion of various sequestrants, chelating or complexing agents into the formula increasing detergency, a built product can allow for the reduction of pH while making retention of cleaning efficiency possible. Sequestrants also, or primarily, react with the calcium and magnesium ions present in either the soil or the hard water employed or both. They aid greatly in soil removal.

4.2 Neutral cleaners

Neutral cleaners are usually “enzyme cleaners.” Certain membranes, such as the CA and some sensitive composite membranes, do not support pH values higher that 7.5 or 9.5 respectively. As the protein solubility curve indicated, this is a bad region for efficient soil removal. In order to make a product, which is buffered to give a pH value of 7.5 or 8 in solution do a good cleaning job on protein, an enzyme (similar to protease of the stomach) is added.

The enzyme slowly digests the protein molecules and makes them into water-soluble fragments. To speed up the action of the enzyme, one should work at the optimum pH of the enzyme activity, which is about pH 9 (already too high for CA) and at temperatures around 120°F, which may also be too high for some membranes. One could increase the amount of enzyme in the cleaner, as more enzyme molecules will be able to do more work. This is however costly. Enzyme cleaners are not only just
composed of an enzyme preparation. They have builders and buffers, surfactants for
emulsifying and dispersing soil.

Depending on the type of soil, it is possible to make a neutral cleaner of quality
without enzymes (a lot less expensive) if no protein is present in the soil, or without
surfactants when no fat is present. Enzymes other than proteases have not been tried on a
large scale, mostly because of the cost factor involved.

4.3 Acids

An acid cleaning step can often be skipped when a powerful quality cleaner has
been used. It is recommended to use acids when high amounts of mineral deposits,
calcium, magnesium, iron are present in the soil or in conditioning the membrane surface
in the case of inorganic membranes. A blend of acids (nitric / phosphoric / citric)
correctly chosen is usually better than straight commodities. Among other things the
blend is easier to handle, has the purity not always found in raw materials (an important
factor in membrane cleaning) and the benefit of the various advantages of the pure acids

5. Solvents

Solvents such as chlorinated hydrocarbons or petroleum derivatives are not
recommended in membrane cleaning. Compatibility with the membranes or the support
material is often not assured, cleaning is restricted to only a particular type of soil (oil
and grease, emulsions), and toxic and environmental hazards make these cleaners more
and more obsolete.

6. Oxidizers

Sodium (or potassium) hypochlorite, chlorine bleach, is often used for cleaning
and sanitizing. It helps in protein removal, but is corrosive, not only on stainless steel,
but on certain membranes such as PA or TC. There are other disadvantages. Even on PS
there are limitations as to concentration and temperature. Again, certain effects seem to
work together, but in different ways than on stainless steel. Whereas on steel the
recommendation with respect to chlorinated cleaners is to remain at high pH in order to
decrease the change of corrosion, the polymeric material suffers more from the
combination of high alkalinity plus chlorine than from mild alkaline chlorine bleach
alone. If membrane specs state temperature range from 60°F to 140°F, pH range 2 to 12
and chlorine level tolerated up to 300 ppm that does NOT mean that it is safe to operate
at 140°F, pH 12 and 300 ppm simultaneously. The temperature tolerance is given at
similar conditions. What one can do is a matter of negotiation between the user, the
manufacture and the supplier.

7. Hydrogen Peroxide

Hydrogen peroxide is used as a cleaning booster in some applications, not as
effective as chlorine, but also not as destructive. In membrane systems it is sometimes
used for cleaning and once again, be cautioned to review the membrane specifications
before use.

The system C.I.P. pH should be closely monitored so as not to exceed the
recommended parameters. Acid-based and Alkaline-based products should be added as
slowly as possible to avoid pH spikes prior to solution equilibrium. The pH limitations
may vary somewhat depending on system manufacturer. As an example for TFC/TFM
membranes, the pH range for the acid wash cycle may be 2.3 to 2.5. The alkaline cycle
pH range may be only 10.0 to 10.5. It is important not to exceed the recommended pH
ranges due to potential shortened life of the membrane elements. In extreme cases chemical damage and loss of flux will result. Usually on TFC/TFM membranes, a minimum pH should be 2.0. A pH of less than 1.5 may cause severe damage to the membranes, glue, and backing material.

Table 1. Membrane pH and Temperature limits for Processing or C.I.P.

<table>
<thead>
<tr>
<th>Membrane Type</th>
<th>Process pH</th>
<th>Process Temperature</th>
<th>C.I.P. pH</th>
<th>C.I.P. Temperature</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ultrafiltration Membranes:</td>
<td>2.0-10</td>
<td>55°C</td>
<td>2.0-11.5</td>
<td>50°C</td>
</tr>
<tr>
<td>PES (Polyether sulfone)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>PVDF (Polyvinilidene fluoride)</td>
<td>2.0-9.0</td>
<td>55°C</td>
<td>2.0-11.0</td>
<td>50°C</td>
</tr>
<tr>
<td>Reverse Osmosis Membranes:</td>
<td>4-10.5</td>
<td>50°C</td>
<td>1.8-11.0</td>
<td>50°C</td>
</tr>
<tr>
<td>TFC (Thin Film Composite,</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cross-linked Polyamide)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Nanofiltration Membranes:</td>
<td>4.0-11</td>
<td>50°C</td>
<td>2.0-11.5</td>
<td>50°C</td>
</tr>
<tr>
<td>TFM</td>
<td></td>
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</tr>
</tbody>
</table>
1. INTRODUCTION

Almost every food processing unit, small or large, handling commodities, like, milk, bakery, beverages, meat and poultry, fruits and vegetable, of cereals/ pulses and oils, generates large quantities of effluent/wastewater everyday. These effluents contain wide range of pollutants including fats/oils/grease, suspended solids, BOD, volatile organic compounds, heavy metals, salts, pathogens, etc. Dairy processing wastewater streams in particular are generated during processing of milk (pasteurization, homogenization, separation/clarification, etc.), manufacturing of dairy products and cleaning operations. The principal constituents of this wastewater are coagulated/dissolved milk solids (mainly fat, proteins, minerals, etc.), cleaning solutions (acids/alkalis/wetting/chelating agents, etc.) and sanitizing compounds (Chlorine, iodophor, quaternary ammonium compounds). Raw wastewater loading for the American dairy industry has been summarized by commodity segment in Table 1. Drainage of these wastes to municipal sewers leads to serious pollution problem, in addition to loss of large quantity of water along with usable solids. Different countries have, therefore, enforced stringent legislation to suitably pretreat the effluent of all manufacturing industries before its disposal. The methods used for pretreatment of industrial wastewater are: chemical, physical, biological and more recently membrane separation processes. Since the costs of effluent treatment is very high, considerable economics can be made by recycling and reuse of water, and the recovery of both suspended and soluble solids by adopting suitable technologies.

<table>
<thead>
<tr>
<th>Products</th>
<th>Wastewater (kg ww/kg milk) range</th>
<th>Wastewater (kg ww/kg milk) average</th>
</tr>
</thead>
<tbody>
<tr>
<td>Milk</td>
<td>0.10-5.40</td>
<td>3.25</td>
</tr>
<tr>
<td>Cheese</td>
<td>1.63-5.70</td>
<td>3.14</td>
</tr>
<tr>
<td>Ice cream</td>
<td>0.80-5.60</td>
<td>2.80</td>
</tr>
<tr>
<td>Condensed Milk</td>
<td>1.00-3.30</td>
<td>2.10</td>
</tr>
<tr>
<td>Butter</td>
<td></td>
<td>0.80</td>
</tr>
<tr>
<td>Powder</td>
<td>1.50-5.90</td>
<td>3.70</td>
</tr>
<tr>
<td>Cottage cheese</td>
<td>0.80-12.40</td>
<td>6.00</td>
</tr>
<tr>
<td>Mixed products</td>
<td>0.80-4.60</td>
<td>2.34</td>
</tr>
</tbody>
</table>

2. MEMBRANE SEPARATION PROCESSES

The development and application of membrane separation processes is one of the most significant recent advances in chemical and biological process engineering. Membrane processes, namely, Reverse Osmosis (RO), Nanofiltration (NF),
Ultrafiltration (UF) and Microfiltration (MF), are advanced filtration processes, which utilize the separation properties of finely porous polymeric or inorganic films. Characteristics of membrane separation process are given elsewhere (Dharam Pal, 2003). Membrane separations are used in a wide range of industrial processes to separate biological macromolecules, colloids, ions, solvents and gases. They also have important medical uses, especially in renal dialysis. The worldwide annual sales of membranes and membrane equipment are worth in excess of $1 billion. The use of membranes for treatment of wastewater merely serve to separate or fractionate components of wastewater into more useful and/or less polluting streams, and do not breakdown or chemically alter the pollutants. Compared to other treatment methods, membrane technology results in fairly quick payback periods, operation is simple, effluent quality is consistently good, results are usually immediate, and it can substantially reduce chemical usage although perhaps not eliminating them entirely, depending on the type of pretreatment required to minimize membrane fouling (Cheryan, 1998). Since the physico-chemical properties of wastewater vary widely, even within the same industry and sometimes within the same processing plant at different times of the year, proper selection of membrane and module is desirable. In addition to feed variation, other aspects that need to be considered for testing of membrane for waste water treatment are pre-treatment options, cleaning problems and issues related to recycling or disposal of permeate and retentate. Though membrane separation processes are being used in all the manufacturing industries, a few specific applications related to effluent treatment of food processing industries are discussed here.

3. **REMOVAL OF FATS/OILS/GREASES**

The food processing industry seeks effective technologies to remove fats, oils and greases (FOG) from food processing wastewater at acceptable costs. The dairy, baking, oil extraction (e.g. olive, soybean, cottonseed, groundnut oil, etc.), fish processing, meat and poultry industries, as well as manufacturers of oil containing foods (e.g. margarine and salad dressing) face the problem of reducing the oil contaminant load to downstream wastewater systems. Recovering valuable byproducts, such as proteins and milk fat in the dairy industry, while reducing the biochemical oxygen demand (BOD) and total suspended solids (TSS) charges from the publicity owned treatment works makes systems that can remove FOG increasingly economical (Miller, 1995). The free oil in a oily waste can be removed by physical separation (density difference) and the unstable oil/water emulsion by combination of mechanical or chemical method followed by gravity separation, but the stable emulsion particularly water-soluble oily waste require more sophisticated treatment to meet present effluent standards. The use of membrane process, particularly UF and MF, has shown great benefits to treating oily wastes of food industries. If the salt content of oily wastewater is too high for direct reuse of permeate in the plant, RO or NF can treat it.

Typically the size of oil droplets in emulsions is between 0.1μ and 0.5 μ. UF membranes have pore sizes below 0.01 μ and this work very well on filtering out FOG. MF membranes with pore sizes above 0.05 μ can also be effective in FOG separation, but there is a potential for FOG break through, especially at high emulsion concentrations. In addition, these MF membranes typically have tortuous path morphologies that tend to trap fine particles and colloids in the membrane and eventually become plugged. Tubular UF membranes have been used successfully in separating proteins and FOG in salad dressing, margarine, bakery and dairy plants achieving FOG reduction in the wastewater up to 99%. Hydrophilic surface membranes enable stable, long-term operation by resisting adsorption of the FOG, whereas the hydrophobic
membranes made of polypropylene, polysulphone polyvinyl difluoride or showed more tendency of fouling even at low concentration of FOG.

4. **DISTILLERY/BREWERY WASTEWATER**

Large volumes of water are used in an ethanol (alcohol) process in a distillery and a brewery. Consequently large volume of wastewater is generated in the form of spillage. A plant producing 100 million liter per year of ethanol may have 900 million liter of spillage to handle. The spillage is hot (85-95°C) and contains TS in range of 5-8% w/w if starch or sugar has been used as the fermentation substrate (Cheryan, 1998). The solids consist of suspended matter in form of dead yeast cells and cell debris (2-3%), traces of residual sugars, nitrogen compounds, and byproducts of the fermentation. The stillage is usually evaporated and dried for sale as animal feed or sent to waste treatment plants. Some ethanol plants may partially clarify the stillage by clarifiers/centrifuges, and the thin stillage recycled to upstream operation. This recycle operation saves wastewater treatment and evaporation costs. MF can be used quite effectively to clarify the stillage with better clarity (no suspended solids) as compared with clarifiers, which should be beneficial in the upstream operations where it is reused. In addition NF or RO can be used to process MF permeate with a view to recover some valuable byproducts.

5. **RECOVERY OF BRINE AND CLEANING SOLUTIONS**

Salting of many varieties of cheeses is a regular feature during their production. During salting the brine picks up cheese constituents, for example, protein, fat, salts and lactose, and bacteria and thus become so cloudy that it has to be discarded. Cheese brine typically containing 17-25% sodium chloride and is at a pH of 4.8-5.0. Use of MF membrane with pore diameter of 0.2μ reduced the bacterial count to less than 10/ml in the permeate (Merin et al. 1983). Present generation UF & MF membranes can remove all the suspended solids (proteins, fat and bacterial cells) and many contaminants making the brine solution as good as before its use (fresh). In one mozzarella cheese plant, four UF spiral modules with 0.76 mm spacer, with a total area of 32 m², process about 34000 litre/day at normal brine temperatures of 10-20°C enable recovery of clean brine up to 99.5% (Cheryan, 1998).

Many food processing industries clean their processing units, such as, HTST plant, UHT, clarifiers/separators, storage tanks, packaging units etc., by caustic (e.g. sodium hydroxide) and acids (nitric, phosphoric, HCl, etc.) The deposited materials like soil, food constituents, bacterial slime and other residues, are mixed with the cleaning solutions, thereby making them unsuitable for reuse. Membrane technology offers the opportunity to recover these acids and alkalis by removing separately the suspended and dissolved solids. Since these cleaning solutions are at high temperature and have corrosive nature, use of inorganic membranes is favored. Stainless steel membranes, incorporated in the “Micro-steel” caustic recovery system for dairy plants (MSS, 1995), is designed to remove suspended solids from CIP solutions used for evaporators and other processing units and thus make saving in caustic soda up to 50% with a payback period of less than a year.

6. **DAIRY PRODUCTS EFFlUENTS**

Dairy industry has several polluting waste streams as mentioned earlier in this write-up. In addition to that, some of the by-products such as UF-permeate & whey are also discharged to the sewers mainly because of very high-energy requirements in processing these diluted streams. Particularly in India and other developing countries,
whey, which is a by-product of cheese, chhana/paneer and casein, is largely disposed off as a dairy waste/effluent. By combined application of MF and/or UF and RO, it is possible to recover all the solids from dairy effluents and thus its organic load can be decreased from 50000 mg/liter to about 300 mg/l (Glover, 1985). The solids recovered from whey and UF permeate can be used for food application and pharmaceutical purposes where as those recovered from the flushing/rinsing of processing units/equipments, floor washing etc. can be used as animal feed. The clear waster/cleaning solution separated from suspended solids by membrane processes can be reused with in the processing plant.

7. OTHER EFFLUENTS TREATMENT APPLICATIONS

In fruits processing (particularly canned fruits) industry, a very high amount of water is used in washing of fruits, processing, can cooling, and cleaning operations. This amount varies from 2,00,000 to 8,00,000 gallons per ton of the fruits. Similarly, large quantities of water are required for blanching of cereals and pulses, for example, soybeans. Such wastewater can be pretreated by RO to remove the soluble solids of the food and extraneous matter like dirt/soil and thus can be made reusable.

8. REFERENCES


MSS 1995. Micro-steel Caustic Recovery System: Membrane system, Membrane System specifications, Wisconsin Rapids, WI.


1. INTRODUCTION

In nature and food systems, microorganisms get attracted to solid surfaces conditioned with nutrients that are sufficient for their viability and growth. These microorganisms initially are deposited on the surfaces and later get attached, grow and actively multiply to form a colony of cells. In this regard, the formation of organic polymers is essential which helps in the proper colonization of microorganisms. These masses of cells further become large enough to entrap organic and inorganic debris, nutrients and other microorganisms leading to the formation of a microbial biofilm. The term biofilm refers to the biologically active matrix of cells and extracellular substances in association with a solid surface However, according to Costerton et al., a biofilm is a functional consortium of microorganisms attached to a surface and is embedded in the extracellular polymeric substances (EPS) produced by the micro-organisms. On most of the occasions where biofilms are a nuisance, the term microbial fouling or biofouling is generally implied. Biofouling refers to the undesirable formation of a layer of living microorganisms and their decomposition products as deposits on the surfaces in contact with liquid media. In dairy and food industry, biofouling causes serious problems such as impeding the flow of heat across the surface, increase in the fluid frictional resistance at the surface and increase in the corrosion rate at the surface leading to energy and product losses.

Biofilms are an accumulation of inorganic and organic materials that can attach to most surfaces. Bacteria, both pathogenic and non-pathogenic, are incorporated into a biofilm during a stepwise formation. With time and nutrients, a biofilm and the bacteria within the biofilm will grow and become strongly attached to the surfaces. On occasion, parts of the biofilm slough off into the surrounding environment. This can be hazardous if the location of the biofilm happens to be in a food processing setting; after sloughing, the bacteria incorporated in the biofilm can contaminate other surfaces, as well as food products.

For this reason, removal of biofilms in the food-processing environment is critical. Formulations and concentrations of cleaning and sanitizing agents, temperature, time of exposure and mechanical activity all play a role in the removal of biofilms. Additionally, bacteriocidal agents can be absorbed onto surfaces to help prevent initial formation or adhesion of bacteria. Cleaning and sanitizing regimes that incorporate steps to remove biofilms will result in a cleaner, safer processing environment and a safer product that has a longer shelf life.

2. FORMATION OF BIOFILMS IN FOOD PROCESSING AREAS

In nature, most bacteria do not exist as suspended, or planktonic, cells. Rather, they exist attached to a surface. Bacteria have the capacity to attach and colonize the surface of most natural and man-made materials. Attachment often results in the production of extracellular polysaccharides and changes in cellular morphology and growth rates. Additionally, diverse genes are expressed in bacteria that are attached to surfaces as compared to their planktonic counterparts. As a result of these changes,
surface-attached bacterial cells display increased resistance to toxic chemicals and biocides.

As bacteria attach to a surface and produce extracellular polysaccharides, a mass or biofilm is formed. Biofilm formation takes place in a step-by-step manner. First, inorganic or organic molecules are adsorbed to a surface. This creates a conditioning layer, or bacterial primer, that increases the ability of bacteria to attach to that surface. Proteins often form conditioning layers that aid bacterial adhesion. In food production facilities, biofilm formation is found more frequently when high protein concentrations are present. Whey proteins, which are prevalent in dairy plants, have been shown to cause an increase in bacterial adhesion and selectively increase the adhesion of several milk-associated organisms.

Once a conditioning layer is formed, bacterial adhesion ensues. Processing factors that increase bacterial attachment to surfaces include high or low pH extremes and high contact surface temperature; both will denature proteins, facilitating the formation of a conditioning layer. Further, low fluid flow rates over a biofilm allow increased nutrient contact time. Other factors include nutrient availability, which is ubiquitous in food plants; length of time that the bacteria are in contact with the surface; bacterial growth stage; and surface hydrophobicity.

In general, increased surface hydrophobicity enhances bacterial attachment. Stainless steel is an example of a hydrophobic surface. *Bacillus* spores, which also have a hydrophobic surface due to their outer coat proteins, have enhanced attachment capability on hydrophobic surfaces compared to vegetative cells. Therefore, spores adhere to stainless steel in greater concentrations than do vegetative cells.

Interestingly, cell viability has limited influence on attachment propensity. Live or dead cells will attach to selected surfaces with similar propensities. Bacterial attachment is mediated by fimbriae, pili, and flagella, all of which are appendages extending outward from the cell surface. Bacterial attachment also is enhanced by extracellular polysaccharides that act to form a bridge between the bacteria and the conditioning layer. This bridge actually is a combination of electrostatic, covalent and hydrogen bonding, along with dipole, Vander-Waals, and hydrophobic interactions. Initially, the bonds between the bacteria and the conditioning layer may not be strong and can be easily removed by flowing water. However, with time, these bonds are strengthened making attachment irreversible.

Once embedded within a biofilm, injured or small, nutrient-deprived cells have the opportunity to repair, metabolize nutrients contained within the conditioning layer, grow and reproduce. As growth continues, the copious volumes of extracellular polysaccharides that are produced further provide a protective barrier around the cells. Inorganic and organic matter flowing over the biofilm becomes entrapped, increasing biofilm size and providing additional nutrient sources. Biofilms develop rapidly when there is a continuous source of nutrients. Under such conditions, a biofilm may be considered "mature" within 24 hours and may continue to grow to millimeter proportions in a matter of days. Biofilm development can occur within one hour with 10% of the bacterial population irreversibly adhering to the conditioning layer. After about 12 hrs greater than 91% of the bacteria are irreversibly attached.

As the biofilm matures, resistance against various disinfectants increases, which may be due to the increased production of extracellular polysaccharides. Biofilm removal during the nightly sanitation routine becomes a difficult task, because the increased chemical contact time and mechanical activity required taxes both personnel and time
If extended production runs are performed, weekly sanitation routines must be exceedingly rigorous in order to remove mature and recalcitrant biofilms.

If nutrients are in close proximity to bacterial cells, motility requirements may be reduced, and thus, energy demands. Therefore, biofilms afford a protection that allows for extended bacterial longevity. Periodically, pieces of the biofilm may slough off due to flow rate dynamics, the shearing effects of flowing fluids, chemicals within the fluid, or changing properties of the biofilm bacteria. The released bacteria may be transported to a new location where biofilm formation can start again or the bacteria may remain in the fluid as a contaminant.

Surfaces in food production facilities, such as stainless steel, aluminum, glass, nylon materials, Buna-N, and Teflon seals, can harbor biofilms. Biofilm formation has been associated with environmental surfaces, such as floors, walls, pipes and drains. Environmental surfaces have led to cross-contamination via air, personnel or cleaning. Biofilms also are found on food contact surfaces, such as gaskets, conveyor belts, pasteurizers, and equipment containing crevices or dead spaces. These areas often are hard to reach during cleaning and sanitation and thus optimal conditions for the formation and development of biofilms are established. The bacteria are protected from sanitizers while being exposed to a flow of water and nutrients. Surfaces that are pitted, scratched, cracked or corroded trap food particles and provide the bacterial adhesion sites required to begin the stepwise formation of biofilms.

Biofilms contain diverse bacterial populations. In food production facilities, biofilms have been found to contain *Listeria, Pseudomonas, Campylobacter, E. coli* and *Salmonella*. Non-starter lactic acid bacteria and thermoduric species often are found in dairy plant biofilms. Dairy plant biofilms may even be predominated by a single bacterial species as the result of pasteurization, which eliminates most gram-negative species, allowing thermoduric species to grow without competition for nutrients.

### 3. INCREASED RESISTANCE OF BACTERIA IN BIOFILMS

It is well established that bacterial biofilms exhibit an increased resistance to antimicrobial treatments than the individual cells grown in suspension. This resistance has been widely observed and is attributed to the varied properties associated with the biofilms including; reduced diffusion, physiological changes due to reduced growth rates and the production of enzymes degrading antimicrobial substances.

A characteristic feature of microbial biofilms is the presence of an exopolysaccharide matrix embedded with the component cells. This exopolysaccharide matrix may act to various degrees as a diffusion barrier, molecular sieve and absorbent. The antimicrobial resistance exhibited by the biofilm is related to the 3 dimensional structures and the resistance is lost as soon as this structure is disrupted. Furthermore, antimicrobial agents are far more effective against actively growing cells i.e., the best disinfectant for planktonic cells are not necessarily the suitable ones for biofilm cells. This implies that the bacteria within the biofilm exhibits a varied physiological pattern and showed nutrient and oxygen gradients across the biofilm. The cells within the biofilm were found to receive less oxygen and fewer nutrients than those cells at the biofilm surface. In addition, in cases of serious biofouling, thick biofilms are formed which may include many metabolically dormant and/or dead cells. This state of the bacterial cells of the biofilm may have an altered growth rate and physiology, resulting in increased resistance to antimicrobial agents.
4. CONTROL AND REMOVAL OF BIOFILMS

Generally, an effective cleaning and sanitation programme, when included in the process from the very beginning, will inhibit both accumulation of particulates and bacterial cells on equipment surfaces and subsequent biofilm formation. However, an inappropriate cleaning strategy would lead to biofilm formation and increase the biotransfer potential.

The control of biofilms represents one of the most persistent challenges within food and industrial environments where the microbial communities are problematic. Adopting different strategies that include physical and chemical methods can eliminate the biofilms in the food industry. In addition, the biological means has been the newer dimension in the recent years for the biocontrol of bacterial biofilms.

Removal of biofilms is achieved by a combination of four factors: 1) formulations and concentrations of cleaning and sanitizing agents; 2) exposure time; 3) temperature; and 4) mechanical activity. Removal of a mature biofilm most often will require extensive mechanical action, such as scrubbing or scraping in conjunction with the use of cleaning and sanitizing agents. Passing sanitizers over the surface removes the top layer and exposes the subsequent layers to nutrients; this hastens the growth and development of biofilms. Repeated sanitizer applications tend to favor the growth of bacteria directly under the surface. These bacteria then produce large amounts of extracellular polysaccharides that protect the cells from further sanitizer applications. The goal of cleaning is to break the bonds of the extracellular polysaccharide-conditioning layer. Once a bacterial cell is released from the protection of a biofilm, it is much less resistant to subsequent bacteriocidal sanitizers used in the cleaning/sanitizing regime.

Although the matrix of the biofilm will affect removal, there are a number of cleaning/sanitization combinations that have been successfully utilized. One such product, SU727 Trippel produced by Suomen Unilever, contains anionic active tensides, organic complex formers, alkali, and hypochlorite at a working pH of 12.5. This product has been proven to remove 90% of the bacterial load contained within biofilms along with the extracellular polysaccharide matrix. Additionally, preparing a stock solution of 23% hydrogen peroxide and 4% peracetic acid, and then mixing the stock to a working concentration of 1-2%, combined with a contact time of 5 minutes at 25°C has been found to effectively reduce the survival of Pseudomonas, Escherichia coli, Salmonella, Bacillus, Staphylococcus and Listeria. Similarly, a 50% and 0.05% concentration of hydrogen peroxide and peracetic acid, respectively, mixed to a working concentration of 1-2% with a contact time of 5 minutes at 25°C was shown to be effective at reducing survival of the above organisms contained within a biofilm. Hydrogen peroxide powder, mixed in 3-6% concentrations, also has been noted to be an effective biofilm removal agent. The oxidative activity of these solutions is thought to be responsible for the bacteriocidal mode of action.

It should be noted that, in general, the greater the contact time, the more effective the bactericidal action. Additionally, any chemical treatment combined with mechanical action will remove biofilms more efficiently. Therefore, circulating water for clean-out-of-place (COP) tanks, floor scrubbers, or good old-fashioned elbow grease with brushes or scrapers are highly recommended. However, care should be taken because some brushes and scrapers may be abrasive and leave scratches on stainless steel surfaces, further promoting biofilm formation.
An example protocol for COP parts is as follows: First, add parts to a chlorinated alkaline detergent (0.5 oz/gal, pH 11-12) in circulating water at 160°F for 20 minutes. Second, rinse with potable water and place parts in circulating 160°F water with phosphoric acid (1 oz/gal) for 20 minutes. Then, rinse with potable water and place parts in chlorine solution (0.3 oz/gal) for 15 minutes. Finally, rinse with potable water. This regime is most effective for detaching biofilms and has been found to be extremely effective on biofilms containing organisms such as Staphylococcus aureus. This may be due, in part, to the composition of the extracellular polysaccharide produced by this organism. The composition of the extracellular polysaccharide varies based on species. Depending on the composition of the biofilm, a combination of detergents may be required to remove it from the surface. Cations, in particular calcium, are thought to play a role in bacterial adhesion. The absence of cations often results in the detachment of bacteria. Therefore, chelators included in detergents may be effective in bacterial detachment and subsequent removal of biofilms.

Cleaning by brushing, scrubbing and scraping surfaces or the use of circulating water often is necessary to detach the extracellular polysaccharide layer. The use of high-pressure spray hoses at distances greater than 250 mm from the surface is not recommended, because this will increase the generation of aerosols and will disperse bacteria over a wide area. Interestingly, high-pressure hoses used above 17.2 bar (250 psi) have not been shown to enhance biofilm removal or to significantly increase the removal of biofilms containing S. aureus. For comparison, household water pressure ranges between 4 and 4.5 bar (60-65 psi); this pressure is too low to contribute significantly to the removal of biofilms.

Acid cleaners can be used to remove inorganic soil or material such as rust. Using softened water during cleaning often increases the effectiveness of these cleaning chemicals. When cleaning, water from the hose should be no less than 130°F because the temperature drops 8°F to 10°F as it flows from the nozzle and contacts equipment. U.S. Department of Agriculture (USDA) permits the use of hot water (180°F) instead of chemical sanitizers. However, this practice is not advisable because it aids in the formation of the conditioning layer by denaturing proteins and increasing the adhesion properties of equipment.

Newer strategies devised for the biocontrol of biofilm formation may be the adsorption of bioactive compounds like bacteriocins onto food-contact surfaces for the inhibition of adhesion of bacteria. By definition, bacteriocins are proteinaceous antimicrobial compounds exhibiting bactericidal properties Nisin, a well-known and most applied antimicrobial peptide has proven to be effective inhibitor of many food pathogens and spoilage bacteria, especially sporeformers. Nisin also has been employed as an anti-biofilm agent. Nisin absorbs to surfaces and acts as a bacteriocidal agent for adhering bacteria. Nisin is a Generally Recognized As Safe (GRAS) substance. It is an extracellular protein excreted by some strains of Lactococcus lactis. Nisin has a mode of action that results in the formation of pores in the cell membrane of the bacteria. Pore formation leads to cell lysis and death. The bacteriocidal activity of nisin has been shown to target other gram-positive bacteria closely related to L. lactis and some gram-positive pathogens, such as Listeria monocytogenes.

5. CONCLUSIONS

Biofilms have been of considerable interest in the context of food hygiene. Of special significance is the ability of microorganisms to attach and grow on food and food-contact surfaces under favorable conditions. Biofilm formation is a dynamic
process and different mechanisms are involved in their attachment and growth. Extracellular polymeric substances play an important role in the attachment and colonization of microorganisms to food-contact surfaces. Various techniques have been adopted for the proper study and understanding of biofilm attachment and control. If the microorganisms from food-contact surfaces are not completely removed, they may lead to biofilm formation and also increase the biotransfer potential. Therefore, various preventive and control strategies like hygienic plant lay-out and design of equipment, choice of materials, correct use and selection of detergents and disinfectants coupled with physical methods can be suitably applied for controlling biofilm formation on food-contact surfaces. In addition, bacteriocins and enzymes are gaining importance and have a unique potential in the food industry for the effective biocontrol and removal of biofilms. These newer biocontrol strategies are considered important for the maintenance of biofilm-free systems, for quality and safety of foods.

6. REFERENCES


1. INTRODUCTION

Intelligent knowledge-based systems (IKBS), knowledge-based expert systems or simply expert systems are a product of artificial intelligence (AI), the branch of computer science concerned with developing programs that exhibit intelligent behavior. These tools represent a departure from the original aim of pioneering AI researchers to build general-purpose intelligent tools for solving a variety of problems. Expert systems are classified for specific uses and it is this specialization, which enables these tools to handle real and different tools instead of contrived, toy ones. The relatively recent availability of low cost microcomputer has facilitated a rapid expansion of expert systems development activities the areas of process control and has been a catalyst for the birth of new interdisciplinary field of knowledge engineering. Computer aided expert systems are a set of computer programs typically:

- Designed for solving complex problems ordinarily requiring human intelligence
- Embodies both expert knowledge and expert inferences. The former would be stored explicitly in a symbolic declarative language; the later would consist of AI heuristic search and reasoning procedures for utilizing the stored information.
- Capable of achieving high performance in narrowly specified domains, of incremental development, of dealing with incomplete or uncertain data, of handling unforeseen situations, and of explaining or justifying its results.

2. CLEANING AND SANITATION

The term “cleaning” connotes the removal of product residues, of deposits of precipitated proteins, of stones and decomposition of products, of dirt and other soiling matter. In brief cleaning is the irreversible removal of the soil (e.g. residues of a product) from the surface of a plant’s equipment. The thoroughly cleaned surface must be free of any visible, touchable or chemically detachable residue of the soil.

Sanitation is a process, which reduces the number of microorganism on plant’s equipment to a level consistent with acceptable quality control and hygienic standards. After sanitization, the surface shall not give a significant increase in bacteriological contamination to the product coming in contact with it. The notion “sanitizing” is not used in all countries or in all languages. A broad interpretation is cleaning plus disinfection.

Cleaning and sanitation procedure consists of a series of cleaning cycles with alternate composition of the medium used. The following stages are commonly used in circulation cleaning:

- Pre-rinse with water
- Rinse with alkali
- Rinse with water
- Rinse with acid
Soil is simply “substance in the wrong place”. It can be either simple product rests or fouling products in the form of a fouled layer and/or microorganisms. The various kinds of fouling mechanisms will produce different types of layers containing one or more components of sugar, fat, protein, etc. There are many possible classifications of soil, based on different criteria. One important classification of food processing is based on a microbiological or non-microbiological type of contamination.

3. CLEANING-IN-PLACE (CIP) MANAGEMENT

For thorough cleaning some part of equipment may have to be dismantled and cleaned by hand. For large plants, CIP cleaning is almost exclusively used i.e. the plant is cleared by circulation or by once-through mechanical cleaning process without dismantling. This has greatly reduced plant downtime and associated cost. It laid down the foundation of automation and computer-aided expert systems for CIP management.

In CIP cleaning, the temperature, the sequence of operations and the duration of the separate rinsing stages are fully automatically controlled and operated. Care must be taken that mixing of product with rinse solution does not occur, all parts and corners of machines/equipment are rinsed properly and that the equipment’s construction material are not attacked by the cleaning solutions chosen. The CIP system can be programmed for a specific application. For example, a CIP program for a pasteurizer circuit can consist of the following stages:

1. Rinsing with warm water for about 8 min
2. Circulating an alkaline detergent solution for about 20 min at 75°C
3. Rinsing out the alkaline detergent with water
4. Circulating (nitric) acid solution for about 15 min at 70°C
5. Gradual cooling with cold water for about 8 min

CIP systems installed in plants can either be centralized or decentralized depending on the nature of plant layout, extent of plant operations, etc. Routing of solution in automatic CIP is controlled by sensors, which measure the conductivity of the Liquid. CIP programs are controlled from a sequence of controllers. The effectiveness of the CIP process depends on the flow rate, concentration and temperature of the cleaning fluids, and the time allowed for each stage in the process. The relevant data of soil and other microorganisms present in the equipment are collected by the sensors or by other methods and transmitted to the controlling computer. After processing the collected data by expert CIP system, it decides the sequence of operation, quantity of cleaning fluids required, flow rate, timing, etc.

4. PERSPECTIVES ON CLEANING, SANITATION AND HYGIENE MANAGEMENT

Hygiene considerations are of utmost importance in the food manufacturing process. Cleaning and sanitation procedure have to be considered as an integral part of food production. On one hand, the ability of equipment to produce high quality foods depends significantly on hygienic conditions, and on the other hand, the intensity of the necessary cleaning and sanitation procedures depends on the previous soiling or fouling phenomena. To set up goals for cleaning and sanitizing, different types of contamination sources have to be addressed. Some of these are listed below:
• Dirty raw material
• Foreign bodies, including foreign odours and flavours
• Dirty production equipment

Another source of contamination is the equipment surface. In this case the aim of cleaning and disinfection procedures is to achieve a hygienic unobjectionable final state of the surface. The surface must be free of soil, pathogenic microorganisms, food-spoiling microorganisms and detergents and/or disinfectant agents. Basic steps in the cleaning procedure are given in the following table:

<table>
<thead>
<tr>
<th>Steps</th>
<th>Function</th>
</tr>
</thead>
<tbody>
<tr>
<td>Prerinse</td>
<td>Rinsing with water to remove grass, loose soil</td>
</tr>
<tr>
<td>Cleaning</td>
<td>Removal of residual soil by a suitable detergent</td>
</tr>
<tr>
<td>Interrinse</td>
<td>Removal and rinsing away of detergent and soil from plant items</td>
</tr>
<tr>
<td>Sanitizing</td>
<td>Destruction of most microorganisms by the application of chemicals with or without heat</td>
</tr>
<tr>
<td>Post rinse</td>
<td>Removal with water (of a suitable bacteriological quality) of sterilant chemicals from the system</td>
</tr>
</tbody>
</table>

**Figure: 1 Cleaning techniques**
Management of hygienic conditions through cleaning and sanitation procedure consists of a series of cleaning cycles with alternate composition of the detergents/chemicals used. Several cleaning techniques (shown in figure 1) have been developed depending on different type of equipment used in plants.

Removal of soil/fouled layers is governed by certain reactions. The physical and physiochemical transformations occurring are melting, mechanical and thermal stress, wetting, soaking, swelling, shrinking, solvation (as dissolution of soluble substances), emulsification, deflocculation, and desorption. The chemical reactions involved are hydrolization, peptization, saponification (to a lesser extent), solubilization (as forming soluble salts through chemical reaction), dispersion, chelation, sequestering, and suspending. These reactions will help to overcome the cohesion forces of soil-soil bonds and adhesion forces of soil-surface bonds (or detergent-surface bonds). The rate at which soil is eliminated during cleaning has been classically described as being logarithmic in nature, which would suggest a first order reaction. Recent research work on cleaning of industrial systems showed better accuracy by using a kinetic model with a coupled reaction. In industries, the reaction is controlled/manipulated with the help of logic controllers. Of late, introduction of computer assisted/aided controller are implemented.

5. TRENDS IN COMPUTER-AIDED CIP MANAGEMENT

The food processing industry is in an era of transition due to competition, a rapidly changing business environment and consumer demands. These require new technology and practices for competitive advantages in the market. A huge amount is being spent every year on modernization including increased computerized or digital automation. Automation offers to food processing industry better profitability, productivity, process efficiency and safer product. Analog controls, used earlier, were adequate under normal operating conditions, but they cannot respond quickly enough during significant process deviations to make required adjustments without overshooting. Software based controls are used in industry now a days, that are much easier to implement new control algorithms. Process control technology has advanced in recent years with the availability of low-cost microprocessor, digital technology, circuit board, sensors etc. Advances in programmable logic controller (PLC) have also greatly assisted process automation. Further neuro-fuzzy logic has improved operational control in food processing. Although pneumatic control systems have long been used in the food industry, the use of computer-based controls provides many additional advantages such as the capability to monitor and control many operations independently and concurrently.

Computer controlled robots are programmed to perform many operations in food manufacturing including CIP management. They are useful in material handling, providing flexibility in loading and unloading. Advanced robotics and modern sensor technology help to develop flexible modular solutions to meet the challenges in food industry.

Machine vision inspection techniques have been developed to inspect and detect process defects at line speed. Vision systems can examine food products for foreign material, wrong color, business scars, and other flaws. Such systems use cameras to detect flaws by color as well as by size. They use lasers to sense differences in internal structure and color that are useful in quality control on processing and CIP lines.

Computerized control offers many benefits over conventional analog control. In implementations, their performance is similar but the cost of the digital systems is lower. Digital system offer more advanced control type. Feed-forward systems compensate for
frequent large disturbances. Decouplers improve the performance of multivariable processes. Adaptive controllers adjust themselves to match changing process dynamics. The communication capability of digital systems allows report generation and remote operation. Setpoint control allows complex processes to be optimized by supervisory computer systems.

The computerized automation of food process is more challenging than that of chemical or pharmaceutical processes. Food processes largely rely on operator’s rule of thumb and are not fully automated. Real challenge in food processes come when the process equipment is subjected to cleaning. Processes may be difficult to control or model by conventional methods, where simplifications or linearization are often made. Computer aided CIP management becomes too complicated because of tightly coupled control loops, nonlinear parameters around the operation point, or some parameters being subject to unpredictable noise. The properties of food material usually vary and depend on unpredictable factors such as seasons, location, and climate. These variations affect depositions and fouling in equipment. Because of these reasons, automation of a food process and its CIP management may cost money. Fuzzy logic and neural network techniques, separately or combined, can be used to facilitate computerized automation.

The concepts of fuzzy logic were proposed as means of expressing the ambiguity and uncertainty in human thinking. Fuzzy logic can capture the approximate, inexact nature of real world. In contrast to the conventional approach of process modeling or control, implementing linguistic rules that come from the experience of operators or the knowledge experts carries out a fuzzy logic system. Therefore fuzzy modeling transforms the problems from building exact mathematical models to encoding a knowledge base containing inexact, commonsense information rules. It is similar to humans’ strategies using imprecise models and decision rules to achieve fairly robust results. It increases the probability of automating some complicated or ill-defined food processes.

An artificial neural network (ANN) is computational model that mimics biological neural systems. Artificial neuron networks are famous for their learning or adapting ability. The network learns from the input and output data of itself, repeatedly. It also can approximate any continuous or discontinuous, linear or nonlinear function. Therefore such networks are very useful for modeling some not well understood food processes, CIP management, etc.

6. SYNERGY BETWEEN OPERATOR, EQUIPMENT, AND EXPERT SYSTEMS

Expert systems consist of engines, database and knowledge base in which human expertise are stored. The engines, which perform inference by using the knowledge bases, are software tools for building and utilizing expert systems. The databases are the temporary store of information or evidence provided directly by the operators or derived by computer during inference.

Several inference engines have been reported. The engines such as EMKCIN, KAS, EXPERT, OPS5, ROSIE, RLL, HEARSAY-III, and AGE are basically production systems with the different kind of knowledge in engineering techniques. In a production system, a natural way of expressing human expertise takes the form of IF-THEN type rules, which are called production rules. The tools should be flexible, interactive and transparent, and has self-explanatory functions that can justify the results of inference.
The acquisition of the human expert's knowledge in a specific domain is considered to be one of the most difficult and important tasks in building an expert system. Although documented knowledge such as engineering practices and standards are available in the domains related to process engineering, these are not enough to build the expert systems. It is important to recognize the fact that a large part of the expertise is not available in written form. The acquisition of the expertise from an operator for the equipment (pressure release system used in CIP management) has to be carried out in the following ways:

In establishing a knowledge base for diagnosis of a pressure relief system, a question and answer approach was taken. By consulting a design manual on safety facilities and engineering documents at hand, a human expert picks up IF-THEN rules. The expert also uses his knowledge on mechanical features of equipment, process networks, fluid dynamics, thermodynamics, etc. to make some decisions. A knowledge engineer asks the reasons why the expert made such decisions and records the reasons. After a set of rules was collected, these are analyzed to form a structure expressing cause and effect relations by the cooperative work between the expert and the knowledge engineer.

![Figure: 2 Process control for CIP management](image)

Above figure illustrates the working relationship among operator, equipment and expert system. Operator's learning is a distribution of truth gathered over a period of time stored in knowledge engines. These knowledge engines are nothing but AI (artificial intelligence) controllers. These controllers help in regulating PID (proportional, integral, differential) controller fixed in equipment. The controlling equipment remains in continuous contact of food processor and CIP system through a network of sensors.

7. COMMERCIAL VIABILITY

The trade reforms initiated by the world trade organization (WTO) have already changed the business environment. The quality of food products should meet the international requirements for viable market in the world. The CAC (Codex Alimentarius Commission) standards on hazard analysis and critical control points (HACCP) have been adopted under Sanitary and Phytosanitary (SPS) agreement. The computerized-controlled operations can assist with HACCP, which, if implemented and executed properly, can assure product safety. Computerized operations increase the monitoring and accountability of an HACCP program. *Listeria* and *Salmonella* are the major safety concerns for the food industries. To meet international standards it is becoming
necessary to implement newer innovations of computer science in food processing sector.

8. CONCLUSION

The present talk highlighted the need of the food industry to improve productivity, food quality, and safety through computerized automation and process control. Fuzzy logic and artificial neural networks are very promising for use in certain food processes that are difficult or impossible to control adequately by conventional methods. These methods complement the conventional methods rather than to replace them. Computer aided expert systems are required in CIP management to clean the equipment in a better way and also produce hygienic products to meet the international standards.

9. REFERENCES

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1 INTRODUCTION

The design of equipment is an essential part of a plant design, the goal of which is to develop and present a complete plant that can operate on an effective industrial basis. To achieve this goal many separate units or pieces of equipment are combined into one smoothly operating plant. If the final plant is to be successful, each piece of equipment must be capable of performing its necessary function. For fabricating different types of equipment, design data need to be developed with regard to material of construction, sizes, operating conditions, number and location of opening, codes, variation allowances etc. The fabricators handle many of the machine-design details, but the design engineers must supply the basic design information.

Unit process principles are used in the design of specific pieces of process equipment. The temperature, pressure and composition of every process stream, stream enthalpies, percent vapour, liquid and solid, heat duties etc. pertinent to the process are determined. In addition to the known specifications for the product and availability of raw materials, the design will be controlled by such items as the expected annual operating factor (fraction of the year that the plant will be in operation), temperature of the cooling water, availability of stream pressures, fuel used, value of by products, cleaning and sanitation requirements, pollution and food safety regulations.

2 EQUIPMENT FLOW SHEETS

Qualitative as well as quantitative had diagrams for the required unit operations involved in the process are essential for equipment design and planning. The qualitative information and the quantitative data are combined to design the location of temperature and pressure regulations and indications, as well as the location of critical control valves and special instruments. On the equipment and the processing line. Equipment design involves determining the size of the equipment in terms of volume, fled per unit tune or surface area. After a complete material balance is made, the mass quantities are used to compute energy balance around each piece of equipment.

3 CATEGORIES OF EQUIPMENTS

Based on their principal functions, various equipments can be grouped into three categories, the heat-transfer equipments, the mass-transfer equipments and materials-transfers handling and treatment equipments. Since principal design features of each category of equipment are widely different, the design approach for them has been described separately.

4 DESIGN AND PLANNING OF HEAT-TRANSFER EQUIPMENTS

Equipments for transferring heat are used in all the process industries. Process design consideration, therefore, are of particular importance to decide the piece of equipment suitable for a process. Modern heat exchangers range from simple
concentric-pipe exchangers to complex design of surface condensers. Between those two extremes are found one conventional shell and tube exchangers, coil heaters, extended surface exchangers and many varieties of other heat exchangers. Selection of heat-transfer equipment requires an understanding of basic theories of heat transfer and problems connected with mechanical design, fabrication and operation.

4.1 Overall coefficients of heat transfer

Many of the important cases of heat transfer involve the flow of heat from one fluid through a solid retaining wall into another fluid. The net rate of heat transfer can be related to the total temperature-difference driving force by employing an overall coefficient of heat transfer.

4.2 Fouling Factors

After heat-transfer equipment has been in service for some time dirt or scale may form on the heat transfer surfaces, causing additional resistance to fluid of heat. To compensate for this possibility, a dirt, scale or fouling factor is included while determining the overall heat transfer coefficient. Because the scale or dirt resistance increases with time the equipment is in service, some basis must be chosen for numerical values of fouling factors. The common basis is a time period of one year have decreased to the design value and shut down for cleaning will be necessary. With this approach, numerous shut downs for cleaning individual units are not necessary. Instead annual or periodic shut downs of entire plant can be scheduled, at which heat transfer equipment can be cleaned and brought to full capacity.

4.3 Cleaning and Maintenance

Heat exchanger require periodic cleaning, tube replacement or other maintenance work. The inside of straight tubes can be cleaned easily by forcing a wire brush or worm through the tubes, but cleaning of out sides of the tube usually requires the removal of entire tube bundle from the exchangers. Consequently many exchangers are provided with, removable tube bundles and the pitch and arrangement of the tubes are often dictated by the amount and type of cleaning that are required.

4.4 Fluid Velocities and Location of Fluids

The major factors involved in determining the best location for fluids in heat exchangers are the fouling and corrosion characteristics of fluids. When one of the fluids is corrosive it should flow inside the tubes to avoid the expense of corrosion resistance material of construction on shell side. Because cleaning inside tube is easier than external cleaning. Considerations should be given the locating the fluid with greater fouling tendencies inside the tubes. If other factors are equal, the fluid under high pressure should fluids may cause excessive pressure drop when passed through the tubes at the required velocities; which must be considered for the best routing of the fluids.

4.5 Ineffective Surface

The non-condensable gases if not removed, get collected and form a blanket around some of the heat exchange surface. The heat transfer surface can also become ineffective because of build-up of condensate when condensing vapours are involved. Consequently, drains, steam traps wide by pass and sight glasses to indicate condensate level are often necessary as auxiliaries on the heat exchangers. When high pressures are used, relief valves may be essential for protection. Poor distribution of fluid also leads to in effective use of the available surface area.
5 DESIGN AND PLANNING OF MASS-TRANSFER EQUIPMENTS

The transfer of mass from one phase to another is involved in the operation of evaporation, drying distillation, absorption, extraction, humidification, and crystallization. Mass transfer between two phases occur when there is a driving force, such as a state of equilibrium represents a theoretical limit for mass transfer operations, which is used in mass transfer calculations. The principal function of the equipment used for this operation is to permit efficient contact between the phases. These equipments require specialized shell internals, insulation pumps, blowers, heaters/coolers and other accessories such as instruments, controls and heat exchangers.

5.1 Entrainment

There is a tendering for liquid carried along with the stream of vapour and can be the cause of serious losses from the liquid being evaporated and contamination of condensate. Excessive entrainment occurs as a result of high evaporation rate. Specially designed entrainment separation is used on the evaporator, which, operate on the principle of ‘momentum separation’ and avoid the incorporation of fluid droplets in the discharging vapour stream.

5.2 Foaming

Formation of a stable blanket of bubbles on the surface of the boiling liquid reduces the heat transfer coefficients, produces problems in the removal of the product and vapour from the evaporator and causes heavy entrainment. To prevent the foam from rising and passing over into the vapour pipe, the liquid is carried up to a level below the top of heating surface, so that the bubbles come in contact with a hot surface and are these by burst.

5.3 Vacuum

The leakage of air into the plant reduces the vacuum and thereby increases the evaporation temperature. The tubes when subjected to a long period of service are proven to the leakage. Leakage in the product tubes will result in one product and steam losses and contamination. The joints on the calandria top and bottom covers, joints between the covers and the division plates require periodic renewal sudden application of steam to a cold plant can cause thermal shock and differential expansion leading to small leak, which gradually becomes larger. It is good practice to isolate the vacuum pump or air ejector from the condenser and test it separately to know whether the fault lies in the evaporator and condenser or in the vacuum pump or ejector.

5.4 Air Filtrations and Flow

Efficient designs of air filters are needed for dryers & coolers to avoid contamination of the product from the air. The filter for drying air is not required to destroy possible airborne bacteria, as the bacteria will not survive when the air is heated. However, as the cooling air is not subjected to heating, it is recommended to design the bacteria absorbing filters for the cooling air in places where air borne bacteria are likely to be found. The filters may be designed in such a way that the clean filtering material is supplied from a roll activated by the pressure drop over the filter to ensure constant flow of clean air for drying and cooling. Careful control of the air velocity is essential to prevent eddy currents up the drying chamber walls, which could result in accumulation of partly dried deposits and product scorching.
DESIGN AND PLANNING OF MATERIAL TRANSFER, HANDLING AND TREATMENT EQUIPMENTS

The most common means for transferring materials is by pumps and pipes. Conveyors, chutes, gates, fans and blowers are example of other kinds of equipment used extensively to handle and transfer various materials. Many forms of special equipment are used for the treatment of materials, as, for example, filters, blenders, mixers, kneaders, centrifugal separators, grinders, kettles, dust collectors and reactors. It must be decided that which type of equipment is best suited for a particular process. Consequently, theoretical design principles, practical problems of operation and cost consideration are all involved in final design of such equipments.

6.1 Power Requirement

A major factor involved in the design of material transfer, equipments is the amount of power that is required for the particular operation. The pump supplies the mechanical power to overcome frictional resistance, changes in elevation, changes in internal energy and other resistances set up in the flow system. Various design factors include the temperature, viscosity compressibility and density of the flowing fluid.

6.2 Piping System

Appropriate choice of material and correct pipe sizing are the key factors for piping system design. There must be adequate flexibility in the system for physical and thermal shocks along with relief valves for operational safety and the auxiliary or standby pumps and lines for flow diversion for product safety. Insulation, stream tracing and sloping of the line to the drain valve or steam trap can over come the problem of water hammer.

Above ground piping system have proved to be more economical except for major water or gas lines. However, overhead line containing a corrosive product should be shielded from open walkways. Improperly designed joints or poor alignment of piping results in piping leaks and corrosion. Future troubles can be minimized by mounting valves properly, protecting them against outside damage and locating them at the most suitable point in the line. Incase of piping arrangement, design should be such that the length of pipe is as short as practicable to avoid any say or dead pocket. Gaskets used at different joints should be sanitary type and non-absorbent material and be of IDF, BIS, and DIN standard. For proper sealing they must match the contour of the groove.

6.3 Pumps

Pumps are used to transfer fluids from one location to another. Power must be delivered to the pump from outside source. The amount of fluid to be pumped, the properties of fluid, pressure head and the type of flow distribution are the major factors, which govern, pump selection. Proper suction pipe size is important for satisfactory pump performance. The air pockets in suction line can be a source of trouble. It is not advisable to use a pump to pump a liquid for which it is not designed. Pump location should be selected so as not to have a dry pump run on the equipment. Milk pumps are designed and fabricated such that they can be dismantled and assembled easily without knocking or hammering to ensure complete and effective cleaning and avoid any source of product contamination.

6.4 Tanks and Storage Equipments

Storage of liquid materials is commonly accomplished by use of cylindrical, spherical or rectangular tanks. The design of storage vessel involves consideration of
details such as size and number of opening, shape of heads, necessary temperature and pressure controls and corrosive action of the contents. The wall thickness must be sufficient to permit safe usage under all operating conditions.

The geometrical dimension, shape and installation of the tank such that each part and corner is assessable for cleaning and inspection. There should not be any sharp edge as it may entrap milk solids and other particles, which may serve the source of contamination. To avoid this, all corners must be smoothed and rounded off. Complete drainage of liquid from the tank is very important, because, incomplete drainage may cause contamination. To ensure complete and effectively fast drainage, slope of the storage tank must be adequately designed.

7 MATERIALS AND FABRICATION

Selection of materials of construction combined with the appropriate techniques of fabrication can play a vital role in the success or failure of a new food processing plant or in the improvement of an existing faculty. As good processing plants turn to higher temperatures and flow rates to boost yields and through puts, selection of construction materials takes on an added importance, that is, to search for more dependable, more corrosion-resistance and food grade materials for construction of those process plants. There are a number of alloys and plastics suitable for a particular application. There are more than 100 different types of stainless steel. The most common are type 302, 304 designed as 18-19 stainless steel, with 18 percent chromium and 8 percent nickel. The addition of molybdenum to allow, as in type 316, increases corrosion resistance and high temperature strength. The fabricating operation on stainless steel is more difficult than on standard carbon steel.

Stainless steel exhibits the best resistance to corrosion when the surface is oxidized to a passive state. This condition can be obtained, at least temporarily, by passivation operation in which the surface is treated with nitric acid and then sensed with water. Localized corrosion can occur at places where material collects, such as in scratches, crevices or corners. Consequently mars or scratches should be avoided and the equipment should specify a minimum of sharp covers, seams and joints. All milk contact surfaces of an equipment should be smooth and polished. The high temperatures involved in welding stainless steel may cause precipitation of chromium carbide at the grain boundary, resulting in decreased corrosion resistance along with the weld. The chances of this occurring can be minimized by using low-carbon stainless steel or by controlled annealing.

The material of construction of pipelines and gaskets etc. must have similar desirable characteristics, that is, smooth, non-toxic corrosion resistance etc. Threads on pipe and the equipments, internal or external are not acceptable. The milk will get trapped and become microbial prove. Plastic or Rubbers used in the dairy need to be of food grade non-toxic material, non-absorbent type, should withstand high and low temperature from 0 to 100°C and should be resilient to tight closures. It should be non reactive with detergents. Welding performed during fabrication must ensure the surface is smooth with no pits on the surface, no burnt areas and no use of dissimilar metal. It is difficult for the purchaser to identify above points and therefore the supplier be asked to give a written certification that they have followed the standard codes of design and fabrication.
8 AUTOMATION

Automatic controlled process and cleaning equipment include automatic valves, sensors and programmable control. If the equipment and the process are correctly automated, high quality product can be secured as this eliminates all the errors, which are liable to occur in a manual process, such as the inadvertent mixing of products or contamination of products with detergents. The equipment is cleaned thoroughly according to a proven programme, which guarantees uniformly high product quality. Uniform treatment of the product and cleaning of the equipment offer the best product quality in terms of flavour, appearance and shelf life. Hazardous malfunction causing damage to personnel, product, and equipment on environment can be avoided through correctly applied automation of crucial steps in the process.

The risk of stoppages is high in manually controlled plants, as even skilled operators have difficulty in supervising large-scale processes adequately. Observation and logic processing can be often so demanding that wrong control operation can easily occur. Properly designed process control can yield more efficient equipment utilization, smaller product losses and lower consumption of heating and cooling media.

9 REFERENCES

INTRODUCTION

The arrangements for cleaning equipments that come in contact with products are an essential part of dairy and food processing plant. The potential effect of poor cleaning, poor standard and poor quality must be kept in mind at all times because a contaminated product does not keep well and is subjected to complains and negative publicity. Therefore, food manufacturers have to maintain high hygienic standard to keep with trade, moral and legal obligations.

Formerly cleaning of dairy equipments was done with people armed with brushes and cleaning solutions. This was not only laborious but was ineffective. To overcome-circulatory cleaning systems have been developed to achieve good cleaning and sanitation results.

Clean-in-place (CIP) means that rinsing water and detergent solution are circulated through process lines without equipment being dismantled. It may be defined as “circulation of cleaning liquids through machines and other equipments in cleaning circuits”. The high velocity flow of liquid over equipment surface generates mechanical scouring effect that dislodges deposits mainly solids and bacteria from vessels and pipe work.

The majority of cleaning and sterilizing liquids used in CIP systems are alkali or acid based and the CIP system will allow accurate dosing of the concentrated cleaning agent, normally into water, to give a low strength solution suitable for cleaning process plant. This solution is then used within the plant to clean and if necessary sterilize the system prior to the next production run. It can be carried out with automated or manual systems and is a reliable and repeatable process that meets the stringent hygiene regulations especially prevalent in the food, drink and pharmaceutical industries.

BENEFITS OF CIP

CIP has many benefits to the end user. Some of the main reasons for implementing CIP are:

- Safety operators are not required to enter plant to clean it
- Difficult to access areas can be cleaned
- Production down time between product runs is minimised
- Cleaning costs can be reduced substantially by recycling cleaning solutions
- Water consumption is reduced as cleaning cycles are designed to use the optimum quantity of water
- The cleaning system can be fully automated therefore reducing labour requirements
- Automated CIP systems can give guaranteed and repeatable quality assurance
- Automated CIP systems can provide full data logging for quality assurance requirements
- Hazardous cleaning materials do not need to be handled by operators
- Use of cleaning materials is more effectively controlled using a CIP system
3 CLEANING OBJECTIVES

Circulatory CIP system adapted to various parts of a processing plant has been developed to achieve good cleaning and sanitation results. Cleaning operations must be performed strictly according to a carefully worked out procedures in order to attain the required degree of cleanliness. In dairy cleaning operations the objective is nearly always to achieve chemical and bacteriological cleanliness. The equipment surface is therefore first thoroughly cleaned with chemical detergent and then disinfected. The following terms can be used to define the degree of cleanliness: 1) Physical cleanliness for removal of visible dirt from the surface, 2) Chemical cleanliness for removal of microscopic residues, 3) Bacteriological cleanliness to attain disinfection and 4) Sterile cleanliness for destruction of micro-organisms. It is easier to achieve bacteriological cleanliness if the surface in question is first rendered physically and chemically clean.

4 TYPES OF CIP SYSTEMS

4.1 Single Pass Systems

In a single pass system new cleaning solution is introduced to the plant to be cleaned and then disposed to drain. In most cases a single pass system would start with a pre-rinse to remove as much soiling as possible. The detergent clean and a final rinse would follow this.

4.2 Recirculation System

In a recirculation system the cleaning solution is made up in an external tank then introduced to the plant to be cleaned. It is recirculated and topped up as required until the cleaning cycle is complete. When the detergent clean is complete it is then normal to carry out a final rinse.

In general recirculation systems use less water & cleaning detergents but require greater capital outlay and in some circumstances may be unsuitable due to cross contamination from one process to another. We can if required calculate usage for these types compared to an existing system to demonstrate potential cost savings and pay back periods.

5 CIP CIRCUITS

For effective cleaning purposes dairy installations are divided into cleaning circuits, which can be cleaned at different times. Generally two different type of circuits are distinguished involving equipments like pasteurizers and other equipments with heated surfaces and secondly equipments with non heated surfaces like tanks and pipe systems. For effective CIP the equipment must be designed to fit into a cleaning circuit and must also be easy to clean. All surfaces must be accessible to the detergent solution with efficient drainage to avoid any pockets and traps for the residual water.

6 CIP PROGRAMS

The cleaning cycle in a dairy through CIP program for different circuit, in general, comprises of following stages to achieve acceptable results:

- Recovery of product residue by drainage and expulsion with water or compressed air
- Warm water rinsing for 10 minutes.
• Circulation of alkaline detergent (0.5-1.5% solution) at 75 C for 30 minutes.
• Warm water rinse for 5-8 minutes
• Circulation of acidic detergent (0.5-1.0% solution) at 75 C for 20 minutes.
• Post rinsing with warm water for 8-10 minutes.
• Thermal disinfection (90-95 C) and cooling for 10 minutes or chemical disinfection.

7 SYSTEM DESIGN

The CIP station in a dairy consists of all necessary equipment for storage, monitoring and distribution of cleaning fluids to the various CIP circuits. There are no limitations to satisfy stringent individual demands to the size and complexity of CIP plant. However, the exact design of the station is determined by factors such as number of cold and hot circuits to be served, cleaning requirement for each process vessel, milk rinses to be collected and processed or not, detergent solution for single pass or recovered for reuse and disinfection methods to be used. Other factors to be considered can include the size of the process vessels; standard of cleaning required, the available cleaning time and the type of cleaning medium.

With this information cleaning heads can be selected to meet the requirements described above. This then allows pumps to be selected to match the flow rates required for the heads and the type of cleaning material being used. The module size and configuration can also be calculated from this information.

7.1 Centralized CIP System

Such a system is used in small dairy plants with relatively short communication lines. Rinsing water, heated detergent solutions and hot water are supplied from this unit by a network of pipes to all CIP circuits in the dairy. The used solutions are pumped back to the central station and to their respective collecting tanks. Detergent recovered can be topped up to correct concentration for reuse and discarded whenever too dirty. A station of this kind is usually highly automated. The detergent tanks are fitted with electrodes that controls conductivity of cleaning solutions. At a preset value a change over valve routs the liquid into the drain. The CIP programs are controlled from a computerized sequence controller.

7.2 Decentralized CIP system (satellite system)

Such a system is an attractive alternative for large dairies where the distance between centrally located CIP Station and peripheral CIP circuits are extremely long. The large CIP station is replaced by number of smaller units located close to various groups of process equipment in the dairy. Various stages of cleaning program are carried out with carefully measured minimum volume of liquid enough to fill the circuit to be cleaned. Water and steam consumption can be greatly reduced. The concept of single use detergent has been introduced in conjunction with decentralized CIP. This allows optimization of detergent composition for certain circuit. Decentralized CIP system reduces the load on sewage system as compared to centralized CIP system.

8 PROCESS CONTROL

The control of CIP systems can very from simple manually operated valve for the rinse/clean/rinse/sanitize cycle to fully computer integrated controls with touch screen operator interfaces. Automation has progressed by use of industrial PCs that can control multiple CIP systems and manage hundreds of custom CIP programs. Systems
for pharmaceutical industry already meet the needs for electronic signature-capture and security features like operator ID are coming into play. As the knowledge of the concepts and techniques spread, equipment manufacturers began designing CIP features into their equipments. Today equipments pretty much comes pre-packaged with CIP.

If the CIP system is being used to clean a number of vessels, then to safeguard the vessels/plant not being cleaned it is necessary to have a safe valve or similar system. The double seat valve has a chamber between two valve seats. When the valve is open liquid will flow through. When it is closed the chamber between the two valve seats has an open part so that any cleaning liquid passing through the inlet seat will drain out of the chamber and cannot cause contamination at the outlet side of the valve. Another method of ensuring that there is no contamination of other process lines during cleaning is to use a swing bend flow plate system where a direct connection is made from the CIP feed to the pipeline feeding the process plant to be cleaned. Proximity switches may be used with the swing bend to ensure that the correct path is selected before valves can be opened and cleaning started.

9 VESSEL CLEANING

There are a variety of different spray devices available the selection of which is dependant on a variety of factors including capital and running costs, supply pressure, cleaning time, vessel size, spray type and soil type. Some of the most common are listed below.

9.1 Fixed Spray Balls

Fixed spray balls are low cost, low maintenance. They operate at low pressure (2 bar) but use high volumes of water. Cleaning times are long and range tends to be about 2-3 meters. These items have a fixed spray pattern and are not really suitable when the vessel is badly soiled or has material baked on.

9.2 Rotary Cleaning Heads for Smaller Vessels

Rotary cleaning heads are higher cost than spray balls. They operate at higher pressure but use a lower volume of water. They are normally more effective over shorter periods so reducing down time of plant and lowering detergent costs. They can be supplied with a variety of different spray patterns ranging from 180 degree down to 360 degree all around.

9.3 Rotary Cleaning Heads for larger Vessels

These heads are high-pressure units, with directional jets offering fast cleaning times. Higher capital costs are involved but fully indexed coverage at long range using low volumes of water and detergent will compensate for this.

10 STERILIZATION IN PLACE (SIP)

When process equipment reaches commercial-scale proportions, the sterilization of essential units by autoclaving becomes impractical and some means of sterilizing the equipment in situ is needed. Such installations, in order to comply with GMP, must be design, installation, and operationally qualified and the sterilization process must be validated. SIP installation will require confirmation that the process equipment, pipe work, and steam supply equipment meet preset specifications for materials and for pressure and temperature resistance. Attention must be paid to the quality of the steam, which will be used. The steam may also pass a micro-filter before use. The cleanliness of
the steam must be maintained by the use of pressure-grade stainless steel or Teflon®-lined tubing and suitably constructed pressure control and shut-off valves and pressure gauges.

10.1 Process

Steam under pressure is passed through the entire installation while allowing the escape of air through properly placed vents in the piping or on the equipment. Steam-resistant bacterial filters usually protect these vents. After a suitable period of steaming, the air vents are closed and steam pressure is allowed to build to the required level. Pressure is maintained during a preset period, and then the steam is released through a condenser. Temperature sensors in the system should indicate that the recorded pressure resulted in the required temperature being reached for sufficient time to ensure destruction of all contaminants. The validity of the sterilization process may be achieved by running culture medium through the sterilized set up in imitation of the manufacturing processes and then incubating a large number of media samples, or the entire batch, to ensure no bacterial growth occurs. Given the critical nature of the SIP procedure, it is probably a good idea to schedule revalidation of the installation at regular intervals.

11 CONCLUSION

The spread of CIP beyond dairy and the global nature of food production are adding fuel to the movement towards international sanitation standards. As production demands grow and downtime becomes a greater concern, CIP is more in demand. The notable change is the escalation in hygienic standards (degree of sanitation). Today, the expectations are for very tight cleaning ranges with microbial swabs and plate counts coming into play.

12 REFERENCES

http://www.i-h-s.co.uk
1 INTRODUCTION

Cleaning implies the removal of undesirable foreign substance from a solid surface. The aim of a proper cleaning procedure may be to produce (i) a physically clean surface, that is, the absence of an optically detectable or physically measurable deposits (ii) a chemically clean surface, that is, the absence of analytically detectable foreign chemical material; or (iii) a biologically clean surface, that is, the absence of any surviving microorganisms. It is a precondition for the production of hygienically satisfactory and high quality foods, that manufacturing equipments are scrupulously clean. Parts of the plant such as pipes, fittings, heat exchanger, tanks, containers, separators, evaporators, butter makers, fillers, cans, bottles, etc. must be cleaned immediately after the end of production.

2 TERMS USED

i. Rinsing: To remove any loosely adherent milky and other residual matter by washing lightly.

ii. Cleaning: The removal of the soil (e.g. residue of a product) from the surface of equipments. The thoroughly cleaned surface must be free from any visible, touchable or chemically detectable residue of the soil.

iii. Sanitizing: A process which reduces the number of microorganisms on plant and utensils to a level consistent with acceptable quality control and hygienic standards. After sanitizing, the surface shall not give a significant increase in bacteriological contamination to the product coming in contact with it. A broad interpretation of sanitizing is cleaning plus disinfecting.

iv. Disinfection: An operation usually carried out by the chemical agents or by heat which destroy pathogens or other harmful microbes but not ordinarily spores.

v. Sterilization: The act or process, mostly by heat, of killing all living cells.

Cleaning compound composition, concentration and cleaning method are dependent upon the type of soil on the surface to be cleaned. Soils from foods will vary as a function of the composition of the food and processing conditions at the surface upon which the soil is deposited. Food constituents are markedly different in their solubility characteristics and in their susceptibility to cleaning as shown in Table 1.

3 CLEANING-IN-PLACE (CIP) SYSTEMS

Manual scrubbing of tanks, vats etc. followed by hosing with water was formerly common practice. This cleaning method was time-consuming, expensive and often unsatisfactory in terms of bacteriological cleanliness. Manual cleaning has, in most dairies, now been replaced by mechanized and in many cases, automated cleaning. The technique is known as CIP, cleaning-in-place. This means that rinsing water and detergent solution are circulated through tanks, pipes and process lines without the equipment having to be dismantled.
### Table 1: Soil Characteristics

<table>
<thead>
<tr>
<th>Component on surface</th>
<th>Solubility characteristics</th>
<th>Ease of removal</th>
<th>Changes induced by heating soiled surface</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sugar</td>
<td>Water soluble</td>
<td>Easy</td>
<td>Carmelization, more difficult to clean</td>
</tr>
<tr>
<td>Fat</td>
<td>Water insoluble, alkali soluble</td>
<td>Difficult</td>
<td>Polymerization, more difficult to clean</td>
</tr>
<tr>
<td>Protein</td>
<td>Water insoluble, alkali, soluble, acid soluble</td>
<td>Very difficult</td>
<td>Denaturation, much more difficult to clean</td>
</tr>
<tr>
<td>Salts: Monovalent</td>
<td>Water soluble, acid soluble</td>
<td>Easy</td>
<td>--</td>
</tr>
<tr>
<td>Polyvalent (i.e., CaPO$_4$)</td>
<td>Water insoluble, acid soluble</td>
<td>Difficult</td>
<td>Interactions with other constituents, more difficult to clean</td>
</tr>
</tbody>
</table>

CIP can be defined as circulation of cleaning liquids through machines and other equipment in a cleaning circuit. The passage of the high-velocity flow of liquid over the equipment surfaces generates a scouring effect, which dislodges dirt deposits. This only applies to the flow in pipes, heat exchangers, pumps, valves, separators etc. the normal techniques for the cleaning of large tanks is to spray the detergent on the upper surfaces and then allow it to run down the walls. The mechanical scouring effect, be improved by the use of specially designed spray nozzle. Tank cleaning requires large volume of detergent, which must be circulated rapidly.

## 4 CIP CIRCUITS

The type of the equipment that can be cleaned in the same circuit is determined according to the following factors:

1. The product residue deposits must be of the same type so that the same detergents and disinfectants can be used.
2. The surfaces of the equipment to be cleaned must be of the same material or at least of material compatible with the same detergent and disinfectant.
3. All components in the circuit must be available for cleaning at the same time.

### 4.1 Compatible material and system design

For effective CIP, the equipment must be to fit into a cleaning circuit and must be easy to clean. All surfaces must be accessible to the detergent solution. There must be not dead end, which the detergent can not reach or through which it can not flow (fig 1). Machines and pipes must be installed in such a manner that they can be effectively drained. Any pockets or traps from which residual water cannot drain will provide sites for rapid multiplication of bacteria and cause serious risk of infecting the product. Material in process equipment such as stainless steel, plastic and elastomers, must be of such quality that they do not transmit any odour or taste to the product. They must be able to withstanding contact with detergent and disinfectant at the cleaning temperature. In some cases the surface of pipes and equipment may be chemically attacked and contaminate the product. Copper, brass and tin are sensitive to strong acids and strong alkalis. Even small traces of copper in milk results in oxidized flavour (oily, train-oil taste). Stainless steel is the universal material for product-wetted surfaces in modern dairies. Metallic
contamination is therefore normally no problem. Stainless steel can however be attacked by chlorine solutions. Electrolytic corrosion is common when components made of copper or brass are built into system of stainless steel. In such a condition the risk of contamination is great. Electrolytic corrosion may also occur if a system with steels of different grades is cleaned with cation-active agents. Elastomers (e.g. rubber gasket) can be attacked by chlorine and oxidizing agents, which cause them to blacken or crack and release rubber particles in to the milk.

![Image](image_url)

**Fig. 1 Examples of position difficult to clean in a pipe system**

Various types of plastic in process equipment may present a contamination hazard. Some of the constituents of some types of plastics can be dissolved by the fat in milk. Detergent solution can have the same effect. Plastic materials for use in dairies must therefore satisfy certain criteria regarding composition and stability.

**4.2 CIP Programmes**

The CIP programmes can be for circuits with heated surfaces and circuit with no heated surfaces. Acid circulation must always be included in the circuit with heated surfaces (e.g. pasteurizers) in order to remove incrusted protein from the surfaces. A CIP programme for a pasteurizer, “hot component”, circuit can consist of the following stages

1. Rinsing with warm water for about 10 minutes.
2. Circulation of an alkaline detergent solution (0.5-1.5%) for about 30 minutes at 75°C.
3. Post rinsing with cold water.
4. Gradual cooling with cold water for about 8 minutes.

A CIP programme for a circuit of pipes, tanks and other “cold components” can comprise the following stages.

1. Rinsing with warm water for 3 minutes.
2. Circulation of a 0.5-1.5 % alkaline detergent at 75°C for about 10 minutes.
3. Rinsing with warm water for about 3 minutes.
4. Gradual Cooling with cold tap water for about 10 minutes.

**4.3 Design of the CIP system**

The CIP station in a dairy consists of all necessary equipment for storage, monitoring and distribution of cleaning fluids to the various circuits. The CIP cleaning system may centralized or decentralized.
Centralized systems are used mainly in small dairy plants with relatively short communication lines, an example is shown in Fig 2. Water and detergent solutions and hot water are kept hot in insulated tanks. The required temperature is maintained by heat exchangers. The final rinse water is collected in a rinse-water tank and used as prerinsing water in the next cleaning programme. The milk/water mixture from the first rinsing water is collected in the rinse-milk tank.

![Fig. 2 Principle of centralized CIP](image)

Cleaning unit (within broken lines), Object to be cleaned
Milk treatment (A), Tank garden (B), Silo tanks (C), Filling machines (D)

The detergent solution must be discharged when they have become dirty after repeated use. The storage tank must then be cleaned and refilled with fresh solutions. It is also important to empty and clean the water tanks, especially the rinse water tanks at regular interval in order to avoid the risk of infecting a clean process line.

Centralized CIP works well in small dairies but in large dairies the communication lines between the central CIP pipe then contain large volume of liquids, also when they are discharge. The water means that large amount of concentrated detergent must be added in order to maintain the correct concentration. The greater the distance, the greater the cleaning cost. A move back towards decentralized CIP systems therefore began in large dairies at the end of the seventies. Each department has a CIP station.

6 DECENTRALIZED CIP

Decentralized CIP is an attractive alternative for large dairies where the distance between a centrally located CIP station and peripheral CIP circuits would be extremely long. The large CIP station is replaced by a number of small units, located to the various groups of process equipment.

The centralized CIP system still has a central design for storage, monitoring, concentration, adjustment and heating of the alkaline detergent, which is distributed to the individual CIP units in a single main line. Supply and heating of rinsing water (and acid detergent if required) are arranged locally at the satellite station.

These stations operate on the principle that the various stages of the cleaning programme are carried out with a carefully measured minimum volume of liquid (only enough to fill
the circuit to be cleaned). A powerful circulation pump is used to pump the detergent through the circuit at a high flow rate. (Fig.3) the circulating phase. The sequence of events in each stage is essentially the same: filling the tank, feeding the batch into the circuit, circulation and drainage of the circuit. Used water and acid detergents are directed to collecting tanks or to the drain, while the used alkaline detergent is pumped to the main line, it has many advantages like water and steam consumption can greatly reduced both momentary and total, milk residues from the first rinse are obtained in a more concentrated form and are therefore easier to handle and cheaper to evaporate. Decentralized CIP reduces the load on the sewage system as compared with centralized CIP, which uses large volume of liquid.

![Satellite CIP system](image)

**Fig. 3 Satellite CIP system**

*Storage tank for alkaline detergent (1), Storage for acid detergent (2), Ring line for detergent (3), Object to be cleaned (4), Satellite CIP unit (5), Decentralized CIP system with its own detergent tanks (6)*

7 **CLEAN-OUT-OF-PLACE SYSTEM (COP)**

Many small parts can be washed most effectively in a recirculating parts washer (sometimes called COP-clean out of place). These units are similar to sanitary pipes washer in that a sanitary tank is generally utilized in combination with a recirculating pump and distribution headers that provide considerable agitation of the cleaning solution. In some cases the parts washer may also serve as recirculating unit for CIP cleaning operations.

8 **CLEANING EQUIPMENTS**

For mechanical washing or cleaning operation different equipments are used in dairies. These equipments may be of either manually operated or power operated type. The different equipments generally used in medium or large dairies are summarized below.

8.1 **Rotary Can Washer**

The rotary can washer carries the inverted cans on a large rotating table. The table is mounted on a vertical shaft, and is rotated by means of an electrical motor through a warm gear drive. The movement may be continuous or intermittent. The cans are loaded manually on the table and it passes through the various sections, viz. pre-rinsing, washing, hot water rinsing sterilization and drying. The rinsing water and washing solution is
circulated through jets installed below the rotating table. The hot air is blown by means of a high speed blower. After drying, the cleaned can is taken out another can is loaded for washing on rotating table. (Fig. 4).

![Fig. 4 Rotary can washer](image)

8.2 **Straight-Through Can Washer**

This type of can washer carries the can through the washer in straight line by means of a continuously moving conveyor or slide along rail as they move intermittently from one jetting position to the next (fig. 5). The driving unit at regular intervals shoves the can forward from one position to the next. The pre rinsing (position 2) is done by spraying sufficient amount of wash water through jets inside can. The position 4 employs an acid cleaning by circulating acid solution. In the washing position (4 & 5), the washing solution at 65-70°C is circulated for two times. At position 6 and 7, hot water at a temperature between 80 and 90°C is used for rinsing. The sterile (position 8 & 9) is done by passing steam through jets at about 107°C temperature. After sterilization, hot air drying (position 10) is done by passing air at 124°C temperature.

![Fig. 5 Straight Through Can Washer](image)

8.3 **Cleaning of Tanks**

The introduction of mechanical methods put an end to the inadequacies of manual cleaning. There are high pressures jetting methods where a small amount of liquid is sprayed on to the walls under high pressure and low pressure jetting methods in which large amount of liquid coming from jet nozzle or rotating turbine nozzles are jetted over the tank walls. Good cleaning and sterilizing results were obtained in tank cleaning with steam jetting methods. The cleaning solution concentrate is atomized by steam according to the injector principle. Using this method the walls of the tank are heated and cleaning
and sterilization is done in one operation. Places that are difficult to reach can be cleaned by this method. For spraying tanks and vessels, spray cleaning devices of various types are used (Fig 6).

![Spray cleaning devices](image)

**Fig.6 Spray cleaning devices**

### 8.4 Cleaning of Evaporators

Difficulties are experienced in the cleaning of evaporators because of their closed design and large internal surfaces and because they are especially prone to the formation of deposits on surfaces which are not wetted. By the use of circulation and spraying with large volume of liquids, complete wetting of surfaces should be ensured. For vapour separators, supply of cleaning solution is often necessary since it is not possible to reach all parts by circulation or once through methods.

### 8.5 Cleaning of Dryers

CIP cleaning is done by fitting spray balls in the plant in such a way that the spray balls cover the entire interior surface. They are permanently placed in the ducts, cyclone and fluid beds (above and below the perforated plates). The spray balls are stationary, and in a large dryer 60-80 spray balls are required. It is possible to leave the spray balls in powder-carrying ducts, cyclone and fluid beds, because the plant is in operation, heated purging air is blown through the entire CIP system, thereby preventing the product from penetrating into the spray balls.

The chamber is cleaned by removing the atomizer and lowering a rotating jet cleaner down into the chamber. The rotating jet cleaner is very effective, as the water hits the surface at high pressure, thereby producing a mechanical action for the removal of wall deposits.

### 8.6 Cleaning of Heat Exchangers

Systems used for processing milk, skim milk and low fat products may be effectively cleaned by recirculating an acid detergent for 20 to 30 minutes and then over riding this by direct addition of a strong alkali which is then recirculate for 45-60 minutes. An intermediate rinse of cold water may be used between the acid and alkaline detergent.

Systems used for processing primarily creams and ice cream mix can be cleaned more effectively if the alkaline detergent is recirculate first for 30-45 minutes followed by intermediate rinse, and then recirculation of the acid detergent for 25-30 minutes.
8.7 Cleaning of UHT systems

Most modern equipment is designed to be CIP, by the circulation of suitable detergents and it is merely dismantled for cleaning or even for inspection. It may be found that some plant areas can not be satisfactorily cleaned by circulation and will need to be cleaned by hand or by steam injection. After processing the product should first be flushed from the heat exchanger and associated pipework with cold, clean water, for about 15 min. The circulation cleaning is then proceed using caustic soda, nitric acid and different heating temperatures. Intermediate cleaning and sterilization are very important steps for the cleaning of UHT plant.

9 REFERENCES


1. INTRODUCTION

Food antimicrobials are compounds used to extend the lag phase or kill microorganisms. They are different than therapeutic antibiotics (e.g. penicillin, tetracyclines) used to treat human or animal diseases. Food antimicrobials are sometimes called “preservatives”. The term “preservatives”, however, often include antioxidants in addition to antimicrobials. Antimicrobials may be classified as “traditional” or “naturally occurring” (Davidson, 2001). A number of traditional antimicrobials, e.g. acetic acid and benzoic acid are approved for use in food by most international regulatory agencies.

Sanitizers are intended to disinfect or sanitize, reducing or mitigating growth or development of organisms including bacteria, fungi or viruses on inanimate surfaces in the household, institutional and/or commercial environments. Sanitizers used by food manufacturers include chlorine and chlorine derivatives, iodine derivatives, quaternary ammonium compounds, acid-anionic sanitizers, hydrogen peroxides, peroxyacetic acid and acidified sodium chloride. Sanitizers are generally used to inactivate target microorganisms on the food contact surfaces of cleaned food processing and food service equipments.

During the past decade, production of food has become complex; the production volumes are larger, the operations are more mechanical, the food is more processed and the time and distance between production and consumption are longer. The focus on healthy food has resulted in more pressure on manufacturers to limit the use of chemical preservatives. The new trend in food production and consumption lead to an increased need for efficient sanitary practices in the food processing industry.

Resistance has been defined as the temporary or permanent ability of an organism and its progeny to remain viable and/or multiply under conditions that would destroy or inhibit other members of the strain. Any resistance of microorganisms to preservatives (or sanitizers) may be innate, apparent or acquired. Bacteria previously susceptible to an antimicrobial compound can acquire resistance through mutation or through genetic transfer processes. Resistance can also be conferred by biofilm formation on food processing surfaces as an adaptive response to protect colonies from cleaning and sanitation. If antimicrobials and sanitizers are to play a major role in effective control of food borne pathogens, food manufacture and others within the food industry must know about the potential for development of resistance among target microorganisms.

Little is known about the disinfectant resistance among food borne pathogens, but some studies on Staphylococcus spp and Listeria monocytogenes have been reported with resistance of 13% to QAC and 19% to benzalkonium chloride, respectively. Pseudomonas spp. are often isolated from food equipment surfaces and are important food spoilage organisms. Their ability to form biofilms confers intrinsic resistance to disinfectants. The resistance of enterobacteria to disinfectants is generally lower than for Pseudomonas sp. The occurrence of such resistant strains to disinfectant may represent...
an economic challenge for the food industry and also have implications for human health.

2. RESISTANCE OF MICROORGANISMS TO DISINFECTANTS

2.1 Limited diffusion through the biofilm

Bacteria growing as adherent biofilms are significantly more resistant towards antimicrobial agents (Korber et al., 1997). The proposed mechanism for resistance is that the glycocalyx may create a diffusion barrier to the antimicrobial agent (Stewart et al., 1998). Diffusion through a biofilm may be affected by charge (ionic) interaction between the glycocalyx and the antimicrobial agent, by an increase in the distance the agent must diffuse, by molecular sieving (size exclusion) and by the viscosity of the glycocalyx. Some researchers suggest that the polyanionic nature of the glycocalyx creates a barrier (charge interaction) to the diffusion of cationic antimicrobial agents. The glycocalyx matrix contributes to the biofilm resistance by cementing cells within biofilm anchoring them to one another and of the substratum. The binding of cells within this protective matrix increases the time required to suspend cells in the antimicrobial agent and increases the time required for the antimicrobial agent to contact cells that remain attached in the deepest portion of the biofilm. It was concluded that it is not the quantity of glycocalyx that causes resistance in biofilms, but that it is the interaction between the glycocalyx, the cells, the attachment and the antimicrobial agent that leads to enhanced resistance (Cloete, 2003).

2.2 Interaction and neutralization of the antimicrobial substrate by the biofilm

Glycocalyx matrix in a biofilm reacts with and neutralizes the antimicrobial agent (Brown et al., 1995). It has been suggested that iodine reacts with glycocalyx compounds and this interaction involves oxidation of the organic molecule by iodine (Alexander, 1983). Gram-negative bacteria growing in biofilms have a higher ratio of unsaturated to saturated fatty acids and a higher ratio of C16 to C18 fatty acids. Resistant bacteria show similar changes in membrane lipid profiles. Research has supported the theory that organic material is somehow attracted to the glycocalyx. At least some of these molecules must diffuse to and into the microorganisms embedded in the glycocalyx to facilitate the observed growth. Non-oxidizing biocides, being organic of small to intermediate size would also associate favorably with the glycocalyx. At least some would diffuse to and into the microorganisms embedded in the glycocalyx and exert their antibacterial activity. The mechanism of increased resistance must be related to altered surface properties of cells growing in the biofilm environment.

2.3 Metabolic state of the organisms in the biofilm

Resistance of biofilms towards antimicrobial agents has been explained by the imposition of slow, biofilm-specific growth within the biofilm (Huang et al., 1995). The physiological state of the cells and the nature of the habitat can do considerable variations in the susceptibility of bacteria to bactericides. The composition of the bacterial cell envelope does not change as a response to available or limiting nutrients, so that the barrier property of the envelope is affected. Exposure to sub-inhibitory concentration of bactericides can lead to phenotypic adaptations, resulting in a resistant cell population. In E. coli certain protein induced by heat or starvation stress also confer resistance to hydrogen peroxide and to ultraviolet light. Most bactericide resistance is due to adaptation, and the resistance phenotype is mostly lost upon removal of the bactericide. Antimicrobial treatment of biofilms resulted in cells near the biofilm-bulk fluid interface losing their respiratory activity first, whilst respiratory activity persisted
deep in the biofilm-bulk fluid interface. Slow or non-growing cells are less susceptible to a variety of antimicrobial agents when compared with cells grown in rich media at high specific growth rates (Gilbert and Brown, 1995).

2.4 Genetic adaptation

Reduced biofilm susceptibility, by genetic adaptation would require that at least some of the cells in a biofilm adopt a distinct and relatively protected, biofilm phenotype. It implies that reduced susceptibility of biofilm bacteria is genetically programmed. The multiple antibiotic resistance (mar) operon is a global regulator controlling the expression of various genes in *E. coli* which constitutes the mar, leads to a multi drug resistant phenotype, which includes resistance towards structurally unrelated antibiotics organic solvents and the disinfectant pine oil. (Maria-Litran *et al.*, 2000).

2.5 Outer membrane structure

Resistance to antimicrobial agents can be due to a mechanism of adaptation of the cell envelope. For bactericides to be effective, they must be able to penetrate the cell envelope and attain a sufficiently high concentration at the target site to exert their antibacterial action. Hydrophilic antibacterial agents are primarily prevented from entering through the outer membrane by the lipopolysaccharide layer and the underlying phospholipids, whereas outer membrane proteins exclude hydrophobic agents.

2.6 Efflux pumps

Multidrug efflux pumps can pump out a wide range of dissimilar compounds (Nickaoido, 1996). QAC efflux pump of *S. aureus* is coded for by two gene systems. The genes qac A and qac B encode for a high level of resistance, and qac C and qac D encode for a low level or resistance. qac C and qac D are further identical to ebr gene encoding for resistance to ethidium bromide in *S. aureus*, explaining why resistance to QAC is often concurrent with resistance to ethidium. The qac A codes for a 50 Kda protein that mediates energy-dependant efflux of both benzalkonium chloride and ethidium bromide. The qac C gene also mediates energy-dependant efflux of benzalkonium chloride and ethidium bromide (Rouche *et al.*, 1990). Active efflux or ethidium bromide was demonstrated in the naturally resistant *L. monocytogenes* strain (Aase *et al.*, 2000) and the adapted sensitive strain, but not the sensitive strain. This could indicate the resistant strains originated from initially sensitive strains that had been subjected to quaternary ammonium compound. The adaptation of *Pseudomonas aeruginosa* to grow in higher concentration of QAC is followed by changes in fatty acid composition (Sakagami *et al.*, 1989). The alteration of membrane fatty acids could not be the explanation for increase in resistance, because the changes were evident from the first subculture and remained steady through the adaptation to higher concentration of QAC (Mechin *et al.*, 1999). Therefore, additional resistance mechanism, such as efflux degradation of disinfectant, slime formation or modified targets probably also contribute to adapted resistance (Sidhu *et al.*, 2003).

2.7 Enzyme mediated resistance

Resistance to antimicrobial agents can be due to enzyme transforming the bactericide to a non-toxic form. Bacteria can degrade a host of aromatic, phenolic and other compounds toxic to several bacteria (Ma *et al.*, 1998). Examples of enzyme mediated resistance mechanism include heavy metal resistance and formaldehyde resistance. Metals include mercury, antimony, nickel, cadmium, cobalt, zinc, lead, copper, chromate and silver. Some heavy metal resistance genes are carried on plasmids, whilst others are chromosomal. The resistance phenotype is usually inducible by the
presence of the heavy metal. Studies on detoxification of formaldehyde by *Pseudomonas aeruginosa* and *Pseudomonas putida* indicated that formaldehyde is reduced by a NAD$^+$-glutathione-dependant dehydrogenase, giving formaldehyde NAD$^+$oxidoreductase.

### 2.8 Cross-resistance

Several investigators have reported cross-resistance between disinfectants (Lemaitre *et al*., 1998). Another subject that has been raised with regard to disinfectant resistance is the possibility of cross-resistance with antibiotics. It has been shown that broad-spectrum efflux of hydrophobic antibiotics, dyes, and detergents makes a significant contribution to the intrinsic resistance in several Gram-negative bacteria. Perhaps of more consequence is the association of qac genes with antibiotic resistance genes in mobile genetic elements, which is probably the primary cause of co-occurrence of QAC and antibiotics resistance.

### 2.9 Co-resistance

Co-resistance between QAC and antibiotics is of interest considering the widespread use of QACs in health care and food preparation facilities. The use of QAC in hospital settings may facilitate the introduction and spread of antibiotic resistance genes, just as the development of antibiotic resistance may introduce QAC resistance genes. While the presence of QAC resistance genes may not guarantee real-world disinfection failure, they certainly increase its probability and co-resistance of QACs and antibiotics requires vigilant monitoring of disinfection efficacy in clinical and food preparation situation. With the present knowledge, staphylococci seem to be in a special position with regard to cross-resistance between disinfectants and antibiotics.

### 3. RESISTANCE OF MICROORGANISMS TO TRADITIONAL ANTIMICROBIALS

#### 3.1 Benzoic acid and its salts

Benzoic acid and its salts were one of the first groups of antimicrobials approved for application to foods. Their prime purpose was to inhibit yeast’s and molds in acidic foods. The innate resistance of yeast and molds to benzoates is of greater concern than that of bacteria. Yeasts like *Schizosaccharomyces pombe*, *Zygosaccharomyces bailii*, *Pichia membranefaciens* are known to be resistant to benzoates. The mechanism, by which yeasts develop resistance to antimicrobials, is related to membrane permeability and the ability of the cells to continuously pump antimicrobials out of the cell. Some microorganisms on the other hand like *Bacillus*, *Pseudomonas*, *Corynebacterium*, *Micrococcus* and *Aspergillus* metabolize compounds like benzoic acid through their β-ketoadiapate pathway, in which benzoic acid is converted to succinic acid and acetyl CoA (Chipley, 1993).

#### 3.2 Sorbic acid

Sorbic acid has also been used as an antimicrobial in foods. Innate resistance to sorbate is demonstrated by bacteria including catalase-negative lactic acid bacteria, *Sporolactobacillus* some *Pseudomonas*, yeasts (including *Brettanomyces*, *Candida*, *Saccharomyces*, *Torulopsis*) and molds (including *Aspergillus*, *Fusarium*, *Geotrichum*, *Mucor*) (Sofos and Busta, 1993).

Yeasts have several mechanisms by which they can develop resistance to sorbic acid. One mechanism for acquired resistance that has been demonstrated among yeast is the triggering of an inducible energy requiring system that increases sorbic acid efflux. The mechanism by which organic acid inhibit microorganisms involves passage of the
undissociated form of the acid across the cell membrane lipid layer. Once inside the cell, the acid dissociates because of the cell interior has a higher pH than the exterior. Protons generated from intracellular dissociation of the organic acid then acidify the cytoplasm and must be extruded to the exterior. Yeasts use the enzymes, H+-ATPase, along with energy in the form of ATP to remove excess protons from the cell. Inhibition and/or inactivation may be due to eventual loss of cellular energy or inactivation or critical cellular function due to low intracellular pH.

Another mechanism used to prevent depletion of energy pools involves the induction of a membrane protein that can decrease the activity of ATPase to conserve energy (Brul and Coote, 1999). In addition, exposure of *S. cerevisiae* to sorbic acid can strongly induce a membrane protein ATP binding cassette transporter (Pdr 12), which is a “Multidrug resistance pump” hat confers resistance by mediating energy-dependent extrusion of anion (Piper et al., 1998). Similar mechanisms likely also exist for bacteria that are capable of developing resistance to sorbic or other propionic acids. Considering the length of time that sorbic and benzoic acids have been applied to food products it would seem, however, that the development of acquired resistance by spoilage and pathogenic organisms is very rare or non-existent.

4. RESISTANCE OF MICROORGANISMS TO NATURALLY OCCURRING ANTIMICROBIALS

Two microbiologically derived antimicrobials that have used for their impact on the development of acquired resistance are natamycin and nisin. Natamycin, formerly called pimaricin, is an antifungal produced by *Streptomyces natalensis* that is effective against nearly all molds and yeasts but which has little or no effect on bacteria.

4.1 Natamycin

De Boer and Stolk-Horsthuis (1977) investigated the potential for development of resistance to Natamycin among fungi. They reported no evidence of resistant fungi in cheese warehouse where natamycin was used for periods of up to several years. They also attempted to induce tolerance in 26 strains of fungi by transferring each culture 25-31 times in media containing concentrations of natamycin equal to and greater than MIC. Hence, they concluded that lack of increased resistance among fungi was due to the lethal (as opposed to static) activity of the compound with the compound’s instability over time.

4.2 Nisin

Microorganisms exhibiting resistance to nisin may inactivate the peptide via enzymatic action or any alter their membrane susceptibility (Montville *et al.*, 2001). *Streptococcus thermophilus*, *Lactobacillus plantarum* and certain species of Bacillus species that produce the enzyme nisinase neutralize the antimicrobial activity of the polypeptide (Hoover and Hurst, 1993). In addition spontaneous nisin resistant mutants, including *L. monocytogenes*, *C. botulinium*, *Bacillus* species and *S. aureus* could occur via exposure of wild strains or transfer of strains in media containing increasing concentrations of nisin. (Montville *et al.*, 2001).

5. CONCLUSIONS

To overcome the potential of development of resistant bacteria, there is a need to carry out extensive work in understanding the frequency and mechanisms of resistance to food antimicrobials and process stresses in food systems. Application strategies are to be
devised to minimize tolerance or resistance development. Simple methods need to be developed to overcome the potential for development of acquired resistance using appropriate antimicrobials, avoiding the use of sub-lethal concentration of antimicrobials, using hurdle technology and combination of antimicrobials.

The effective cleaning before disinfection, using recommended concentration of disinfectant, temperature and contact time and finally rinsing and drying of the surfaces after disinfection will in most cases will prevent problems with disinfectant resistant bacteria.

6. REFERENCES


1. INTRODUCTION

In contrast to Quality Control, which is a reactive system with emphasis on measurement that is statistically relevant and focuses on legal requirements, Quality Assurance is a preventive approach with an emphasis on operational procedures. These must be robust, regularly reviewed, and focused on the consumer. To establish quality parameters, the food microbiologist uses two approaches; the first sets out to determine the total load or numbers of microbes in a sample, and the second attempts to determine the presence or absence of a particular microbial species, usually a pathogen or related type used as their indicators. Thus, while the first type of microbiological quality assurance test aims to establish that food products meet statutory requirements, the second type of analysis is mainly focused on public health impacts; with regulatory requirements being an integral part of the testing procedure. Enumeration of specific microbial groups is of major importance and is directly associated with the safety or assessment of the risk of foodborne illness. The results are not always absolute in conventional testing and are often influenced by the method used. Moreover, the time taken to complete conventional microbiological assays has changed little over the years as it depends on the time taken for microbes to grow and multiply so as to give a visible colony on the surface of nutrient solid medium, colour change by the metabolism of specific chemicals, or obvious turbidity in the medium. Accordingly, much effort has been devoted to shortening assay times and to replacing the visible end points with alternative measurements.

The procedures used in conventional assays involve blending sample with a diluent, preparation of serial dilutions, and inoculation of liquid or solid growth medium followed by incubation for periods that may vary from 1 to 7 days. The visible colonies that have grown on solid medium are counted or the turbidity of liquid medium is noted. Further biochemical tests are often done, especially to confirm the identity of pathogens or organisms indicative of their presence. Thus, it may be seen that much of the routine of food microbiology is laborious, technically demanding and slow to yield results. In recent times, some of these steps have been mechanized, for example through the use of diluters, plate inoculators and colony counters, but the overall assay times have not altered much, even with the advent of improved and more selective media. In addition to the general testing requirements under quality control programmes, there has been an added element of quality assurance that is being pursued vigorously under the implementation of Quality Management Systems like ‘Hazard Analysis Critical Control Point’, commonly known as HACCP. To further enhance the utility of these proactive management systems there is a need to develop rapid techniques that are sensitive and accurate.

Several biotechniques are increasingly being employed for assuring the quality and safety of food products. The first symposium to focus on these methodologies was held in the USA in 1973 and was entitled ‘Rapid Methods in Microbiology and Immunology’. Since then, many new approaches have been described, like; Electrical methods (conductance or impedance, electrochemical assays), Chemical methods (direct...
epifluorescent filter technique (DEFT), bacterial ATP bioluminescence), Cytometry, Biosensors, Agglutination methods (immunological assays) and Nucleic acid technologies (polymerase chain reaction (PCR), ribotyping, microarrays) of which bioluminescence based procedures have found wide application as real time monitors.

The firefly luciferin-luciferase system is the most frequently used bioluminescent reaction for analytical purposes. It can be used for assays of ATP and any enzyme or metabolite participating in ATP forming or degrading reactions (cf. ATP monitoring). ATP can be used as a measure of biomass (amount of living material), since the intracellular level of ATP is similar in all living cells, and is rapidly degraded when the cell dies.

Rapid microbiology and hygiene monitoring are popular applications of the ATP assay. The gene coding for firefly luciferase has become one of the most frequently used reporter genes used in molecular biology to study transfer and expression of genes.

Bacterial luciferase combined with oxidoreductase enzymes can be used to monitor NADH and NADPH in a similar way, as is done with firefly luciferase for ATP. Horseradish peroxidase and luminol can be used to measure H₂O₂ production. Similarly, several enzymes and other substances participating in luminescent reactions may be used as labels in immunoassays. Thus luminescence analysis has many applications in a variety of areas. If, e.g., a completely new system for clinical analysis should be built up today, a likely candidate for the analytical system would be luminometry. This would enable all assays (assays of enzymes and metabolites, immunoassays and many bacteriological assays) to be performed using the same instrument. Some of the specific applications of bioluminescence as real time monitors are detailed below.

2. **ATP BIOLUMINESCENCE**

All living cells contain ATP (adenosine triphosphate), the high-energy intermediate that powers most energy-consuming reactions. The test depends on the reaction between ATP and the enzyme luciferase, producing light, which is measured photometrically, with a claimed sensitivity down to 10⁻¹⁶ mol ATP l⁻¹. It is a rapid test, taking <1 hour to complete. The light yielding reaction can be represented as follows:

1. \[ \text{Luciferase} + \text{Luciferin}(LH₂) + \text{ATP} \rightarrow (\text{Mg}^{2+})\text{Luciferase–Luciferin}(LH₂)–\text{AMP} + \text{PP}_1 \]
2. \[ \text{Luciferase–Luciferin}(LH₂)–\text{AMP} + \text{O}_2 \rightarrow \text{Luciferase} + \text{Luciferin}(L) + \text{AMP} + \text{CO}_2 + \text{hv} \rightarrow (\text{light}) \]

The light-yielding reaction is efficient, producing a single photon of light for every luciferin molecule oxidized and thus every ATP molecule used.

The Kits are based upon the bioluminescent measurement of ATP, present in all metabolically active cells. The emitted light intensity is linearly related to the ATP concentration and is measured using a luminometer. Bioluminescence is now the most widely used method for the assay of ATP due to its very high sensitivity, wide dynamic range and ease of use.

The problem with most foods is that they also contain ATP from non-microbial sources, and that the ATP content of microbial cells is variable depending upon their nature, type of microorganism (e.g. bacterium, yeast) and their physiological state. In addition the assay has no specificity. It is possible to destroy the somatic (food) cell ATP
by using detergents to lyse the cells and ATPase to destroy the ATP or to remove microbial cells from the sample by filtration prior to extracting their ATP.

However, the most widespread application of ATP measurement is as a hygiene test to monitor the cleanliness of food production areas. For this, the surface is swabbed and the total ATP on the swab is extracted and measured. For this application it does not matter whether the ATP is derived from food residues or from microorganisms, as both are indicative of an inadequately cleaned surface. There is interest in developing ATP bioluminescence for the detection of specific microorganisms. Current research is focused on combining ATP bioluminescence with techniques for specifically removing target organisms from food, such as immunomagnetic separation, or by specifically lysing target cells with bacteriophage.

Generally, clean surfaces show low levels of total ATP. Therefore, light output greater than 2 to 3 times background of the clean surface indicates that the area tested is contaminated with biological material. However, the method is very sensitive and in practice a threshold of 10 times background can be accepted. In all cases, users should determine the background ATP levels of all surfaces to be controlled. Testing surfaces immediately after they have been cleaned using the most rigorous cleaning techniques conveniently does this.

The bioluminescent method gives a measurement of total ATP on a surface, which is a very sensitive method for hygiene monitoring. This should be kept in mind when comparing with the results of conventional methods. A surface may well be sterile, but if it is contaminated by any biological materials (as indicated by the presence of ATP) it will provide for rapid growth of microorganisms. This source of contamination is detected by the ATP test but is missed by traditional microbiological methods.

Although it has been recognized for many years that ATP-bioluminescence could be exploited as a means of monitoring the hygienic status of materials, such as work surfaces, the technique required the development of luminometers to measure low light levels. Bioluminescence is now widely used to assess the hygienic quality of a work surface. Samples are taken by sweeping an ATP-free swab over a surface and then measuring the amount of ATP through a series of extract procedures. First generation instruments required the operator to swab a site (usually standardized at 10cm\(^2\)) and then immerse the swab in a releasing agent, mix with the luciferase-luciferin solution and place in a cuvette for the light reading. Once the second reagents had been added the light emitted had to be measured immediately. Therefore there were a number of pipetting steps plus potential delays in reading the values, which were all sources of error. Second generation instruments have the reagents in the swab handle, which are released over the swab tip when required and the whole unit is placed in the luminometer.

Correlation between standard plate counts and light output from an ATP bioluminescence assay is frequently good (r>0.85). However precise correlation should not expected since the method also detects non-microbial ATP, which in many real-life factory situations provides the majority of the ATP pool and non-culturable microbes. The absence (or low colony count) of microbial growth after sampling the test surface would indicate it was microbiologically clean. However food residues can serve to enable sublethally injured cells to recover. Hence the combined detection of microbial ATP and food debris is an advantage. A positive ATP value infers the sample is contaminated but does not determine whether it is due to microorganisms or food residues. Setting `in-house' acceptance values for luminescence readings can be
troublesome, for the reasons given above, if plate counts are used as the `golden rule'. A better approach is to set the level of bioluminescence criteria according to cleaning regimes that is the values obtained after a good clean and after a deep clean. These readings should be monitored to ensure that standards are maintained or even improved. Subsequently ATP-bioluminescence has become established as a means of monitoring the cleaning regime especially at a Critical Control Point of a Hazard Analysis Critical Control Point (HACCP) procedure. The examples of applications are extremely broad with widespread acceptance.

3. **LUMINOMETRIC DETECTION OF RESIDUAL CLEANING AGENTS AND DISINFECTANTS**

Chemical risks in food processing include cleaning agent and disinfectant residues remaining after insufficient rinsing of the process line. These detergents can be detected easily and at very low concentrations by using BioTox™ Toxicity Screening System. The method is non-specific and can be applied to both rinse waters and process surfaces. The detection time is only 5 minutes. The variation of detection limits for most commonly used agents is ranging from a 1/17 to 1/9615 dilution of the ready-to-use concentrations. Conclusions about the level of chemical contamination can be done if the agent and its response are known. The principle of the measurement is that the bacteria and the sample are mixed together and after an incubation period the light output is measured (with e.g. Aboatox 1253 Luminometer).

![Image of luminometric detection process]

4. **APPLICATION OF BIOLUMINESCENCE IN DEFT**

Automated microscopy methods have been widely applied. Due to the relatively low density and small size of microbes, they must be treated to stand out from the background mass. One such example is the Direct Epifluorescent Filter Technique (DEFT) that depends on the uptake of acridine orange by the cells. Viable cells fluoresce orange under ultraviolet light due to their ribonucleic acid (RNA) content, whereas dead or non-growing cells fluoresce green due to interactions of the dye with deoxyribonucleic acid (DNA). Samples are concentrated by filtration, stained and viewed microscopically. Image analysis equipment can be used to automate counting. These tests have been employed mainly on products that have not undergone a heat treatment (to prevent the possibility of misleading results) and food products that can be easily filtered. The sensitivity is only ~10^4 cells/ml. A variant of the technique is the hydrophobic grid membrane technique.

The DEFT is a labour-intensive manual procedure and the first fully automated instrument based on fluorescence microscopy was the Bactoscan (Foss Electric, Denmark). Milk samples placed in the instrument are chemically treated to lyse somatic cells and dissolve casein micelles. Bacteria are then separated by continuous centrifugation in dextran/sucrose gradient and are incubated with a protease to remove
residual protein, then stained with acridine orange and applied to a disc rotating under a microscope. The fluorescent light from the microscope image is converted into electrical impulses and recorded. Using bioluminescent markers has extended the application.

An instrument-based fluorescence counting method (Autotrak), in which samples were spread onto thin plastic tape, was developed for the food industry, but the debris from food samples interfered with the staining and counting and gave significantly higher results than corresponding viable counts.

5. APPLICATION OF BIOLUMINESCENCE IN CYTOMETRIC TECHNIQUES

Flow cytometry based techniques have been reported recently. The sample containing microorganisms is injected into a stream of fluid, which then passes a sensor where each particle is detected. The cells under investigation are inoculated into the centre of a stream of fluid (known as sheath fluid). This constrains them to pass individually past the sensor and enables measurements to be made on each particle in turn, rather than average value for the whole population, the sensing point consists of a beam of light (either UV or laser) that is aimed at the sample flow, and one or more detectors that measure light scatter or fluorescence as the particles pass under the light beam.

Fluorescent probes based on enzyme activity, nucleic acid content, membrane potential and pH have been developed and examined. Use of antibody-conjugated fluorescent dyes confers specificity to the system. Perhaps the most successful application of flow cytometric methods to food products has been the use of Chemunex Chemflow (D-Count) system to detect contaminating yeast in dairy and fruit products.

The technique is still in its infancy and although good results are being reported for some foods, sensitivity for specific detection of a particular organism in different foods is rather less developed. The success of the system depends on the development and use of suitable staining systems and the protocols for the separation of microorganisms from food debris that would otherwise interfere with the detection system.

Chemunex (Maisons-Alfort, France) has developed a relatively new cytometric technique based on Solid Phase Cytometry. In this procedure samples are passed through a membrane filter, which captures contaminating microorganisms. A stain is then applied to the filter to fluorescently mark metabolically active microbial cells. After staining, the membrane is then transferred to a Chemscan RDI instrument, which scans the whole membrane with a laser, counting fluorescing cells. The complete procedure takes about 90 minutes to perform and can detect single cells in filtered samples. It is ideally suited to the analysis of water or other clear filterable fluids, and special labeling techniques could be used to detect particular organism of interest.

6. APPLICATION OF BIOLUMINESCENCE IN AGGLUTINATION METHODS

Immuno-chemicals have been used for several decades to detect microflora in foods. Microorganisms are antigenic and, thus, stimulate the production of antibodies when injected into animals. Antibodies are protein molecules that are produced by animal white blood cells in response to contact with a substance causing an immune response. The area to which an antibody attaches on a target is known as the antigen. Two types of antibodies can be employed in immunological tests. These are known as
monoclonal and polyclonal antibodies. Polyclonal antibodies react with a broad range of antigens, whereas monoclonal antibodies are highly specific to particular antigenic structures. Both types of antibodies have been used in reagent kits for the detection and identification of specific type of bacteria, their surface structure and toxins. The antibodies are tagged to assist in the measurement of the antigen-antibody complexes. The most sensitive labels are radioactive isotopes but these cannot be used in food production environments, hence, fluorescent antibodies labeled with fluorescein or umbelliferones are most common. There have also been reports of the incorporation of antibodies, produced in plants, in packaging films. They show visible changes on reaction with the target microbes.

A number of agglutination reactions have been commercialized by manufacturers and have been successfully used within the food industry. They offer a relatively fast test time, are easy to use and require no specialist equipment; making them ideal for quality assurance applications. Good examples are the latex agglutination kits for Salmonella confirmation; Oxoid Salmonella Latex kit, Micro-screen Latex Slide, Wellcolex Colour Salmonella Test, Spectate Salmonella Test. The last two can even differentiate between serogroups. Agglutination kits have been also developed for the detection of microbial toxins.

Enzyme immunoassays have been extensively investigated as rapid detection methods for foodborne microorganisms. They have the advantage of specificity conferred by the use of a specific antibody, coupled with coloured, fluorescent or bioluminescent end-points that are easy to detect, either visually or with a spectrophotometer, fluorimeter or luminometer.

7. CONCLUSIONS

Bioluminescence based methods; especially ATP bioluminescence could prove to be a valuable tool in conjunction with visual assessment to ‘positively release’ plant after cleaning. Its use allows corrective action to be taken before production starts and reduces the risk of poor cleaning, resulting in product quality problems. Other uses are to optimize cleaning regimes and so contribute to cost effective chemical use. However, ATP Bioluminescence is not a direct replacement for microbiological testing. Such testing should still be carried out for monitoring background flora or checking for the presence of specific spoilage or pathogenic organisms. If used in conjunction with other control measures, a proactive and effective hygiene management system can be developed, and with regular review of results, the system can evolve and improve.

8. REFERENCES


TREATMENT OF DAIRY INDUSTRY EFFLUENTS THROUGH BIOLOGICAL PROCESSES

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The Dairy Industry in India has grown to a large size after independence. The annual production of milk in India has recently been estimated to be about 20-25 million tons. There are more than 100 plants in public sector units. Private sector plants have about 25 units producing 60-7,500 tons of milk products annually. The improved facilities to farmers have made it possible to collect milk over large areas and to bring it to central processing plant. This has resulted in higher concentration of waste and the dairy waste being rich in nutrients may endanger the aquatic life if let into rivers without treatment.

Effluents from dairy industries have COD of around 1500 mg/l. This effluent can be classified as a low strength wastewater. These effluents have high organic content, nutrients and suspended solids. Normally industrial effluents may have the toxic and synthetic inorganic compounds also. But in the case of dairy industry the effluents have easily biodegradable matter, which can pollute the receiving water bodies. Several methods of aerobic biological treatment have been tried out and have been successful to quite an extent, but have always had problems of handling the sludge produced during the treatment and also the high energy cost to operate the aeration units. Thus treatment of dairy wastewater by anaerobic methods is being studied in greater details.

However, a major problem expected while treating dairy industry effluents using the anaerobic route is the possible toxic effects of high molecular weight fatty acids on the methanogenic bacteria. The results of a batch reactor study, conducted to determine the effect of fatty acids commonly found in milk, are as follows: Seven fatty acids (butyric, palmitic, oleic, stearic, myristic, lauric and caproic acids) were added to each of seven batch reactors. These reactors had acetate as the primary substrate for the methanogenic bacteria. These reactors were inoculated with active methanogenic culture and incubated at 37°C. The results at the end of the batch operation are shown in Figure 1.

It can be seen that there was hardly any reduction in the organic carbon content of those reactors, which contained butyric, oleic or lauric acids. This indicates a total inhibition of the methanogenic bacteria since they could not degrade even the acetate present in the medium. While it may be true with oleic and lauric acids, it cannot be so with butyric acid since butyric acid is a common intermediate formed in almost all anaerobic reactors. Therefore, we can attribute it only to the high concentration of butyrate that was present in the reactor and the absence of acetogenic bacteria, which could break down the butyrate to acetate. In the case of the batch reactor containing myristic acid, the COD reduction was about 44%. This indicates the breakdown of the acetate present but the myristic acid was largely untouched; nor did it have any significant effect on the viability of the methanogenic bacteria. The concentration of each fatty acid used in these studies was approximately the value of that acid normally found
in undiluted milk. Since such high concentrations cannot exist in the effluent, toxicity and subsequent inhibition of methanogenic bacteria by these fatty acids is rather far fetched.

The results are summarized in the table below:

<table>
<thead>
<tr>
<th>Higher fatty acid present in the reactor</th>
<th>COD at the beginning of the batch (mg/l)</th>
<th>COD removal (percentage)</th>
</tr>
</thead>
<tbody>
<tr>
<td>ACETATE MEDIUM</td>
<td>2392</td>
<td>92.3</td>
</tr>
<tr>
<td>BUTYRIC ACID</td>
<td>6256</td>
<td>6.71</td>
</tr>
<tr>
<td>PALMITIC ACID</td>
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<td>STEARIC ACID</td>
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</tr>
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</tr>
<tr>
<td>CAPROIC ACID</td>
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</tbody>
</table>

The loading rates permissible in an anaerobic waste treatment process are primarily dictated by the concentration of the anaerobic microorganisms in the reactor. A waste treatment process for low strength wastes will be economic if a large volume of waste can be forced through the system in a relatively short time period. For this purpose, processes are required in which the biomass retention time can be controlled independent of the wastewater flow rate. Conventional anaerobic treatment processes of the flow through type are therefore inadequate to treat low-strength wastewaters. The
solution for the biomass retention problem resulted in the development of different anaerobic processes. New biotechnologies based on attached biofilm or microbial conglomerate processes have recently gained considerable interest.

In all the attached growth systems and in some of the suspended cell systems, the biomass is retained in the reactor for longer time (and hence solids retention time is independent of the hydraulic retention time). This is attained because in attached growth systems the biomass i.e. the microorganisms taking part in the treatment process, are attached to some inert surface which retains the biomass inside the reactor in spite of the high linear velocity of liquid inside the system. In some systems such as the upflow anaerobic sludge blanket (UASB) reactor, though the cells are in suspended form, they agglomerate to form larger clumps (granules) and remain settled in the system.

One type of attached growth system is the anaerobic rotating biological contactor (AnRBC). In the AnRBC, the cells taking part in the treatment process form a microbial film attached to the rotating disc. The organic matter present in the wastewater is degraded by the population of microorganisms attached to the disc. Organic materials from the liquid are adsorbed onto the biological film. As the microorganisms utilize the substrate, the thickness of the microbial film will increase. In the outer portion of the film, the microorganisms get the substrate in concentrations equivalent to that in the bulk liquid. But in the case of cells in the interior of the film, the substrate has to diffuse through the film. Due to this transport-related process, the substrate concentration gradually decreases as it goes to the inner side of the film.

The depth that substrate penetrates into the microbial film is dependent upon (a) waste water flow rate (b) the strength of waste water (c) the diffusivity of the substrate molecule into the film and (d) the rate of substrate utilization by the biomass. For high or medium strength wastewaters, though the concentration of substrate decreases from the substrate concentration in the bulk liquid to a lower value, the innermost layer may still be in contact with a substrate concentration sufficient enough to support its growth. But in the case of low strength wastewaters, as the substrate concentration in the bulk liquid itself is less; it may become zero before reaching the inner most layers. In that case the innermost layers will be in a substrate-limited substrate gradients in film condition.

In a study carried out for treatment of dairy waste waters using the anaerobic as well as RBCs, different hydraulic retention times were employed. The two reactors were operated under different feed rates i.e., 1 liter/day, 2 liter/day and 3liter/day. From the results obtained, we find that both aerobic as well as anaerobic RBCs were able to treat the dairy effluent with comparable efficiencies. For the AnRBC the startup time was more compared to the AeRBC. But after startup, the reactors showed similar efficiencies in treating the effluent.

From the data tabulated below, it can be seen that both AnRBC as well as AeRBC performed well in treating dairy industry effluent. In these types of fixed-film reactors, substrate availability inside the biofilm plays an important role in the efficiency of treatment.
<table>
<thead>
<tr>
<th>Reactor</th>
<th>HRT (hours)</th>
<th>COD of treated effluent (mg/l)</th>
<th>COD removal</th>
</tr>
</thead>
<tbody>
<tr>
<td>AnRBC</td>
<td>108</td>
<td>276</td>
<td>0.8512 kgCOD/m³/d</td>
</tr>
<tr>
<td></td>
<td>54</td>
<td>184</td>
<td>0.9442 kgCOD/m³/d</td>
</tr>
<tr>
<td></td>
<td>36</td>
<td>100</td>
<td>1.020 kgCOD/m³/d</td>
</tr>
<tr>
<td>AeRBC</td>
<td>236.25</td>
<td>184</td>
<td>0.9094 kgCOD/m³/d</td>
</tr>
<tr>
<td></td>
<td>135</td>
<td>176</td>
<td>0.9296 kgCOD/m³/d</td>
</tr>
<tr>
<td></td>
<td>90</td>
<td>100</td>
<td>1.020 kgCOD/m³/d</td>
</tr>
</tbody>
</table>

In AnRBC treating dairy industry effluent, performance improved when hydraulic retention time was decreased as seen from the COD removal data. It was also observed that development of the biofilm on the carrier surface improves the biodegradation rate of organic matter. In the case of the AeRBC, formation of biofilm was rapid and as a result the COD removal improved at a faster pace. After the formation of a thick biofilm in both reactors the efficiency increased. With reduction in hydraulic retention time the COD removal improved in both the cases. This is quite surprising and the only way to explain this observation is in terms of the increased biomass concentration on the disks at lower HRTs since the experiments were conducted in a continuous stretch, starting with the higher HRTs.

Another recent development in the treatment of dairy effluents using anaerobic bacteria is the use of the anaerobic hybrid reactor. This is an upflow anaerobic reactor wherein the microorganisms are grown in form of granules and are kept in a fluidized state for better interaction with substrate material. In this concept there is no support media used. Only the system conditions of pH, temperature, and active inoculum acclimatized to the particular substrate is needed. The anaerobic microorganisms, both acidogens and methanogens, form flocs as they grow with time under favorable anaerobic conditions and grow into granules, thereby creating high cell density in the reactor. Taking advantage of the mass of the granules the upflow keeps them in fluidized conditioned so as not to let them settle at the base of the reactor and at the same time not carrying them out of the system. This ensures better interaction of the granules with the incoming substrate material leading to faster removal of COD from the wastewater. A very short HRT (Hydraulic Retention Time) is needed for treatment by this process, thereby needing much smaller reactor volume as compared to the other processes.

The best results obtained for three hybrid reactors are tabulated below. It can be seen from the results that a very high degree of COD removal could be obtained. The HRT values as low as 2 hours with effective COD removal could be achieved for treating the Dairy wastewater by this type of anaerobic hybrid reactor. There is a requirement of acclimatization of the microorganisms to the reactor environment at low loadings for about seven to fifteen days while starting up the reactor for the granules to form and then the loading can be gradually increased.
<table>
<thead>
<tr>
<th>Reactor</th>
<th>COD removal (Kg COD/m$^3$ of reactor volume/day)</th>
<th>HRT (hours) (Minimum value achieved)</th>
</tr>
</thead>
<tbody>
<tr>
<td>HR-1</td>
<td>30</td>
<td>8</td>
</tr>
<tr>
<td>HR-2</td>
<td>30</td>
<td>1.8</td>
</tr>
<tr>
<td>LHR</td>
<td>10</td>
<td>2.5</td>
</tr>
</tbody>
</table>

The successful operations using the laboratory scale hybrid anaerobic reactors have prompted us to take it up to the pilot plant level and is expected to materialize in the near future. The Department of Biotechnology, Government of India, is likely to support these studies. The basic data on the proposed pilot scale unit will be as follows:

- Capacity: 10,000 litres of untreated effluent per day
- HRT: 2.0 hours
- Inlet COD: 1200 mg.l$^{-1}$
- Outlet COD: Below 100 mg.l$^{-1}$
- Gas production: 5400 litres (STP) per day.
- Methane content in gas: 65-70%
- Reactor volume: 800 litres (approx.)

While the effluents generated by the dairy industry could be treated effectively by the conventional activated sludge system, application of the high cell density anaerobic systems will make it much more attractive as well as cost effective. The gas generated in these units could be used as a supplementary fuel in the boilers and the resultant savings in boiler fuel is expected to pay back the entire cost of installation of the plant in a reasonable period of time.
1. INTRODUCTION

In the recent past, the production of food has become complex and food processing and preparation operations have grown in terms of volumes. Such new trends in food production and consumption have led to an increased need for efficient sanitary practices in the food industry.

Further, with the liberalization of global food market under WTO regime, food supply has gained the potential to spread pathogens & other contaminants, which were once geographically isolated at one place. To minimize the risk of food borne illnesses and health hazards to the consumers, Codex standards have been recognized as the international standards by WTO. Considering the inadequacy of finished product testing to ensure safety and suitability of food, Codex committee on food Hygiene (CCFH) has developed guidelines on general principles of food hygiene to be implemented throughout the food chain in order to prevent food contamination.

The contaminants enter the food chain via environment, water, food contact surfaces, raw materials, or through personnel handling the food. Food handlers are the potential source of bacteria causing food borne illnesses, which are at best unpleasant, and at worst they can be fatal. As the health costs increase, added emphasis is placed on preventive medicine, of which, food sanitation may be considered to be a part when one considers the benefits of prevention of food borne diseases.

Therefore, we need to understand the role of food handlers vis a vis quality and food safety concerns agreed under sanitary and phytosanitary declaration of WTO. Harmonization of national regulations/ standards based on risk assessment approach to reorient our sanitary practices is a major issue to deal with the present food safety crisis.

2. FOOD HANDLER: A POTENTIAL SOURCE OF CONTAMINATION:

Outbreaks of foodborne illnesses date from the inception of food industry. Bacterial infections including Diphtheria, Scarlet fever, Tuberculosis and Typhoid fever predominated before World War II and were attributed to poor personnel hygiene and sanitation, inadequate food handling and animal health issues.

3. TRANSMISSION OF DISEASE CAUSING ORGANISMS

Pathogenic organisms causing illnesses could come from the animal, the human handler, the environment, water, equipment, air, and raw materials or due to poor sanitation practices. The food handler may transmit the disease causing organisms directly to food via atomized particles extruded from the nose/mouth while talking, sneezing or coughing over raw material, packing material, food itself or indirectly through doorknobs, pencils, books, washroom fittings, clothing, money, knives and equipment. The latter could be prevented by foot-operated controls at washbasins, self-closing doors etc. The transmission of a contaminant could be either from ill or from carrier food handlers. An ill person shows the symptoms of the disease. Carriers are divided into 3 groups:
Convalescent carriers are the people who after recovering from an infectious disease continue to harbor the causative organisms for variable length of time, usually less than 10 weeks.

Chronic carriers are people who continue to harbor the organism indefinitely although they do not show symptoms of disease (a constant threat to food plants are the food handlers who possess the pathogenic variety of Staphylococci as part of their natural skin flora.)

Contact carriers acquire & harbor a pathogen through close contact with an infected person but do not acquire the disease.

Some common human illnesses transmitted through foods are Respiratory diseases like Common cold, sore throat, Pneumonia, Scarlet fever, tuberculosis etc and intestinal disorders like diarrhea, nausea, vomiting, typhoid, infectious hepatitis etc.

4. PERSONAL CLEANLINESS
The word sanitation is derived from a Latin word ‘sanities’ meaning ‘health’. The goal of sanitation is attainment & maintenance of hygienic & healthful conditions. “Hygiene” means practices necessary for establishing & maintaining good health. To explain the importance of employee hygiene practices, it is beneficial to look at different parts of human body in terms of potential sources of contamination.

4.1 Skin
The epidermis the outer layer of skin has corneum on the outermost side, which forms an impermeable barrier to microorganisms. New cells replace this layer as they wear away. The inner layer of skin, Dermis unlike epidermis has blood & lymph vessels, nervous tissue, glands and ducts. The glands of dermis secrete perspiration and oil. When perspiration, oil and dead cells mix with environmental substances such as dust, dirt and grease, they form an ideal environment for bacterial growth. Thus the skin becomes a potential source of bacterial contamination. Food borne illness may occur if a food handler is a carrier of Staphylococcus aureus or S. epidermidis, two of the predominant species present on the skin, hair follicles and ducts of sweat glands. They are capable of causing abscesses, boils and wound infections. Keeping the skin clean helps to prevent skin disorders.

4.2 Fingers
The hands may pick up bacteria when they touch dirty equipment’s, contaminated food, clothing or other areas of body or may spread through dirty fingernails. The employee should use hand dip sanitizer / plastic gloves to reduce transfer of contamination.

4.3 Hair
Microorganisms especially Staphylococci are found on hair. Washing hair twice a week, avoiding scratching of head and wearing a headgear should give adequate protection from contamination through hair.

4.4 Eyes
The eye itself is normally free of bacteria but mild bacterial infection may develop, resulting in bacterial presence on eyelashes and at indentation between the nose and eye. By rubbing the eyes, hands are contaminated.

4.5 Mouth
Many bacteria including those causing diseases could be found in mouth and on the lips, which could be transferred to food, through sneezing, smoking, spitting. Brushing teeth prevents the buildup of bacterial plaque on teeth & reduces degree of
contamination through mouth. Prohibition of spitting, smoking eating and chewing and use of facemask in food handling areas reduces contamination.

4.6 **Nose, Nasopharynx & Respiratory tract**

The nose and throat have a more limited microbial population than mouth because of the body effective filtering system and virus inactivating agents found in serous fluid of the nose. Occasionally Staphylococci, Streptococci and Diphtheroids may inhabit upper respiratory tract/ tonsils. But the ailments associated with respiratory system are all highly contagious like, common cold, sinus infection, sore throat, scarlet fever, bronchitis, tonsillitis, and influenza. Employees with any of them should not be permitted to work; they not only endanger the products they handle but also fellow employees, through their coughs and sneezes which contain atomized droplets of mucous containing the infectious agent.

4.7 **Excretal organs**

Approx. 30-35% of the dry weight of intestinal contents of humans is composed of bacterial cells including coliforms, *Streptococcus faecalis*, Enterococci, Salmonella, Shigella etc. Feacal contamination could spread from clothing, improperly washed hands to other employees and to food product.

5. **STRATEGIES FOR ACHIEVING EFFECTIVE PERSONAL HYGIENE AND SANITARY CONDITIONS**

5.1 **Codex guidelines**

The Codex guidelines on Food Hygiene Training should be implemented in letter and spirit by all food Plants. All personnel should be made aware of their role and responsibility in protecting food from contamination or deterioration. Food handlers should have the necessary knowledge and skills to enable them to handle food hygienically.

5.2 **Food handlers’ employees’ responsibilities**

5.2.1 **Health:** Employees should maintain a good physical, mental and emotional health to reduce respiratory or gastrointestinal disorders and other physical ailments.

5.2.2 **Illnesses/Wounds:** Injuries including cuts, burns, boils and skin eruptions should be reported to employer. Abnormal conditions such as respiratory system complications like head cold, sinus infection, bronchial or lung disorders & intestinal disorders such as diarrhea, should be reported to the employer so that work adjustments can be made to protect food from the handlers illness or disease.

5.2.3 **Hygiene:** Personal cleanliness that should be practiced includes daily bathing, hair washing at least twice a week, wearing clean undergarments and uniform and maintenance of short & clean fingernails.

5.2.3.1 **Hygienic practices**

a. Habits such as scratching the head or other body parts, tobacco chewing, eating, smoking in food processing areas should be stopped
b. The mouth and nose should be covered during coughing and sneezing
c. Hands should be kept out of food. Food should not tested from the hand nor should it be consumed in food production areas
d. The hands should be washed thoroughly with soap under warm running potable water after visiting the toilet, using a handkerchief, and smoking, handling soiled articles and handling money.
e. Rules such as “no smoking” should be followed and other precautions related to prevention of contamination should be taken
f. Where required employees must use disinfectant hand dips.
g. Employees should not touch exposed food. Food contact surfaces or food packaging material with bare hands but should use spatulas tongs or gloves. When gloves are used employees should wash their hands before putting on gloves. Multi use gloves should be washed & sanitized while single use gloves should be discarded and replaced after the employee touches any non-product contact surface. Gloves worn outside the food production area should be discarded before returning to the food production area.

h. Employee should use footbaths containing sanitizer when entering food production areas.

i. Objects that may fall into or otherwise contaminate food like jewelry, watches, and pens must be removed.

j. Personnel effects & street clothing must not be kept in food handling areas & must be stored in a manner to prevent contamination of food.

5.3 Management responsibilities

5.3.1 Hygiene policy: Food Organizations should establish personal hygiene rules that are clearly defined and uniformly and rigidly enforced. These regulations should be documented and pasted and / or spelled out in booklets. The policy should address personal cleanliness, working attire, acceptable food handling practices, prohibited practices like tobacco chewing, smoking etc. Employers should be responsible for making certain that the public is protected from unsanitary practices that could cause public health concerns.

5.3.2 Facilities and infrastructure: Safe food handling requires appropriate equipment and supplies.

a. Equipment: Food handling & food processing equipment should be constructed according to regulation of appropriate regulatory agency.

b. Garments: Gloves, footwear, smocks, should be made of impermeable material, in good repair and easily disposable.

c. Hand washing: Hand washing stations to have knee /foot/ elbow operated faucets and remote operated liquid soap dispensers hand sanitizing facilities should be at each location where good sanitary practices dictate there use. Effective hand cleaning & sanitizing preparations, water at suitable temperature, sanitary towel services or suitable drying services to prevent cross contamination.

d. Welfare facilities: Toilet dressing rooms should be clean, well lighted, located away from production areas. Canteen area should be clean & free from insects and spills.

5.3.3 Enforcement of hygiene implementation:

a. Supervision: Supervisors should observe employees daily for infected cuts, boils, respiratory complications & other evidences of infections.

b. Self hygiene: Supervisors & managers should set an example for employees by their own high level of hygiene &good health.

c. Employee selection: Responsible employers should exercise caution in selecting employees by screening unhealthy individuals through a pre employment medical examination.

d. Regular medical examination: Regular medical examination should be conducted on all employees on intervals specified in the system.

e. Visitors: Instructions should be in place for the precautions to be taken by the visitors & outsiders. Employers should be responsible for making certain that the public is protected from unsanitary practices that could cause public health concerns.
5.4 Sanitation training

Since no formal training or education is usually required, a job, as a worker, in the food industry is frequently the first employment for young people and often on a part time basis while these persons are still pursuing their high school or graduation studies. The age, the multiple responsibilities of school/studies, home and work lead to a very rapid employee turn over job change rate in this industry. With the combination of low pay scale and the temporary nature of employment, added to sometimes-inconvenient work hours, the high turn over rate is easily understandable. As a result, there is a frequent need to train new employees in the machines of the job as well as sanitation principles and practices. Workers who understand the reasoning behind sanitary practices and the biological basis for the reasoning will be able to abide by the practices better. Training programs should be an on-going process and not a one-time event. Induction training to new workers and refresher training for the regular employees should form a part of the management system. Training needs of staff and workers vary therefore these should be routinely reviewed and updated where necessary.

5.4.1 Suggested topics: The following are the suggested topics that could be included in a sanitation-training program of the food handler.

a. Food borne diseases: What are the causes and how to prevent them?
b. Food protection: how and why?
c. The nature of food: in particular its ability to sustain growth of pathogenic or spoilage micro organisms.
d. Contamination of food: Where and when does it happen during processing and packaging, storage, transportation with various kind of contamination physical chemical or microbiological via air utensils and equipment, other food contact surfaces, water, raw material food ingredients, additives etc. and most often through personnel.
e. Importance of cleaning and sanitizing equipment & storage and reuse of equipment.
f. Safe handling techniques of strong cleaning chemicals and potentially hazardous toxic chemicals like insecticides & pesticides.
g. The role of personal or food handler: health; illness; personnel hygiene or cleanliness.
h. Sanitary practices including good manufacturing practices (GMP) and good hygiene practices (GHP).

5.4.2 Employee education & training on HACCP: Product safety systems are people programs. Training and educating people are an essential part of safety system. Employees must develop an awareness of safety and create a pro-active environment for dairy product safety. The training & education on HACCP should include pre requisites for HACCP, Principles of HACCP, Benefits of HACCP, Role that the staffs plays in product safety for example action to be taken when a CCP deviates from its critical limit.

5.4.3 Assessment of training: As the ISO 9001: 2000 version of the QMS demands, periodic assessment of the effectiveness of training and instruction programs should be made as well as routine checks that processes are being carried out under sanitary conditions.

5.5 Food sanitarian

The appointment of a Food Sanitarian should be a paramount ingredient in a sanitation program of every Food Plant. The food Sanitarian is responsible for development, effective implementation and periodic revision of SSOP’S (Standard Sanitation Operating Procedures). These procedures are fundamental to the success of
Sanitation Program of every Food Plant. SSOPs should also be defined for maintenance of Personnel Hygiene and hygienic practices.

5.6 Automation

Modernization of infrastructure would obviously involve automation and thus, less chances of food contamination through food handlers. Nevertheless, the latter’s education on his role and responsibility towards ‘Safe Food‘ manufacture is fundamentally important.

6. CONCLUSIONS

A free global food trade in the post WTO regime has increased the chances of pathogens crossing international borders. This presents a challenge to every employee in the food production and processing industry. To accept the challenge, the ideal would be to have mandatory Sanitary Training Certification for all food industry workers. But the cost would be too great in consideration of the benefits derived. Certification of Managers, however, could be a step toward accomplishing the same objective. Such a training if effectively percolates down to the shop floor level would not only provide benefits to the owner in food savings and winning customer’s delight but also benefit the customer in better food and reduction of food borne disease outbreaks.

7. REFERENCES

1 INTRODUCTION

The evidence is clear, and public-health officials and experts agree: single-use foodservice packaging is a safe, sanitary and sensible means of serving food and beverage. With increasing concerns about food-borne disease, this is reassuring news indeed for both food-service professionals and patrons. Single-use foodservice products are an important part of our nation's modern food-safety and sanitation system. They are a vital, yet often overlooked, way to guard against food-borne disease. Because foodservice packaging products are so integral to many foodservice operations, people generally tend to forget these products' historical role in safeguarding public health. Public-health concerns over the spread of disease through common public drinking cups prompted the introduction and widespread use of disposable cups early in the 20th century as a sanitary solution. The foodservice packaging industry is committed to providing clean, safe single-use containers and packaging for serving food and beverage in a sanitary manner.

2 FOOD PACKAGING

Packaging can be defined as a tool that protects and contains our goods with the aim of minimising the environmental impact. Considerable advancements have taken place in area of food packaging. A major change has been our ability to protect and preserve products with Packaging. We have ensured the availability of products out of season, over long distances in various forms, fresh as well as processed. Today, the consumer has a wider selection of food items.

Packaging has become a socio-scientific discipline with the modern role of:

- Containing and safety that is of paramount importance.
- Facilitating the handling, storage and distribution.
- Protecting against biological, chemical and distribution damages
- Providing convenience
- Informing through the medium of labeling
- Security through a tamper evident design
- Contributing to the product image through structural and graphic design
- Increasing the shelf life and ensuring longer availability.
- As a marketing and advertising tool.
- Environment protection by taking responsibility of empty packaging after its use.

3 SANITATION

The U.S. Food and Drug Administration’s Food Code, which serves as a model for state and local public health standards, authoritatively spells out the sanitary and health advantages of single-use foodservice packaging. According to the code, "In situations in which the reuse of multiuse items could result in food-borne illness to consumers, single-service single-use articles must be used to ensure safety."
food causes most food-borne illnesses. However, the FDA now confirms that improperly cleaned and sanitized foodservice utensils can also transmit food-borne disease, a threat that single-use products can help minimize. If cups, glasses, plates, flatware and other reusable items cannot be properly cleaned and sanitized due to inadequate facilities or equipment, the FDA specifically directs foodservice operators to use single-use foodservice packaging.

3.1 Sanitation standard operating procedures during packaging

Each processor should have a written sanitation standard operation procedure (SSOP) that is specific to each location where fish and fishery products are produced. These sanitation controls need not be included in the plant’s Hazard analysis of critical control point (HACCP) plan. Sanitation control records must document SSOP monitoring and corrective actions. The SSOP should address at least the following sanitation conditions and practices concerning packaging:

<table>
<thead>
<tr>
<th>Condition/Practice</th>
<th>Recommended Inspection</th>
</tr>
</thead>
<tbody>
<tr>
<td>Protection of food, food-packaging material, and food-contact surfaces from adulteration with lubricants, fuel, pesticides, cleaning compounds, sanitizing agents, condensate, and other chemical, physical, and biological contaminants.</td>
<td>Daily before the start of operations</td>
</tr>
<tr>
<td>Food, food-contact surfaces, and food-packaging materials shall be protected from contaminants that may drip, drain, or be drawn into the food. Compressed gases that contact food or food contact surfaces of equipment shall be filtered or treated in a way that ensures that they will not contaminate the food with unapproved indirect food additives or other chemical, physical, or microbiological contaminants.</td>
<td>As necessary to ensure control</td>
</tr>
<tr>
<td>Proper labeling, storage, and use of toxic compounds. Toxic compounds shall be identified, held, used, and stored in a manner that protects against contamination of food, food-contact surfaces, or food-packaging materials. The plant is designed to minimize the risk of contamination of the food, food-contact surfaces, and food-packaging material</td>
<td>Daily before the start of operations</td>
</tr>
<tr>
<td>Control of employee health conditions that could result in the microbiological contamination of food, food-packaging materials, and food-contact surfaces.</td>
<td>Daily upon arrival</td>
</tr>
<tr>
<td>Exclusion of pests from the food plant.</td>
<td>Daily</td>
</tr>
</tbody>
</table>

3.2 Single-use foodservice packaging

Nearly half of the outbreaks of food-borne disease occur in restaurants, cafeterias, schools, and other foodservice operations, according to the Centers for Disease Control and Prevention. For good reason, foodservice managers rank overall sanitation as their number-one issue of concern. As eating out and ordering food "to go" becomes more and more a part of our everyday lives, single-use foodservice packaging is a practical, economical way to reduce the potential for the adulteration of food from improperly cleaned and sanitized dishware and utensils. When properly stored and handled,
foodservice packaging products help foodservice operators meet the spirit, as well as the law and convey a sanitary image.

3.2.1 Resolutions adopted for single-use foodservice packaging: As several resolutions from major environmental health organizations demonstrate, public-health professionals continue to recognize the important role of single-use foodservice packaging:

- "Paper and plastic articles continue to be an appropriate and necessary alternative to reusable in many foodservice circumstances, e.g. fast-food, take-out, 'Meals on Wheels,' isolation units, temporary events and others. Restricting the use of paper and plastic cups, plates and containers will have a potentially adverse impact upon the extra measure of disease prevention that disposables bring to certain foodservice systems".
- "Single service products contribute significantly to sanitation levels in food service and packaging and constitute an essential element in preventing food-borne disease."

3.2.2 Scientific Studies: The scientific studies have shown that single-use foodservice packaging products are significantly cleaner than reusables. They offer less opportunity for contamination from careless handling or poor dishwashing.

A study involving 107 foodservice establishments in four cities showed that more than 17 percent of the reusable items tested exceeded the 100 colonies-per-utensil standard. However, only 3 percent of the single-use items tested exceeded this standard. Average counts for microorganisms on reusable ware were more than three times higher than on single-use items. The study concluded that "Single-use foodservice ware is significantly more sanitary than reusable foodservice ware at the point just prior to the consumer receiving the items."

3.3 Packaging equipment design and food safety

Safety and sanitation, from plant design to cleaning procedures, are a top priority for food processors and packagers. New design elements of packaging equipment are a vital part of this continuous evolution of food safety and sanitation. These new elements help plant managers more effectively implement cleaning practices and, in many cases, the new designs also create a more efficient overall process. Various organizations, governmental and private, offer guidelines to equipment manufacturers on sanitary designs - information that can be vital to plant managers and owners in selecting packaging equipment.

3.4 Sanitation system for food packaging

Many features that enable easier sanitation on systems are visible and obvious while others exist out of view or are not visually apparent. For example, in order for many parts of a packaging system to be cleanable to a microbiological level, the grade of stainless steel must be polished to a very high degree to reduce the grooves formed in the metal. The effects of these efforts are not visible to the naked eye but can significantly reduce the chances of contamination. Hermetically packed and sealed or solid components are another feature that is not visually apparent. On many systems hermetic seals on hollow parts or changing a hollow part into a solid part is a major change that isn't visibly discernable. This ensures that these areas do not become inadvertent collection points.

3.4.1 Protection of Food and Food-Packaging from Contaminants: The supervisors should receive basic food sanitation training. Hair restraint use, glove use, hand washing, personal belonging storage, eating and drinking in processing areas, boot
sanitizing, use of proper sanitation equipment, plant grounds and waste inspections, plant and cooler inspections, packaging material storage inspections, and corrective actions should be noted on the daily sanitation report.

3.4.2 Labeling, Storage, and use of Toxic Compounds: Cleaning compounds, sanitizing agents, lubricants, and pesticide chemicals should be properly labeled and stored outside processing and packaging areas, separately from packaging materials. Food-grade chemicals and lubricants should be stored separately from non-food-grade chemicals and lubricants.

3.4.3 Exclusion of Pests from the Food Plant: Worker health and corrective actions should be noted on the daily sanitation report. A pest management firm should treat the outside of the building every other month, inspect the interior of the building and treat as necessary with appropriate chemicals. Plant grounds and interior areas should be kept free of litter, waste, and other conditions that might attract pests. Outer plant doors must be kept closed, processing areas be screened with plastic curtains, and electric bug-killing devices be located outside entrances to processing areas. No pets should be allowed in the plant.

4.0 CONCLUSION

Even after learning about the sanitary benefits of single-use foodservice packaging, in office or school, it may be convenient for people to use reusable mugs instead of single-use cups. But the fact is, most people don't or can't take the time away from work to clean coffee mugs properly; they just give them a quick rinse. To properly sanitize a mug, it should be washed thoroughly and then rinsed for 30 seconds in water of 170 degrees F or more, and a good detergent should also be used (something many offices don't have on hand). Sink areas in washrooms and office kitchens often harbor bacteria since so few workers bother to clean up after use. Over time -- due to lack of proper cleaning -- grime, residue and bacteria accumulate on the cup. Also, office workers can often mishandle their cups, spreading germs from dirty hands. Cups are frequently used by more than one person and not properly cleaned. So, switch to a single-use cup! There need not to be worry about the bacterial and sanitation problem (or have to spend time away from washing cup in the sink!), because each cup is new and fresh.

5 REFERENCES
1. INTRODUCTION

Livestock sector plays an important role in Indian economy by contributing to food security, rural income and livelihood. With growing demand for livestock products organized development of livestock sector including meat industry is an important requirement. Processing and utilization of meat and byproducts in an effective manner is important to sustain livestock production. Meat sector contributes Rs. 20856 crores to the total output (Rs. 1,30,233 crores) from livestock sector annually (1999-2000) through 4.6 mt of meat and byproducts. When a meat animal is slaughtered and processed only one-third is meat and the rest comprise byproducts and waste, which need to be adequately processed and disposed in order to recover useful products and meet the environmental regulations. Though meat sector produces pollutants of biodegradable nature but their management is essential to prevent public health risks, meet the regulations and provide positive image to the sector. Waste is defined as materials resulting from meat and byproducts processing operations that have no current economic value to the processor and that normally have a cost associated their disposal (Van Oostrom, 2001).

2. MEAT INDUSTRY WASTE

Meat industry waste comprise large waste (dung and urine), slaughterhouse waste (blood, meat scrap, paunch (rumen) and intestinal contents and byproducts processing waste (rendering plant and casings processing waste). In addition wastewater may also contain small amount of soil and grit from pre-slaughter washing of animals, as well as detergents and other chemicals used during processing and cleaning. Small-scale slaughter does not result in excessive waste loads when distributed geographically. However, centralized slaughter requires greater attention to manage the waste.

2.1 Quantum of waste water generation

- **a.** Large abattoirs (>200 large animals or >1000 sheep & goats/day) - >100 m$^3$/day
- **b.** Medium abattoirs (50-200 large animals and 300-1000 sheep and goats/day) - 50-100 m$^3$/day
- **c.** Small abattoirs (less than 50 large animals or 300 sheep and goats/ day) - Less than 50 m$^3$/day

2.2 POLLUTION LOAD PRODUCED PER LARGE ANIMAL

(estimated from Aurangabad municipal abattoir)

- **a.** COD load 6.50 kg.
- **b.** BOD load 3.57 kg.
- **c.** Suspended solids 0.53 kg.
- **d.** Flow 30 m$^3$/day for 100 animals with BOD of 8,320 mg/l and COD 15038 mg/l.
2.3 Solid waste generation

a. Large animal: 50 kg per animal of 150 kg live weight or 275 kg per tonne of live weight killed or 27.5% of live weight of the animal.

b. Sheep and goat: 170 kg per tonne of live weight killed or 17% of live weight of the animal.

3. Quality of meat industry pollutants

Blood is the major item contributing to pollution with high BOD of 150,000-200,000 mg/l. Red meat slaughterhouses (ruminants and pigs) have a pollution potential of 26 kg BOD per tonne of live weight compared to less than 10 kg BOD per tonne of live weight in case of poultry. Methods for pollution reduction and upgrading of animal byproducts need due consideration as an average of 4.5 kg protein is lost to the sewer for every 454 kg of live weight kill in the animal processing industry. Depending on the water used in slaughter and byproducts processing BOD level is reflected in the effluents. For water conversation which has become more important, greater attention is given to dry clean up and recovery of blood, fat, meat scraps and paunch content etc.

4. WASTE MANAGEMENT PRINCIPLES

a. Waste avoidance and reduction at source

b. Waste recovery, reuse and recycling

c. Waste treatment and disposal.

Waste conservation and dry collection of different waste components facilitates better and economic treatment and disposal of waste. Managing solid waste is usually more cost-effective than treating and disposing of it as a part of wastewater. Collection of gut contents and dung in a relatively dry form can considerably reduce the wastewater pollutant loading and waste water treatment costs. Segregation of wastewater to recover animal tissues from those of fecal matter and gut contents allows animal tissues recovered for rendering without contamination and down grading of rendering material. Similarly gut content and feces without animal tissues could be composted by simple techniques (windrow method) and free from odors and better utilized.

Blood is most commonly collected for inedible processing by allowing it to drain into a collection pit or trough. Blood loss from the carcass is also observed at hide pulling, brisket cutting and head removal, which can be collected by dry cleaning. Usually blood is dried to produce blood meal. The most popular method involves coagulating the blood proteins by steam injection, centrifuging the coagulum from the aqueous fraction, and then drying the coagulum (Fernando, 1992). Temperature of 90-95°C is optimal for coagulation. Ageing of blood improves coagulation. For ruminants yield of 12 to 15g of dried blood per kilogram of dressed carcass weight could be obtained. Dry cleaning methods should be employed to collect meat and fat trimmings and fine debris from carcass saws. Gratings and perforated baskets in floor drains are normally used to prevent large pieces from entering the wastewater.

4.1 Rumen and Paunch

Rumens are processed for recovery of edible products (tripe), for pet food production or for rendering. Pasture fed large animals may contain 30-40 kg of rumen material. Wet dumping and washing with liberal quantities of water facilitate recovery of only about 10% to 30% of the nitrogen and phosphorus and 40% of the total solids by screening or sedimentation. However, dry dumping involving opening the paunches to release their contents without the aid of water and washing for recovery of tripe or pet
food processing or rendering can reduce the waste water loading from paunch handling by 90% or more. Dewatering of dry-dumped paunch contents (8% to 10% total solids) to 15% to 20% total solids makes them more manageable. The recovered liquid is high in nitrogen, phosphorus and BOD₅ but its volume is low and the mass of soluble pollutants lost to waste water is only half that of wet dumping systems.

Condemned paunches and other inedible gut material is macerated in a mechanical gut cutter, followed by separation of tissue from gut content, usually in a rotating wash screen. Intact gut rendering could also be considered comparing the disadvantages of degraded tallow quality and value, lower protein content of meal and increased rendering costs against the advantages of reduced fat losses, a reduction in waste water and solid waste loads and simplification of materials handling equipment.

4.2 Casing processing

Large volumes of water, gut contents and tissues are added to waste water when animal intestines are processed to casings. It is desirable to render the animal tissue and pass the fecal waste to be treated with other gut content wastewater.

4.3 Rendering plants

Washings from raw material handling, condensate from cookers, stick water and wastewater from tallow refining are the sources of organic loading for treatment before disposal. Minimizing addition of water to raw materials and use of dry conveyance systems would minimize wastewater from raw material handling. The volume of condensate from dry rendering systems depends largely on the amount of raw material and water loaded into the cookers. The non-condensable gas portion from cookers requires further treatment to remove odor before discharge to atmosphere. Stick water is the aqueous phase of the wet rendered material separated after the cooking stage by various decanting, pressing, centrifugation and drying steps. Stick water contains solubilized fat, protein and minerals and contributes to pollutant loading. Concentration by evaporation and ultra filtration could be used for recovery of solids.

4.4 Hide and skin handling

Washing to remove blood and loose contaminating material, salt and other chemicals lost to waste water and flushings (removal of flesh or adipose tissue on the hide) contribute to waste loading with pollutants.

5. TREATMENT OF WASTE WATER

The strategy for wastewater treatment depends upon the characteristics of effluents, volume of effluents, standards imposed, land and investments available. Different treatments practiced in meat industry are:

5.1 Physical treatment

Screening, gravity separation and dissolved air flotation. Static screen, internally fed rotating drum screen and externally fed rotating drum screen are in vogue. Slots of 0.5 to 1.0 mm are suitable for most applications in meat industry. Gravity separation is through a primary clarifier with top and bottom scrapers, which continuously remove the floating, grease and settled solids. Hydraulic- retention time in primary clarifiers is usually between 30 and 60 minutes. Due to higher operating costs and odor development gravity separators are replaced with screening or a combination of screening and dissolved air flotation technology.
In the dissolved air flotation (DAF) process, suspended solids in the wastewater are removed by flotation assisted by air bubbles. The rising bubbles adhere to suspended solids in the wastewater and assist flotation. Floating solids are recovered with scrapers. There are higher capital and operating cost than passive gravity separation. DAF works faster and produces drier sludge.

5.2 Physicochemical treatment

In order to remove soluble proteins, fat emulsions or colloidal material from wastewater adjusting pH and dosing wastewater with specific coagulants and flocculants is practiced. Dissolved matter is precipitated and agglomerated into larger particles that can be recovered by Physical Process such as DAF or settling. Adjusting wastewater pH to 4 and 5 will remove many proteins from solution. Use of cationic and anionic coagulants with pH adjustment can provide more effective removal of protein and other organic material. Iron and aluminium salts are the common cationic coagulants. Anionic coagulants, which remove hemoglobin, include sodium hexametaphosphate at pH 3.5 and sodium alginate at pH 3.5-4.5. Physicochemical treatment is more suitable where land area is limited. High cost of chemicals and their down stream problems are the limitations.

5.3 Anaerobic treatment

Anaerobic lagoons are used to convert organic matter in the wastewater to methane and carbon dioxide in the absence of oxygen by the three main groups of bacteria, acidogenic bacteria (hydrolytic and fermentative), acetogenic bacteria and methanogenic bacteria. The last group uses the acetic acid, formic acid and hydrogen gas produced by the former two groups as substrates for methane production. A balance between microbial populations is essential and pH of 7 with high level of bicarbonate alkalinity is desirable. Waste water temperature of 20-30C results satisfactory performance. Removal rates of 70% to 90% for COD and BOD5 are achieved. Low operating costs and low sludge production are advantages. Anaerobic treatment result only 5 to 15% of COD removed as sludge compared to 40-60% for aerobic biological treatment and 100% for physical and physico-chemical treatment. Methane yields of upto 0.23kg per Kg COD removed which is 92% of the Theoretical maximum. Disadvantages include non-removal of nitrogen and phosphorus and odor nuisance and corrosion of equipment due to hydrogen sulfide. It is generally applied as treatment step before discharge to public sector, aerobic biological treatment or land application.

Anaerobic Lagoons are 3 to 6m deep with hydraulic retention time of 5 to 15 days and of greater length: width ratio with influent and effluent at opposite ends. Sludge needs to be removed every 5 to 10 years. Promoting stable scum layer, covering the lagoon with membrane or making the lagoon as deep as possible reduce odor problems.

High rate anaerobic systems (high densities of anaerobes, 4000 to 8000 g per cubic metre measured as suspended solids) are suitable where land area is limited and biogas collection and strict odor control are to be achieved. Anaerobic contact process, up flow anaerobic sludge blanket process (UASB) and anaerobic filter are the high rate systems. Anaerobic sequencing batch reactors (SBR) which work with repeated cycles of fill, react, settle and decant have been indicated promising for meat processing waster water (Morris et al., 1998). Sequencing batch reactor is considered as a viable alternative to conventional continuous flow activated sludge treatment for efficiency of 5 day BOD reduction and suspended solids removals, nitrification, de-nitrification and chemical precipitation of phosphorus (Irvine et al., 1983). Higher capital and operating costs with more sensitivity to variations in organic loading have been the limitations of high rate anaerobic systems.
5.4 Aerobic treatment

Anaerobically treated wastewater is treated aerobically to remove residual BOD\textsubscript{5} and suspended solids and to oxidize ammonia and hydrogen sulfide to less harmful nitrate and sulfate. Aerobic lagoons (oxidation ponds, aerated ponds) high rate systems (activated sludge treatment, attached growth systems (Trickling filters) and constructed wet lands are used before discharge to surface waters. Goopy et al., (2004) suggested that duckweed could be grown on abattoir effluent, and produce a plant material that is high in both crude protein and phosphorus, which can be used as a feed stuff with high nutrition value. Bentonite at 0.5% found to ameliorate the toxic effect of unmodified effluent to duckweed.

5.5 Solid waste treatment

Animal tissues, fecal and gut content solids, solids and slurries removed from Primary and physicochemical waste water treatment systems and sludges produced from biological waste water treatment systems comprise the solid wastes which are to be treated by rendering, land filling, land application and composting based on suitability. Waste tissues and slurries suitable for use as animal feed could be rendered to obtain returns and avoid disposal costs. Fecal wastes, gut contents and biological treatment sludges are unsuitable for rendering but useful as fertilizer and soil conditioner. Land application of these wastes must be managed to avoid odor, leaching to ground water, run off and adverse effects on animal and human health. To avoid such undesirable impacts solids are commonly treated by composting, which is a popular method of stabilizing waste solids from meat processing. High temperatures achievable (50 to 800\textdegreeC) during composting kill pathogens and help to insure a safe product. (Van Oostrom, 2001).

6. CONCLUSIONS

In Indian situation with inadequate infrastructure facilities in the slaughterhouse adoption of appropriate means of waste disposal is essential to improve the image of the meat industry and prevent environmental and public health risks. Recovery of solid wastes and their disposal through composting and land application as fertilizer would considerably improve the present image of the slaughterhouses. While modernization of all the existing slaughterhouses would take longer time in view of the constraints associated but waste collection and disposal need to be undertaken on priority.

7. REFERENCES

Table 1. National Standards for Slaughterhouse and Meat Processing Effluents

<table>
<thead>
<tr>
<th>Category</th>
<th>Limit not to exceed mg/l</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>BOD</td>
</tr>
<tr>
<td><strong>Slaughterhouse</strong></td>
<td></td>
</tr>
<tr>
<td>Above 70 TLWK</td>
<td>100</td>
</tr>
<tr>
<td>70 TLWK &amp; below</td>
<td>500</td>
</tr>
<tr>
<td><strong>Meat Processing</strong></td>
<td></td>
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<tr>
<td>Frozen meat</td>
<td>30</td>
</tr>
<tr>
<td>Raw meat from SH</td>
<td>30</td>
</tr>
<tr>
<td>Raw meat from other sources</td>
<td></td>
</tr>
</tbody>
</table>

BOD: Biological oxygen demand 5 days at 20ºC, TSS: Total suspended solids, TLWK: Tonnes live-weight killed.
In case of disposal into municipal sewer where sewage is treated, the industries shall install screen and oil and grease separation units. The industries having slaughterhouse along with meat processing units will be considered in meat processing category as far as standards are concerned.


Table 2. Land requirement of ETP for 100 large animals or 500 sheep and goat

<table>
<thead>
<tr>
<th>Unit</th>
<th>Nos.</th>
<th>Size (L x B x D) m</th>
<th>Area (m²)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Screen chamber</td>
<td>1</td>
<td>1.5x0.3x0.4</td>
<td>0.45</td>
</tr>
<tr>
<td>Oil and grease trap</td>
<td>1</td>
<td>0.75x0.6x1.25</td>
<td>0.45</td>
</tr>
<tr>
<td>Septic tank</td>
<td>1</td>
<td>7.0x3.0x2.5</td>
<td>21.00</td>
</tr>
<tr>
<td>UASB</td>
<td>1</td>
<td>4.0 dia, 6.5</td>
<td>12.57</td>
</tr>
<tr>
<td>Aeration basin</td>
<td>1</td>
<td>6.0x3.5x3.0</td>
<td>21.00</td>
</tr>
<tr>
<td>Secondary clarifier</td>
<td>1</td>
<td>2 dia, 2.5</td>
<td>3.14</td>
</tr>
<tr>
<td>Polishing Pond</td>
<td>1</td>
<td>14x10x2.5</td>
<td>140</td>
</tr>
<tr>
<td>Sludge drying beds</td>
<td>4</td>
<td>4x2x0.3</td>
<td>32.00</td>
</tr>
</tbody>
</table>

Total land area 230.61
Total land requirement 1.5x230.61 = 345.92 m²