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ENVIRONMENTALLY SOUND TECHNOLOGIES IN THE FOOD INDUSTRY

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Preface

Several factors render food processing one of the most important areas of industrial activity in the ESCWA member countries. The economic importance of the industry's operations in these countries is equalled only by the crucial nature of its activities from a social perspective.

The food processing industry (FPI), traditionally conservative in comparison to other branches of industrial enterprise as regards the selection and rate of implementation of new technology, has been the target of considerable technological innovation, particularly during the past two decades. Many of these innovations have targeted the environmental impact of the industry's operations. Others have been aimed at enhancing product quality and shelf life, allowing producers in both developed and some of the industrializing countries to gain a significant edge in wider markets. The end result of both types of innovation is rejuvenated, leaner, more competitive enterprises and, of greater importance, enterprises that are more compatible with new global environmental quality standards.

Two issues that come to the forefront in considering FPI technology development in the developing countries deserve special attention: The first concerns the relatively fragmented nature of FPI operations in these countries; the second, of special relevance to the ESCWA member countries, is the high volume of water consumption and wastewater in FPI operations. Both issues require special attention in devising modalities for the acquisition and wide adoption of the appropriate technology.

The present study is one of three carried out within the work programme of the Sectoral Issues and Policies Division for the biennium (1998-1999) with a view to examining various aspects of the agro-food sector in the ESCWA member countries. Of the two other studies conducted within this domain, the first was devoted to FPI production and quality technology[1] and the second to FPI competitiveness and productivity.[2]

This study is also part of a continuing effort by ESCWA to promote environmentally sound technologies (EST) in its member countries. The last in this series addressed EST in the tanning industry.[3] Previous activities in the same domain addressed cleaner production technology in the oil and gas sector.

The present study consists of four sections. Following a brief introduction, the first section presents an overview of the food processing industry's raw materials and principal waste output items. The second takes a closer look at the status and environmental impact of seven major FPI segments in the ESCWA member countries and outlines the main features of environmentally sound alternatives.

The third section discusses some of the more notable environmentally sound technologies, with emphasis on that of relevance to water conservation, recycling and treatment. Other promising technology to be commercialized is also discussed.

The fourth and final section of the study focuses on policy issues relating to the acquisition, development and wide adoption of EST in the ESCWA member countries. The nature and orientation of strategies for these objectives are considered.

It is hoped that this study will provide the basis for efforts aimed at the assessment and wide adoption of EST in the ESCWA member countries. Such efforts will, of necessity, need the collaboration and contribution of the concerned government departments, enterprises and industrial federations, as well as that of professional associations, to ensure a viable future for the food processing industry.

Hazem El-Beblawi
Executive Secretary of ESCWA

[1] "Production and quality technologies in the agro-food industry in ESCWA member countries" (E/ESCWA/TECH/1999/6).

[2] "Productivity and competitiveness of the agro-food industry in the ESCWA member countries" (E/ESCWA/ID/1999/11).

[3] "Environmentally sound technologies in the tanning industry" (E/ESCWA/TECH/1997/2).

CONTENTS

LIST OF TABLES

CONTENTS (*continued*)

LIST OF FIGURES

LIST OF BOXES

LIST OF CHARTS

ABBREVIATIONS

ATAS	Advanced technical assessment system
BOD	Biological oxygen demand
BOD_5	Biological oxygen demand (five-day)
$CaCO_3$	Calcium carbonate
CIP	Clean in place
CO	Carbon monoxide
CO_2	Carbon dioxide
COD	Chemical oxygen demand
^oC	Degree Celsius
DNA	Deoxyribonucleic acid
EPA	Environmental Protection Agency (United States)
ESCWA	Economic and Social Commission for Western Asia
EST	Environmentally sound technologies
ETI	Environmental technology initiative
FAO	Food and Agriculture Organization (United Nations)
FDA	Food and Drug Administration
FOG	Fats, oils and grease
FPI	Food processing industry
g	Gram
GJ	Gigajoule
GMP	Good manufacturing practice
HACCP	Hazard analysis and critical control point
HDPE	High density polyethylene
HSCW	Hot standard carcass weight
HTST	High Temperature and Short Time
IPM	Integrated pest management
ISO	International Organization for Standardization
IT	Information technology
ITRC	Industrial Testing and Research Centre
kg	Kilogram
kGy	KiloGray
kJ	Kilojoule
kV/cm	Kilovolt/centimetre
kWh	Kilowatt-hour
l	Litre
LPG	Liquid petroleum gas
m^3	Cubic metre
ME	Milk equivalent
MF	Microfiltration
mg	Milligram
mg/l	Milligram/litre
MJ	Megajoule
t	Metric ton
NH^{4+}	Ammonium
NIR	Near Infrared
NO	Nanofiltration
NO_2	Nitrogen dioxide
NO^{2-}	Nitrites
NO^{3-}	Nitrates
NO_x	Nitrogen oxide
ODS	Ozone depleting substances
PAN	Polyacrylonitrile
PC	Personal computer
PEF	Pulsed electrical field

PES	Polyethersulfone
pH	Acidity/alkalinity index
PM	Particulate matter
PO^{4-}	Phosphates
PS	Polysulfone
PVC	Polyvinyl chloride
PVDF	Polyvinylidene fluoride
R and D	Research and development
RO	Reverse osmosis
S and T	Science and technology
SCF	Supercritical fluid
SIC	Standard industrial classification
SO_2	Sulfur dioxide
SO_x	Sulfur oxide
TDS	Total dissolved solids
TFF	Tangential flow filtration
TS	Total solids
TSS	Total suspended solids
UF	Ultrafiltration
UHP	Ultra-high pressure
UHT	Ultra high temperature
UNEP	United Nations Environment Programme
UNIDO	United Nations Industrial Development Programme
USDA	United States Department of Agriculture
UV	Ultraviolet
VOCs	Volatile organic chemicals
WHO	World Health Organization

I. THE FOOD PROCESSING INDUSTRY RESOURCES AND ENVIRONMENTAL PROFILE

A. INTRODUCTION

Few aspects of FPI have escaped the sweeping changes it has undergone, particularly during the past three decades. The transformation witnessed in this industry has affected processes, product design concepts, packaging, marketing networks, management methods and even the nature of some of its raw materials.[4]

The changes that have taken place in this industry have largely been driven by one or more of the following factors:

(a) Greater concern for public health and safety under pressure from governments and consumer protection groups.

(b) Competition and the need for wider markets in many of the industry's sectors, necessitating the use of more effective sterilization and pasteurization techniques and more effective packaging.

(c) The need for conformity to ever-more stringent regulations governing environmental impact and product quality.

Changes incorporated into FPI operations during the past few decades originated in a wide variety of scientific disciplines and fields of technology. Innovations from the fields of biotechnology and microelectronics have played a major role in radical changes. However, this in no way depreciates the contribution of the more "traditional" fields of scientific and technological knowledge in chemical, mechanical and electrical engineering and in the agricultural sciences.

In response to this economic and regulatory pressure referred to above, the incorporation of more modern scientific and technological inputs into the food industry, particularly in developed countries, has transformed the industry into a far more knowledge-intensive enterprise than ever before. Furthermore, inputs designed to serve specific environmental or regulatory obligations have given rise to wider improvements affecting both technical and managerial aspects of industrial practices. Thus, the incorporation into FPI operations of new in-line sensors has brought about a wide-ranging capability in monitoring and control. Similarly, the introduction of computers has resulted in changes in raw materials procurement and stock management that have transcended firm boundaries and transformed certain segments of the industry into interdependent networked operations.

The net result of the changes that have affected FPI operations in developed countries is undoubtedly that of improved productivity and competitiveness, posing even greater challenges to the FPI in ESCWA and other developing countries.

However, as is often the case in innovation and technological development, challenges are accompanied by opportunities. This is especially true in the case of FPI operations, where modular design concepts facilitate the introduction of incremental innovation that may eventually be integrated into a functioning whole through modern information technology, and where components at the heart of such innovation are, as a rule, readily accessible.

In essence, the multiple task of achieving continued growth and enhancing profitability and competitiveness in FPI operations in the ESCWA member countries is increasingly dependent upon minimizing their effect on the environment. The advent of global standards for regulating environmental

[4] Thus, the use of genetically-modified crops and ingredients produced by genetically-altered micro-organisms, an idea that belonged to the realm of science fiction only thirty years ago and is almost routine.

impact in all spheres of industrial activity has already reshaped technology acquisition and technological development in the developed countries. Should they wish to continue operating, enterprises in the ESCWA member countries will need to institute similar changes.

In seeking greater compatibility with environmental regulations, an effective criterion of success is whether the resources and environmental capital have been maintained or upgraded to a level that allows similar, future development. Such conditions can obviously be met only when resource base exploitation and environmental degradation is minimized or entirely reversed through material, energetic and technological inputs. Nowhere is the application of such measures more appropriate, in the ESCWA member countries than in the case of water resources and their utilization in food production and food processing.

Although environmentally sound technologies encompasses a complex and heterogeneous group of production, packaging, testing and distribution methodologies, it is useful, to define three main EST categories:

(a) Processes developed to neutralize the environmentally harmful effects of a given industrial operation without modifying the original. Almost all effluent treatment technology falls into this category, e.g. flue gas desulphurization, catalytic converters for car exhausts, and water treatment and detoxification;[5]

(b) Modification of existing processes, mainly through the introduction of new monitoring and control techniques as well as changes in the raw materials of intermediates used in the process, with the aim of eliminating or minimizing negative environmental effects. Examples of such processes include, waste heat recovery, co-generation technology in energy generation, and the introduction of advanced inline measurement, control and computerized optimization technology in conventional processes in order to reduce undesirable by-products and achieve cleaner and more efficient conversion;

(c) Adoption of both new and traditional technology that is inherently sound from an environmental point of view, for example: solar energy for drying crops and process water pre-heating; and certain new industrial modifications based on biotechnology.[6]

In general, EST in the first category has been the subject of greater interest and has tended to evolve and become absorbed more rapidly than that in the second and third categories. Technology in the first two categories is, on the other hand, essentially more widespread than that in the third. There are several reasons for this: Initially, is the fact that, in the first category, the need for redesigning and remodelling entire production operations is minimized. Technology in the first category in particular is often an addition to existing plant structures. On the other hand, the introduction of EST of the third category generally requires radical transformation and therefore risks of being hindered by lack of investment capital and by a variety of techno-economic considerations.

All three categories of EST are generally applicable in food processing. The fact that food production processes often have well-defined raw material inputs and even involve standardized processes with only limited margin for change, have strengthened the tendency for EST in the first category.

It is useful to recall at the outset that environmental soundness is not solely dependent upon the technology being implemented. Rather, it is a function of a multitude of factors that relate to management practices, the resource base, social and cultural conditions, and the mode of implementation of the technology. The fact that the present study is mainly concerned with the technological aspects of FPI

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5 See Bizri, O., Environmentally Sound Technologies for Sustainable Development, Issue 7, ATAS 1991.

6 Clean technology is defined as "manufacturing processes or product designs that produce no noticeable pollution or waste due to energy-use or material conversion". Clearly, this is an ideal that is seldom attained, if at all. It is often the case that environmentally sound technologies is adopted merely as an improvement over that being replaced, rather than to eliminate pollution or waste.

operations should not be taken as an indication that these other factors are any less important. However, in the absence of essential technological innovation many of these factors become less effective or cease to operate.

B. KEY RESOURCES USED IN THE FOOD-PROCESSING INDUSTRY

Resource used in food-processing include a variety of mainly agricultural raw materials of various grades, water, and energy in a number of forms. In addition, a range of inorganic substances is finding increasing uses in various branches of the industry as additives, waste treatment and sedimentation aids, disinfectants and cleansing agents. The following is a summary of some of the issues pertaining to these inputs and their environmental impact.

1. *Raw materials*

Agricultural raw materials used by the industry[7] directly affect the extent and intensity of the pollution generated by its operations. This is related to their inherent constitution, the extent and nature of cleaning needed in the preparative and intermediate stages, and the pesticide residues they have retained, as well as refuse resulting from spoilage, due, for example, to inadequate transportation arrangements,[8] inefficient storage or process failure.

Pollution due to chemical substances used in food processing is often the source of major concern. Examples include chemicals used for cleansing and sanitizing both the raw materials themselves, as well as the equipment, working surfaces and shop floors. Chemicals used in the intermediate preservation of products, in pest eradication and in refrigeration constitutes another group of chemical pollutants.

2. *Water*

The food processing industry is an avid user of water resources. Abundant and inexpensive water is a prerequisite for the industry.[9] Table 1 presents typical rates of water consumption in a number of food processing sectors.

Water is used in three distinct modes: as an ingredient in numerous unit processes, as a cleaning medium[10] and for conveying raw materials and by-products. Water is thus the primary ingredient in the beverages and fermentation segment. An example of the extent of the use of water as a cleaning medium is provided by processing plants in the fruit and vegetable sector in industrialized countries: around fifty per cent of the water utilized in these plants is for washing and rinsing. Dairy processing plants, likewise, utilize water, primarily, as a basic cleaning agent for plant and process machinery. Certain branches of the fruit and vegetable processing industry still use water to convey produce between process units. Similarly, water is used in poultry processing to transport feathers and other animal parts in water flumes.

Patterns of water use are, therefore, the focus of attempts to limit or eliminate pollution generated by the industry. Reduction of water consumption in the conveyance of raw materials as well as in plant and equipment cleaning is the target of attempts at new process design and recycling operations.

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[7] With the exception, of course, of most branches of the beverage and the specialty foods industry. The former resembles manufacturing industries in that products are created by combining a number of raw materials, increasingly of non-agricultural origin. Furthermore, this industry is less polluting than other branches of the food processing industry. Specialty food products on the other hand, require less water and utilize preprocessed inputs.

[8] Food processing establishments are generally located close to their agricultural sources. This has the effect of generally reducing spoilage during transportation.

[9] Indeed, some countries impose minimum requirements for water use in cleaning certain food products during the various processing stages. Thus, minimum requirements are set by the United States Department of Agriculture (USDA) on the amount of water needed to clean poultry products.

[10] Both for the industry's raw materials and for equipment and other plant items.

TABLE 1. TYPICAL RATES FOR WATER CONSUMPTION FOR VARIOUS INDUSTRIES

Industry	Product	Range of flow L/Mt
Fruit and vegetable	Green beans	2 500-4 000
	Peaches and pears	800-1 100
	Other fruit and vegetables	200-1 800
Food and beverage	Beer	500-850
	Bread	100-200
	Meat packing	800-1 100
	Milk products	500-4 100

Source: Metcalf and Eddy's Wastewater Engineering: Treatment, Disposal, and Reuse, 3rd ed., 1991.

3. *Energy use*

In comparison to other industrial activities such as metal fabrication and pulp and paper production, the food processing industry is not generally regarded as energy-intensive. Electricity is generally used to run food-processing machinery. Natural gas and fuel oil are used in boilers and for steam generation in plants in many developing countries, including those in the ESCWA region.

C. OVERVIEW OF THE ENVIRONMENTAL IMPACT OF THE FOOD PROCESSING INDUSTRY

1. *Wastewater*

Wastewater produced in food processing is often cited as the primary area of concern in rendering the industry more compatible with environmental considerations. In general, wastewater produced by this industry contains few hazardous and persistent substances. Thus, with the exception of certain toxic cleaning and sanitizing agents, wastewater from food-processing establishments is almost entirely composed of organic matter that is amenable to conventional biological treatment technology.

Nevertheless, a major problem with wastewater discharge by the food processing industry arises when production facilities are located in rural areas in which public water resource networks and water treatment systems, still rare in many ESCWA member countries, are designed to serve small populations. Even small-sized plants, processing, for example, 20 Mt of fruit and vegetables or canning or frozen packaging, might use a hundred cubic, or 100,000 litres of clean drinking-quality water. The wastewater such a factory produces also seriously affects the quality of local water supplies and surface water integrity.

Issues of principal concern in FPI wastewater are biochemical oxygen demand (BOD); the amount of total suspended solids (TSS); nutrient loading, namely nitrogen and phosphorus compounds; pathogenic organisms and residual chlorine, as well as pesticide and herbicide levels.

An important indicator of the level of wastewater pollution is provided by the five-day Biochemical Oxygen Demand (BOD_5) (box 1). This criterion is used to gauge the level of treatment needed before effluent may safely be discharged into a receiving water system, such as a river, lake or coastal waters.

Pathogenic organisms are a major source of wastewater contamination, particularly in meat, poultry, and seafood processing. Wastewater bearing high levels of such organisms has to be disinfected prior to discharge. Chlorine is often used for this purpose. Recently, however, chlorine use has come under pressure from a variety of sources.[11] As a result, it is being gradually replaced by ozone and ultraviolet (UV) radiation. Further discussion of disinfection with ozone and ultraviolet radiation is presented in section IV.

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[11] Chlorine generates high levels of chlorine-bearing organic chemicals now considered carcinogenic.

Another aspect of wastewater constitution is the acidity or alkalinity of a wastewater stream, as measured by its pH value.[12] This is of paramount importance to the integrity of natural receiving systems and wastewater treatment plants. In the latter, micro-organisms used in wastewater treatment can function only within a relatively narrow range of pH values. Low pH, indicating high acidity, is particularly damaging. Values in the range 5-9 are generally acceptable.

Box 1. Definitions of frequent terms pertaining to environmental pollution

Five-day biological oxygen demand (BOD_5)

Biological oxygen demand is relatively high in the food processing industry in comparison to other industries. This is indicative of the fact that food processing wastewater contains higher percentages of dissolved and suspended solids, minerals, and organic nutrients containing nitrogen and phosphorus the degradation and subsequent transformation of which use up the oxygen in the receiving water system.

Strict regulations set by government authorities in the industrialized countries place limits on BOD levels in FPI effluent. Firms discharging wastewater with BOD_5 levels in the range of 250 – 300 mg/L are obliged to pay extra costs towards the necessary additional treatment. Facilities discharging wastewater exceeding permissible BOD_5 levels into a receiving water system are heavily fined. Due to such stringent regulations, many food-processing establishments are taking steps to either reduce, recycle (or renovate), and/or treat their wastewater before discharge.

pH (acidity/alkalinity index)

The index of the acidity or alkalinity of a solution as measured on a scale, the "pH scale", of 0 to 14. The midpoint, 7.0, represents neutrality. The pH is the index of concentration of acid or alkali in a solution rather than the amount of acid or alkali it contains. The negative of the logarithm of the hydrogen ion concentration of a solution, that is, the weight of hydrogen ions in grams per litre of solution, is its pH. Neutral water, for example, has a hydrogen ion concentration of 10^{-7} grams per litre; thus its pH value is 7.0.

Total suspended Solids (TSS)

The particles which can be removed from a solution by filtration, usually specified as the matter which will not pass through a 0.45 micron pore diameter filter, expressed in units of weight per volume, usually in grams or milligrams per litre.

Total dissolved solids (TDS)

Total weight of solids dissolved in process water, normally expressed in ppm per unit volume of water. TDS is determined by:

(a) Filtering a given volume of water through a sub-micron filter;

(b) Evaporating the sample at a defined temperature, commonly in the range of 103-105° C;

(c) Weighing the residue.

Total solids (TS)

The weight of all solids, organic or inorganic, both dissolved and suspended, per unit volume of water. The weight of total solids in a solution is generally determined by evaporation of a measured volume of water at 105°C in a pre-weighed dish.

Chemical Oxygen Demand (COD)

An indirect measure of the amount of oxygen needed to oxidize matter in a water sample. Its laboratory measurement is based on the amount of chemical oxidant used up by both inorganic and organic matter in the water sample.

Volatile Organic Chemicals (VOCs)

Organic chemicals possessing high vapour pressures at relatively low temperature, i.e. vaporize at temperatures close to ambient or room temperature.

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[12] This is defined as the negative logarithm of the concentration of hydrogen ions in an aqueous medium.

2. *Solid waste*

Organic and packaging waste constitute the principal issues of concern in the food processing industry. Raw material processing residues including, rind, seeds, skin, bones, feathers, etc., are the main sources of solid organic waste. Other sources of organic waste include paper, cardboard and plastic sheeting. Inorganic waste includes glass, metal and other mainly packaging items. Phosphates, and other inorganic chemicals from segregated washing streams, are another possible source of predominantly inorganic chemicals in FPI wastewater streams.

The food processing industry in the industrial countries has been able to reduce organic waste levels through resale for reprocessing. Biodegradable and recyclable packaging materials are also gaining ground. Among the latter, aluminium, glass, and high density polyethylene (HDPE) are increasingly being used.

Solid waste from regular food processing activities is generally rich in both nitrogen and phosphorus. Many solid waste varieties produced by this industry can be processed into valuable products including organic fertilizers and animal feed.

Wastewater treatment sludge obtained from sedimentation or filtration operations is an important source of solid waste in the FPI. Rich in organic material as well as inorganic chemicals, with animal and plant nutritive properties, it is generally disposed of after further processing as an animal feed supplement, or, after composting, as a fertilizer additive. Chemical additives for a variety of purposes renders wastewater sludge unsuitable for animal feed, however. Its particular composition often renders this sludge unsuitable also for composting into an organic fertilizer. This underscores the need for serious attention in designing in-process water-use strategies, in-plant wastewater routing and the final treatment processes, indeed all of the steps involving the use of water in this industry. Solid waste and wastewater sludge laden with harmful chemicals, the disposal of which as fertilizer or animal feed supplements is prohibited, have to be disposed of by dumping or incineration.

A growing tendency in industrial countries is the application of the “zero emissions” principle. However, this requires the establishment of a network of firms that utilize waste streams as raw materials.

3. *Air emissions*

Air emissions are of major concern in the food processing industry whenever fossil fuels are used in its operations. Apart from this, most food processing operations emit low levels of air pollutants. Air emissions from biological treatment processes, in common with present-day breweries, may sometimes be a source of serious concern, albeit of possibly more limited proportions and consequences, in comparison to water-borne pollutants.

By virtue of the sheer volume of agricultural and food products transported to and from FPI facilities by motor vehicle, the industry’s air emissions should also be reduced as a result of developments in the search for cleaner fuels and automotive engines.

II. ENVIRONMENTALLY SOUND TECHNOLOGIES AND RELATED PRACTICES IN SELECTED SEGMENTS OF THE FOOD INDUSTRY

The primary objective of food processing is food preservation, enabling its shipment and storage to distant markets and its perennial consumption. Processing also renders foods more convenient to cook or serve, a factor that explains the rising popularity of canned and other processed foods in urban and industrialized settings. This chapter briefly addresses process inputs, as well as environmental hazards created by FPI operations in the following segments:

Fruit and vegetable processing;
Milk and dairy product processing;
Meat, poultry and seafood processing;
Vegetable oil manufacture;
Grain milling and bakery operations;
Sugar manufacture;
Beverages and fermentation products.

A. FRUIT AND VEGETABLE PROCESSING

The fruit and vegetable processing segment is a competitive international industry, encompassing fruit and vegetable canning and freezing, extraction of fruit and vegetable juices; and the production of ketchup and other tomato sauces, preserves, marmalades, jams, and jellies.

Fruit and vegetable processing is an established area of industrial activity in all ESCWA member countries. During the past two to three decades, considerable expansion has been witnessed in several of these countries, prompted, no doubt, by increasing populations and changing lifestyles as well as by export opportunities. Further expansion in the manufacture and consumption of processed fruit and vegetable products in the ESCWA member countries might be expected, at least in view of the aforementioned.

The goal of the canning and freezing processes is to destroy any micro-organisms in the food and prevent their re-contamination. Heat is the most common agent used to destroy micro-organisms.

Removal of oxygen can be used in conjunction with other methods to prevent the growth of aerobic micro-organisms. Freezing on the other hand halts or greatly retards action by all micro-organisms. Despite the fact that canning and freezing of fruit and vegetables[13] involves a number of basic procedures, these vary greatly from plant to plant. These variations may involve the inclusion of certain operations for some products and changes in the sequence of steps used in process operations, as well as essential process parameters.

In general, the differences are greater in operations involving the extraction and processing of fruit and vegetable juices.[14] This is dictated of course by the types of raw materials, as well as by the characteristics of the resulting juices, e.g., acidity, aromatic content, susceptibility of the ingredients to oxidation, etc.

The principal steps in processing fruit and vegetables are set out in box 2. Chart 1 provides a flow diagram for the canning of fruit, vegetables and fruit juices. A typical canning plant would generally employ the following process operations:

Cleaning the raw products received from the field;
Inspection (culling, trimming, sorting, grading or sizing);
Peeling, coring or seed removal;

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[13] Typical canned products processed in the ESCWA member countries include carrots, peas, fava beans, chick peas, beets, tomatoes, apples, peaches, pears and apricots.

[14] Typical juices processed in the ESCWA member countries include orange, grapefruit and tomato.

Blanching;
Cooling (after blanching);
Canning and heat sterilization or freezing;
Inspection, packaging, casing and storing.

Box 2. The principal steps in processing fruit and vegetables

(a) General cleaning and dirt removal;

(b) Removal of leaves, skin and seeds;

(c) Blanching or juice extraction;

(d) Washing and cooling (in the case of canned food processing);

(e) Packaging;

(f) Clean-up.

The blanching operation is the major difference in the processing of the two main groups of products, i.e., fruit and vegetables: most fruit is merely placed in cans and allowed to cook during the sterilization process; the majority of vegetables need to be blanched.[15]

Peeling, coring, halving, pitting, etc., occur prior to blanching in fruit processing. With vegetables, however, these steps often follow blanching. The three basic peeling methods for both fruit and vegetables are: mechanical, steam, and lye peeling. The type of fruit or vegetable generally determines the choice of method.

Fruit and vegetable juice processing is often carried out by means of concentrates in facilities that do not handle the raw materials. Such facilities generate much less solid waste, of course. On the other hand, facilities that process raw fruit and vegetables often sell processed or semi-processed by-products such as peel, pulp, molasses and essential oils to other industries.[16]

Both batch and continuous units are utilized for blanching in the canning industry. In continuous processes cans are fed through an air lock into a retort, rotated through a pressurized heating chamber, then cooled through a second section using a separate cold-water cooler.

Sterilization of acidic canned fruit and vegetables[17] is carried out using static retorts, basically, large pressure cookers. In some designs, vibration of the cans during sterilization is possible in order to achieve rapid heat penetration. In the aseptic packaging process, fruit and vegetables are sterilized and cooled before being put into pre-sterilized containers and sealed in a sterile atmosphere.

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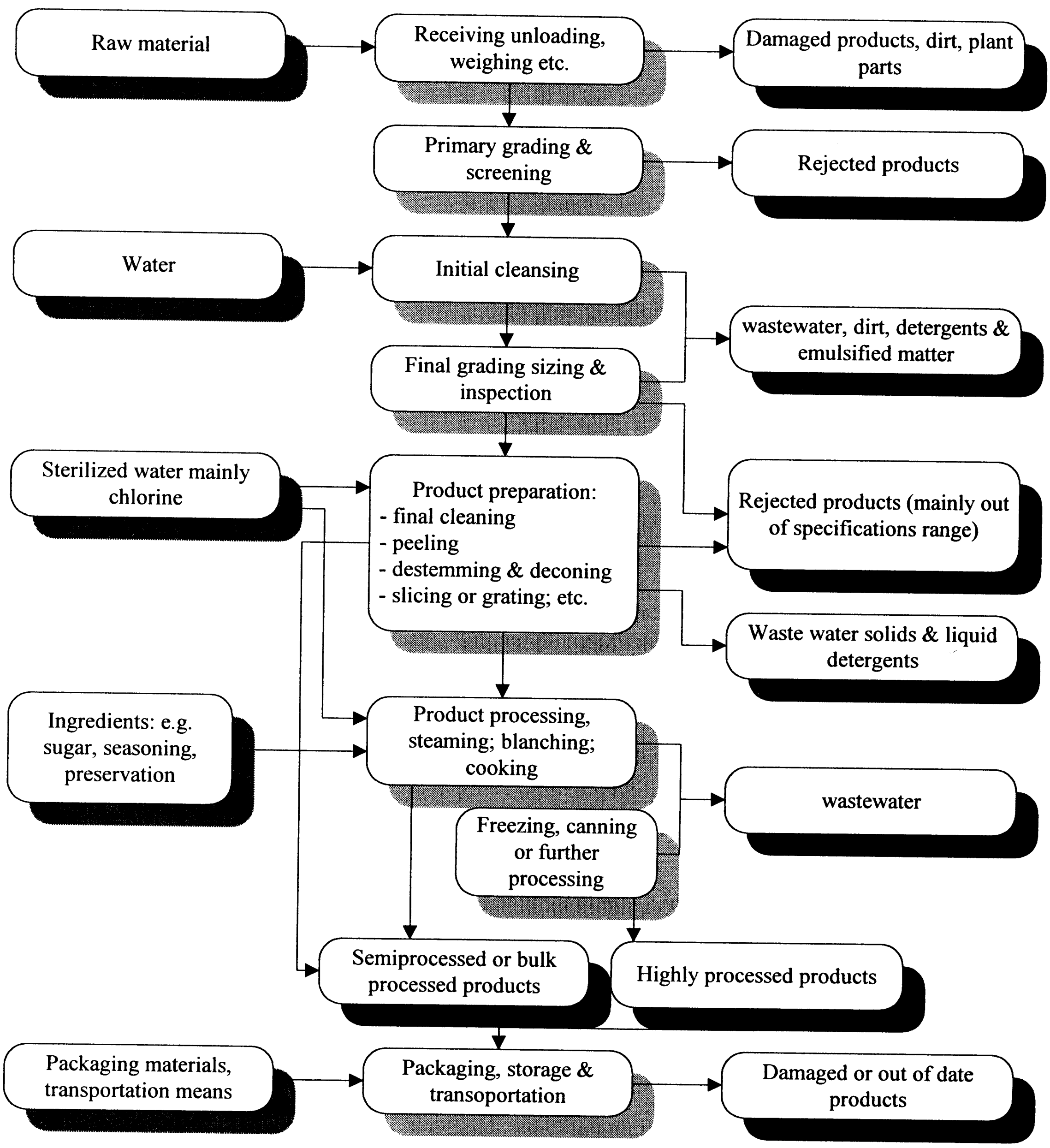
[15] The fact that vegetables have much lower acidity and contain heat-resistant soil organisms necessitates the more intensive heat treatment. The more intensive heat treatment for vegetables is also necessary to fully develop their flavour and texture.

[16] In citrus fruit processing, peels are collected following fruit pressing, ground, then treated with lime to neutralize residual acids, after which an essential oil d-limonene can then be extracted for use in other industries. The liquid obtained in the course of this process is screened to remove large particles and concentrated in an evaporator to produce a syrup which may also find uses in other industrial processes.

[17] With a pH of 4.5 or lower.

Chart 1. Fruit and vegetable processing operations



Source: Adapted from the "Technical pollution prevention guide for the fruit and vegetable processing industry in the Lower Fraser Basin", Environment Canada, DOE FRAP 1996-18.

1. *Process operations in tomato canning*

By way of illustration, the following paragraphs describe steps involved in the canning of whole tomatoes.

(a) *Preparation*

Tomatoes are thoroughly washed using high-pressure water spraying or counter-current streams of water on a moving belt or agitating screens. Grading for size is by means of a series of screens with different mesh sizes. Classification according to ripeness or shape is carried out manually.

(b) *Peeling and coring*

Hand peeling was the general practice following scalding. Steam and lye peeling have become more widely used, however. In the former process tomatoes are exposed to steam to detach the skin, which is then removed mechanically. A hot lye solution of 10 to 20 per cent alkali is used in the lye peeling. Thorough washing is needed to remove excess alkali that adheres to the surface of the peeled product.

Coring is effected by means of a device that uses pressurized water.

(c) *Filling*

Peeled and cored tomatoes are automatically conveyed to a filling point. Cans and glass containers are cleansed using hot water, steam or pressurized air, prior to being filled with the solid product. A light purée of tomato juice is often added together with a small amount of sugar and citric acid.[18]

(d) *Exhausting*

The next step involves removing air from the container. This helps extend the shelf life of the product. Reduced pressure is generally obtained by the use of heat. Thus the cans or jars filled with tomatoes may be preheated before filling, then sealed hot.[19]

(e) *Sealing*

This is invariably done by mechanical means. Before the lids are sealed, machines reduce the pressure in the headspace by a blast of steam or by means of mechanical pumps.

(f) *Heat sterilization*

Destruction of micro-organisms causing spoilage is effected by heat during processing. Temperature and exposure times vary from one raw material to another. It is also important to take the dimensions and the material of the container into account in the design of the sterilization step.

Lower temperatures of around 100°C, are adequate with an acidic product such as the tomato. Containers may thus be processed in steam or hot-water cookers at atmospheric or slightly increased pressure. Rotary continuous cookers, operating at 100°C have replaced retorts and open-still cookers for processing canned tomatoes.

(g) *Cooling*

Rapid cooling is essential following heat sterilization in order to avoid overcooking. This is achieved by adding water to the cooker or by conveying the containers into an enclosure equipped with a cold-water spray.

(h) *Labelling and casing*

High-speed glueing and labelling machines are generally used. The labelled cans or jars are then packed into cartons for shipping or temporary on-site storage.

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[18] Acidification with 0.1 to 0.2 per cent citric acid is used to prolong preservability and improve taste. The addition of 2-3 per cent sucrose and some salt is purely to improve taste.

[19] Cans or jars may also be passed through a steam chamber prior to sealing. This has the combined effect of expelling air gases as well as raising the temperature. Sealing containers in a vacuum chamber is also possible in cases where further heating of the contents is undesirable.

2. *Fruit and vegetable waste streams and pollution abatement*

Table 2 provides a list of the major sources of environmental pollution resulting from fruit and vegetable processing operations, with possible measures that may alleviate or eliminate their adverse impact.

TABLE 2. FRUIT AND VEGETABLE PROCESSING OPERATIONS AND POSSIBILITIES FOR POLLUTION ABATEMENT

Operation	Objective	Possibilities for waste reduction and pollution abatement
Inputs and inventory	Improving input raw material quality	- Work with suppliers to improve quality (e.g., feedstock/product condition, ripeness, damage, and variety)
Inventory	Waste reduction through management improvement	- Institute computerized reception and intermediate storage systems in order to apply "just-in-time" concepts
Ingredient despatch and make-up	Improving process control	- Improve product initial cleansing and conveying systems: use dry initial cleansing and conveying rather than wet initial cleansing and conveying
Product preparation	Waste reduction	- Minimize product contact during cleansing - Re-examine process steps to identify possible redundancies, e.g., necessity for peeling certain products, possibilities of incorporating peel as ingredient in other steps or products - Optimize waste dump frequency and examine possibilities for reuse of cleansing and ion-exchange washings - Improve peeling, slicing, cutting, grating, evaporation and sterilizing technology - Install drip trays to catch juice/product on conveyors preparation and trimming tables - Explore different blanching processes to reduce water usage
Various operations throughout process	Recycling and reuse	- Install equipment and re-arrange flows to recirculate product wash water for non-critical cleaning processes - Install settling tanks and monitoring equipment to treat water from flumes for in-plant raw material transportation - Install auxiliary equipment to regenerate cooking oils or despatch for off-site regeneration - Recover usable material from wastewater, e.g., starch, sugar, citrus oils, etc. - Wash organic residues in order to optimize extraction of valuable essential oils and other usable products - Install composting or vermiculture facilities for organic waste material that may not be used as input in other industrial processes or as animal feed
Waste treatment and disposal	Wastewater reuse	- Remove excess water from organic solid waste by mechanical means
Marketing	Waste reduction	- Develop new products that allow profitable use of off-specification material and quality trimmings, e.g., in salads, pre-cooked meals, jams, etc.

Source: "Cleaner Production Fact Sheets; Food Manufacturing Series", the UNEP Working Group, Centre for Cleaner Production in the Food Industry, University of Queensland, Australia. Published on the Internet.
URL: http://www.Geosp.uq.edu.au/emc/CP/Fact 3.htm

(a) *Wastewater and solid waste*

Contaminated wastewater and solid processing residues constitute the principal pollution sources from fruit and vegetable processing. Wastewater from this industry is generally rich in suspended solids, sugars and starches. Significant amounts of pesticide residues may also exist in the wastewater stream.

Solid waste, on the other hand, includes rind, seeds, and skin from raw materials. It can often be re-sold as animal feed. Alternatively it can be composted or vermi-composted[20] into organic fertilizers.

One of the difficulties faced in waste management in the fruit and vegetable processing sector is its seasonal nature and dependence upon the varieties of fruit and vegetable being processed. The composition of wastewater and solid waste produced by a given plant will vary, of course, according to the specific raw material being processed.

In general, solid waste reduction has received little attention. Pre-treatment to reduce raw material losses is, nevertheless, reflected in the reduction of both solid and water-borne waste.

Most EST advances and research in fruit and vegetable processing have focused on reducing the volume of wastewater. As to wastewater treatment, most fruit and vegetable processors in the industrial countries use traditional bio-processes for wastewater treatment. Application of wastewater treatment methodologies based on improved understanding of chemical degradation routes of pesticides and herbicides have helped reduce their residues in wastewater discharge in these countries. This may be a useful line to follow in research aimed at similar results in the ESCWA member countries.

(b) *Air emissions*

Fruit and vegetable processing involves a number of high-moisture operations. Air emissions may, therefore, tend to be steam-borne or associated with water vapour. The high moisture content of such emissions may interfere with the collection or destruction of undesirable constituents. Special consideration is therefore necessary in the design and operation of equipment dealing with air emissions produced in this segment.

Wastewater treatment ponds and temporary solid waste dumps may be another source of malodorous emissions.

Particulate matter (PM) is emitted mainly during handling, trimming, cleaning and drying of solids. Whereas soil-based dust may constitute the most common PM source emitted during cleaning and trimming, PM produced during thermal processing operations includes the condensates of vapours. Their sizes may fall within the low-micrometre or sub-micrometre particle-size ranges.

Volatile organic chemicals (VOCs) are highest in thermal processing operations, such as cooking and evaporation.

Emission controls available to the canning industry include wet scrubbers, dry adsorbents, and cyclones. In particular, control of VOCs from gas streams is most commonly carried out using absorption, adsorption and afterburning. Absorption involves wet scrubbing with aqueous solutions. Mist eliminators are necessary downstream of the scrubber.

Adsorption of VOCs is most commonly carried out using activated charcoal. This is a relatively expensive technique and may not be effective in certain situations. Particulate matter is most commonly dealt with using Venturi scrubbers, dry cyclones, wet or dry electrostatic precipitators (ESPs), or dry filter systems.

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[20] Vermi-composting is the term used in describing a composting technique in which varieties of earthworms are deliberately introduced with a view to enhancing the quality of the resulting compost.

Condensation of vapours emanating from cooking, drying or expression of certain fruit may be carried out to retrieve essential oils. This also reduces the VOC load in fruit and vegetable processing emissions.

Condensers may be used in either direct or indirect contact with the vapour. The most frequently used one is the indirect contact type which is less demanding on construction materials and maintenance.

B. PROCESSING OF MILK AND DAIRY PRODUCTS

The basic function of the milk and dairy products segment is the manufacture of foods based on milk or milk products, as well as the extraction and processing of other milk components for use in other industrial or medicinal applications.[21] The dairy sector is often divided into two sub-segments: fluid milk products, and processed milk products. The fluid milk category includes milk-based chocolate drinks, as well as yogurt and related products. A list of fluid milk and processed dairy products is presented in table 3.

TABLE 3. FLUID MILK AND PROCESSED DAIRY PRODUCTS

Products of the fluid milk category	Processed dairy products	
Pasteurized milk	Cream dried, powdered	Butter
Yogurt	Curds	Butter oil
Skimmed milk, fluid, processed, fresh	Dairy powder blends	Cheese
Whole milk, fluid, processed, fresh	Dairy powders with fat additives	Cheese spreads
Buttermilk	Evaporated milk	Chip dip (milk base)
Chocolate drink (milk base)	Ice-cream	Condensed milk
Cream, fluid, processed, fresh	Powdered milk	Cottage cheese
Cream, fluid, processed, sour	Processed cheese	Ice milk products
Egg nog	Sherbets	Lactose
	Specialty cheese	Malted milk mix
	Whey products	Milk-shake mix
	Paste cheese	

In many of the industrialized countries, e.g., the United States and those of the European Union, production of fluid milk products, with the exception of skimmed milk and butter, has steadily declined during the past decade. On the other hand, production of specialty items such as yogurt and ice-cream has increased. A similar trend might be expected in the ESCWA countries in respect of the latter development. The fact that little large-scale processing of fluid milk products has taken place in the past, coupled with changing lifestyles and rising standards of living, albeit principally in certain sectors of the population, should provide the impetus for such future expansion.

Facilities in the fluid milk processing category are for pasteurization, homogenization, vitamin fortification, bottling and distribution of fluid milk and cream and related products. The principal steps in processing dairy products are listed in box 3.

Box 3. The principal steps in processing dairy products

(a) Milk clarification or filtration;
(b) Blending and mixing;
(c) Pasteurization and homogenization;
(d) Process manufacturing;
(e) Packaging;
(f) Clean-up.

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[21] Based on the Standard Industrial Classification (SIC) system. This segment's operations are further sub-categorized as fluid milk industry - (SIC) codes 1041, and other dairy products - (SIC) codes 1049.

1. *Raw materials*

Raw materials utilized in the dairy products processing industry typically include:

(a) Dairy products: milk and milk products including cream, condensed or dried milk and whey, etc.;

(b) Non-dairy ingredients: sugar, corn syrup, fruit, flavours, nuts, preserves, and fruit juices that are utilized in certain manufactured products such as ice-cream, flavoured milk, frozen desserts, yogurt, and others such as food colouring, biscuits and chocolate-solids.

There is a good deal of variation from one processing establishment to another in the raw materials selected for inclusion in a single dairy product. Chart 2, illustrates the sequence of operations involved in milk and dairy processing, emphasizing material inputs and waste output.

(a) *Process and handling operations*

Receiving, storage, transfer, clarification, separation, pasteurization and packaging are common to most categories of the milk and dairy product segments. Other operations, including churning, flavouring, culturing and freezing, are carried out in specific segments.

The following sections describe the principal operations in milk and dairy product processing facilities.

(b) *Transportation*

The principal raw material, milk, arrives at dairy processing plants in metal, generally stainless steel, cans or tanker trucks.[22] These are usually emptied into receiving tanks upon receipt or after a short period of storage. Other raw materials, such as sugar, corn syrup and preserves, arrive, suitably packaged, in either liquid or solid form.

2. *Unit operations*

The following typical unit operations are employed in the dairy products industry for processing milk and other non-dairy ingredients into specific dairy products:

(a) Storage of raw materials: storage of raw milk and other ingredients in controlled and refrigerated storage tanks, the latter primarily for the storage of fruit;

(b) Clarification/separation: straining and separating the various components of the liquid products by centrifugal devices or mechanical filters;

(c) Pasteurization: heating the milk products in either continuous flow units or batch type units;

(d) Homogenization: breaking up the butterfat particles and keeping them in suspension by the use of pressure pumps;

(e) Deodorization: removal of the off-odours and flavours in the raw milk by vacuum steam injection treatment;

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[22] The practice in the case of factory processing of fluid milk in the ESCWA member countries is to use metal, generally aluminium cans, or plastic, mainly polyethylene or polypropylene, containers for the transportation of milk from farms or herding areas to processing locations.

(f) Evaporation: removal of water in milk, cream and/or whey by heating with steam in a vacuum chamber;

(g) Churning: agitating, separating, and gathering of the oily globules for butter;

(h) Cooking: cooking and inoculating the milk products with a culture for cheese production;

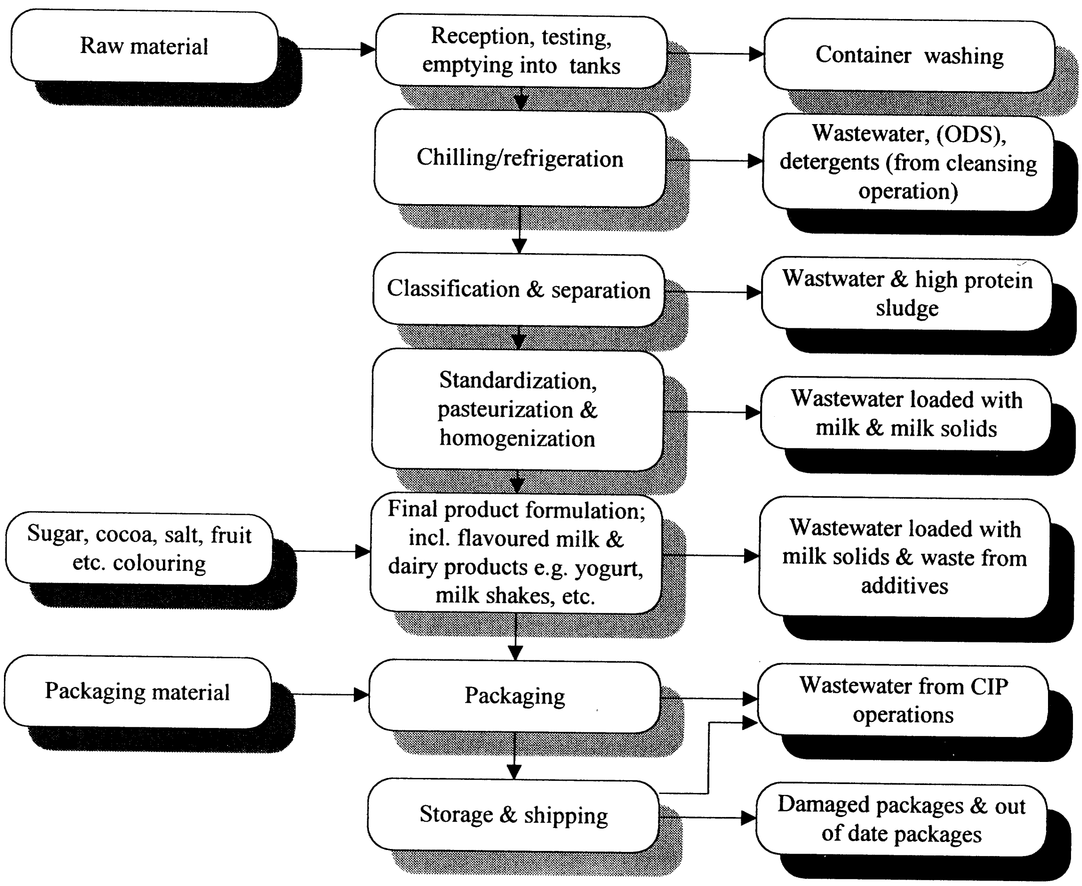
(i) Flavouring: blending of the other ingredients such as liquid fruit juice, artificial flavours into the products (ice-cream);

(j) Solid injection: addition of nuts and fruit pulp into the products (ice cream);

(k) Storage of processed products: cold storage for the manufactured products;

(l) Bottling and packaging the products for the end users.

Chart 2. Milk and dairy processing operations



Source: Adapted from the "Technical pollution prevention guide for the fruit and vegetable processing industry in the Lower Fraser Basin", Environment Canada, DOE FRAP 1996-11.

(a) *Effluent in milk and dairy processing*

Table 4 presents a list of major sources of pollution generated by fluid milk and dairy product processing. Objectives targeted by environmentally sound technologies and other measures aimed at improving waste management are included in the last column of this table.

TABLE 4. PRINCIPAL MILK AND DAIRY PROCESSING OPERATIONS AND POSSIBILITIES FOR POLLUTION ABATEMENT

Operation	Objective	Possible improvements through technology inputs and work procedures
Raw materials: arrival, handling and unloading	Waste reduction	- Reducing waste might require improving herd quality as well as improved technology inputs in milking, refrigerated transportation and reception facilities, e.g., intermediate storage under cover - Implement material handling, storage control and transportation container designs that minimize or eliminate spillage
Ingredient handling	Waste reduction	- Introduce modern in-plant ingredient transportation and handling technology, e.g., pneumatic conveyor systems for dry materials
Product preparation	Waste reduction and quality improvements	- Introduce systems that minimize foaming - Install seals, valves and pumps that minimize leakage - Inspect lines and connections for leakage
Processing	Waste segregation and reduction	- Introduce automatic temperature control systems - Separate drained contents of processing lines, during operation change over, from general waste stream - Improve separation systems using centrifugal separators or other controllable mechanical devices - Improve work space cleaning practices by separating solid from liquid waste at earliest opportunity - Install equipment that allows utilization of whey in products or install anaerobic digesters to generate methane gas - Install computerized inventory systems to control ingredient use and avoid waste due to accumulation of out-of-date raw materials, e.g. nuts, fruit parts, etc.
Product despatch	Waste reduction	- Install computerized inventory systems to control intermediate storage and shipping
A variety of operations throughout	Recycling and by-product reuse	- Install means to allow recovery of entrained products, especially highly concentrated material as in evaporators and condensed milk lines - Install means that allow reuse of process water from pasteurizing units - Recover broken or damaged packages and recycle contents, preferably in-house for animal feed supplements, etc. - Segregate detergent as well as acid and alkali-laden waste for separate treatment routines - Install screens to separate solids from wastewater streams

Source: Adapted from "Cleaner Production Fact Sheets; Food Manufacturing Series", URL: http://geosp.uq.edu.au/emc/op/Fact2.htm

3. *Dairy wastewater streams*

A considerable wastewater stream is generated in milk and dairy processing during start-up and shut-down operations performed in high-temperature, short-time (HTST) pasteurization processes. This waste stream is generally composed of pure milk raw material mixed with water and a limited amount of cleansing ingredients. Another dairy segment waste stream is produced from equipment and tank-cleaning wastewater. Both streams contain waste milk and a variety of sanitary cleaners. An important characteristic

of milk-processing wastewater is that the milk in the wastewater tends to degrade, giving rise to corrosive lactic and formic acids. Pollutants and effluent parameters of concern in the dairy industry include:

Biological oxygen demand (BOD_5);
Total suspended solids (TSS);
pH (acidity and alkalinity);
Temperature;
Phosphorus, nitrogen and chloride content;
Process wastewater volume;
Oil and grease.

Further information on the above-mentioned pollutants and effluent parameters is presented below.[23]

(a) *Biological oxygen demand (BOD_5)*

Waste material in dairy plant wastewater consists of milk solids and other organic matter. Cleansing materials, sanitizing solutions and lubricants also tend to be of an organic nature, although some inorganic substances may be used in cleaning operations. As a result, the BOD_5 concentration of raw wastewater in the dairy products processing industry typically falls within the range 1,000-4,000. This is reported to correspond to an actual waste load of between 16 and 0.4 kg per 1,000 kg of milk equivalent.[24,25]

A positive correlation has been established between BOD_5 and the concentration of solids in dairy wastewater. The ratio of solids concentration to BOD_5 was found to be around 0.4. Economics dictate that treatment to remove BOD_5 in the liquid phase is higher than that designed to remove BOD_5 in the solid phase. Every effort should be made, therefore, to reduce the solid phase BOD_5 in dairy effluents. Common physical separation methods such as screens, filters and centrifugation are used to remove the major proportion of solid BOD_5 sources prior to discharge to the city sewer. Some of the centrifuges are equipped with the automatic clean in place (CIP) system and collect the sludge as solid waste.

After separating the bulk of the solids in the process effluent, the remaining soluble BOD_5 in the wastewater is generally treated on-site using biological treatment systems such as trickling filters or activated sludge processes.

Organic components of non-dairy ingredients (e.g., sugar and syrup), cleaners, sanitizers and lubricants, released from the mechanical conveying systems, are additional sources of BOD_5 in the wastewater.

(b) *Total suspended solids (TSS)*

The amount and nature of suspended solids in raw dairy plant waste varies widely among different processing operations and plants. Up to 2g/l of suspended solids, most of which are organic and derived from milk, can be recovered from dairy wastewater. Such solids include coagulated milk, particles of cheese curd as well as solid material, e.g. pieces of fruit and nuts from ice cream processing operations. Suspended solids loadings range between 0.03 and 2.9 kg of suspended particles for 1,000 kg of milk equivalent.

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[23] This data is based on the United States Environmental Protection Agency, Office of Research and Development, Dairy Food Plant waste and Waste Treatment Practices, March 1971 (EPA Report 12060).

[24] "Technical pollution prevention guide for dairy processing operations in the Lower Fraser Basin", Environment Canada 224, West Esplanade, North Vancouver, B.C., V7M 3H7.

[25] Milk Equivalent (ME) is a unit derived from the correlation that 100 kg of processed milk is equivalent to 1,000 kg of whole milk received, i.e., approximately 10 per cent by weight.

(c) *Phosphorus, nitrogen, and chloride*

As indicated above, a considerable source of phosphorus, nitrogen and chloride pollutants in dairy wastewater is the use of detergents and sanitizing agents used in routine cleaning and sanitizing operations. Adoption of Better Management Practices has been found to reduce the need for detergents in several cleaning procedures. The use of filter separations is a cheap and relatively rapid means of removing or reducing the concentration of these pollutants.

(d) *Phosphorus*

Only a small part of the phosphorus in dairy wastewater comes from the milk or milk products that enter the waste stream. Wastewater containing 1 per cent milk would normally contain about 12 mg/l of phosphorus, determined as phosphate (PO_4^{3-}). The bulk of the phosphorus in this waste originates from the detergents and cleansing solutions, which typically contain significant amounts of this substance. A wide range of phosphate concentrations, between 9 and 210 mg/l, with a mean approximate value of 28, reflects a corresponding variation in the use of detergents and in the recycling of cleaning solutions.

(e) *Nitrogen*

Typical ammonia nitrogen concentrations in milk processing wastewater range between 1-13.4 mg/l, with a mean value around 5.5 mg/l. Total nitrogen concentrations fall within the range of 1-115 mg/l, with a mean value at around 64 mg/l. At a concentration of around 1 per cent in wastewater, milk alone would contribute about 55 mg/l of nitrogen. Quaternary ammonium compounds and certain other detergents and sanitizing agents further contribute to nitrogen concentrations in dairy processing wastewater.

(f) *Chloride*

Chlorine-based sanitizing agents and brine from cooling and refrigeration equipment are the principal sources of chloride in the wastewater. Milk and milk products contribute a very small part of the chloride load. Thus, at a 1 per cent concentration of milk in the wastewater, milk would contribute 10 mg/l of chloride compared to the normal range of chloride concentrations of between 1.9-0.05g/l and a mean value at around 0.5g/l.

(g) *Process wastewater volume*

The volume of wastewater produced by dairy processing plants covers a wide range, 542-9,000 litres per 1,000 kg of milk equivalent. The actual amount of water finally rejected may be much less than this in actual fact. In particular, water recycling could play a major part in reducing water consumption.

(h) *Oil and grease*

The concentration of oil and grease in wastewater is of special concern for facilities discharging to surface waters or municipal treatment systems. Discharge limits for oil and grease in some industrialized countries are around 150 mg/l.

(i) *Temperature*

Thermal pollution may constitute a problem in situations where discharge is into surface water systems of limited proportions or into small treatment plants. In general, the temperature of the wastewater stream is affected primarily by the degree of hot water and steam recycling operations and the temperature of the cleaning solutions. Higher temperatures can be expected in plants that manufacture dried, evaporated or condensed milk products. Typical temperature values of raw dairy wastewater range between 8 and 38°C with a mean value of around 24°C.

(j) *Wastewater pH*

The pH of raw dairy wastewater varies from 4.0 to 10.8 with a mean value of around 7.8. The main factor affecting the pH of dairy plant wastewater is the type and amount of cleansing and sanitizing compounds discharged to waste at the processing facility.

The amount of whey from the cheese manufacturing processes released into the effluent stream also influences the ultimate pH value of the wastewater. The combined dairy processing waste stream is generally neutral. Deviation from neutrality may be corrected through the addition of chemicals such as caustic soda (NaOH) and sulphuric acid (H_2SO_4), used to re-establish the neutral pH of the combined effluent.

4. *Waste management methods in milk and dairy processing*

Dairy plant wastewater effluent consists mainly of lost raw materials as well as intermediate and finished products. Materials used in cleaning and sanitizing containers and processing equipment appear in process wastewater discharged by the plant. Whey, a by-product of cheese manufacturing operations, is a significant pollution problem. Waste generating processes of major significance in the dairy products processing machines are the following:

(a) Washing, cleaning and sanitizing of piping, pumps, processing equipment, tanks and filling machines;

(b) Start-up, product changeover and shut-down of high temperature and short time (HTST) and ultra high temperature (UHT) pasteurizers;

(c) Losses in filling operations through equipment jams and broken packages;

(d) Lubrication of casers, stackers and conveyors.

In summary, the focus of EST in the milk and dairy processing industry in the developed countries, has essentially been on:

(a) Improved energy use through heat recycling and the use of more modern evaporation and heat exchange systems;

(b) Retrieval of useful by-products from waste streams to the greatest possible extent economically feasible;

(c) Treatment of wastewater and gaseous effluent in accordance with ever-stricter regulations.

In the latter area, in particular, new fermentation processes that make use of innovative enzyme systems in special bioreactors may achieve the dual purposes of reducing pollution loads in wastewater and extracting useful by-products for use in industrial and other applications.

C. MEAT, POULTRY AND SEAFOOD PROCESSING

Meat, poultry, and seafood processing present firms and public treatment facilities with greater challenges than other FPI segments. Blood, tissue fragments and the products of their degradation produce waste streams with extremely high BOD values. Pathogenic organisms constitute another important hazard. It is for this reason that this segment of the food processing industry is closely regulated and monitored by public health and other government departments. Specialist-inspectors and local health officials maintain an especially close watch over meat, poultry, and seafood facilities both in the industrialized countries and in many of the developing countries.

With minor exceptions, meat, poultry and seafood processing practices in the ESCWA member countries lack the sophistication of modern plants in the developed countries. The fact that most processing is carried out by small and micro enterprises hampers adequate waste processing. Improvements have nevertheless occurred at two levels: In most ESCWA member countries enterprises based on reprocessing waste from abattoirs and butchers' shops make daily rounds to collect refuse, mainly bones, excess fat and other waste for processing into gelatin, glue and assorted fat products; in addition, new meat and poultry processing plants, particularly in the gulf region, are better equipped than older facilities for waste collection, handling and further processing. Table 5 presents a list of meat processing operations and their major waste items. Essential steps in meat and poultry processing are listed in chart 3.

TABLE 5. MEAT PROCESSING OPERATIONS AND THEIR WASTE

Operation	Waste items
Transportation and holding	Manure, hair, feather, grit, dead animals
Slaughter	Blood and other body fluids
Cleaning	Manure, hair, feather, grit
Trimming, cutting and evisceration	Blood and other animal tissue
Inspection	Rejects
Processing into canned and other prepared foods	Additives, including spices, sauces, brines, drippings Oils and fatty material from cooking Damaged batches and packages, etc.
Cooling and storage	Contaminated ice and other cooling aids, damaged products due to poor warehousing or other defects

Source: "Cleaner Production Fact Sheets; Food Manufacturing Series", the UNEP Working Group, Centre for Cleaner Production in the Food Industry, University of Queensland, Australia. Published on the Internet.
URL: http://www.Geosp.uq.edu.au/emc/CP/Fact7.htm

1. *Meat and poultry processing waste streams*

Waste streams in this segment generally include process wastewater; carcasses and skeletal waste; fats, oils, and greases (FOG); feces; blood; and eviscerated organs. In a number of industrial countries solid waste from this segment is often used as animal feed additives.

Abattoir solid waste is high in protein and nitrogen. As such they constitute suitable sources for fish farming feed and canned pet foods. Skeletal remains are converted into bonemeal, a rich source of phosphates for fertilizers. Fat, oil and grease waste, particularly from fish canning plants, are further processed to extract raw materials used in several industrial sectors including toiletteries and beauty products.

2. *Water consumption in meat and poultry processing*

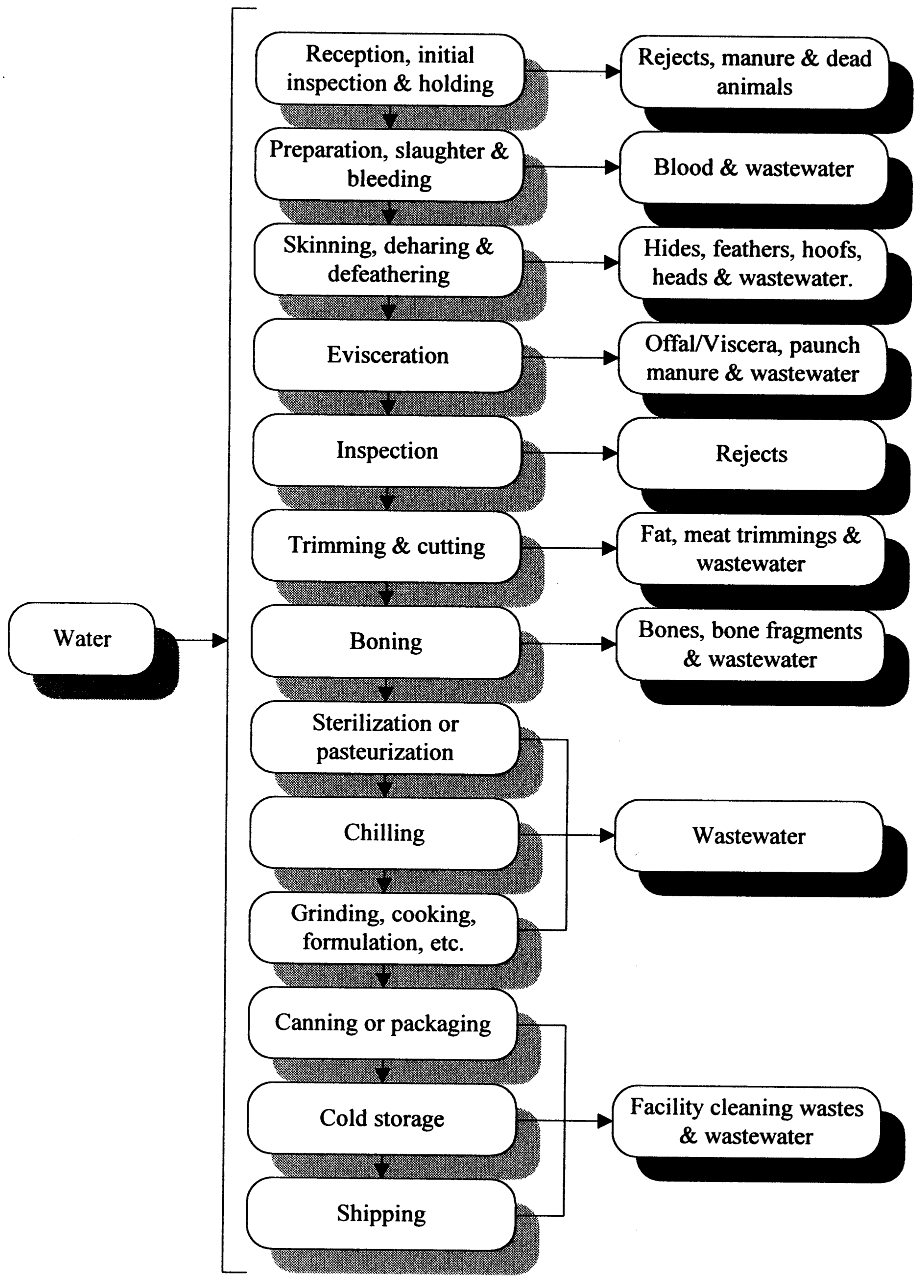
Water is used in meat and poultry processing facilities primarily for washing carcasses at the end of each operation. Additional water is used for cleaning machinery and process areas. Little of the water intake of a meat or poultry processing plant is incorporated in unit output. Thus, the volume of wastewater constitutes 80-95 per cent of the total freshwater input. It is estimated that between 44 and 60 per cent of process water is used up in the slaughter, evisceration and boning operations.[26] Water consumption rates range from 6-15 m^3/ton.[27]

[26] Fact sheet 7, an electronic publication of "The UNEP Working Group Centre for Cleaner Production in the Food Industry", supported by the University of Queensland, the Queensland Department of State Development, the United Nations Environment Programme and the Queensland Environmental Protection Agency.
URL: http://www.geosp.uq.edu.au/emc/CP/default.HTM

[27] Calculated on the basis of hot standard carcass weight (HSCW).

In general, poultry processing is more water-intensive than red meat processing. This is primarily due to the fact that, in the latter, water is used for scalding prior to de-feathering and for chilling the birds after cleaning, as well as for transporting feathers, and body parts via water flumes.

Chart 3. Meat and poultry processing operations and major input and output items



Source: "Cleaner Production Fact Sheets; Food Manufacturing Series", the UNEP Working Group, Centre for Cleaner Production in the Food Industry, University of Queensland, Australia. Published on the Internet.
URL: http://www.Geosp.uq.edu.au/emc/CP/Fact7.htm

Water consumption rates in developed countries are in the range 15-90 m^3/1,000 birds processed[28] and vary considerably depending on the type of process used.

The most significant factor in water consumption for cleaning of work space is the total surface area requiring cleaning. The intended market is an important factor in determining the level and intensity of cleansing processes.[29]

Fresh water intake has a major impact on the volume and pollutant load of the resulting wastewater. Meat and poultry processing plants generally produce wastewater with high organic loads, particularly rich in oils and grease, salt, nitrogen and phosphorus. Rendering operations are a source of considerable wastewater contamination. Although wastewater from rendering operations represents around 10 per cent of the total volume of meat and poultry processing wastewater, it contains around 60 per cent of the plant's total COD output. Comparison of red meat processing COD output without rendering to that measured for processing plants incorporating rendering operations reveals that the latter generate around 49 kg COD/ton HSCW, whereas the former produce only about 13 kg COD/ton HSCW.[30] Table 6 summarizes the results of a survey of nine red meat abattoirs in Australia.[31]

TABLE 6. SUMMARY OF SURVEY RESULTS ON EMISSIONS FROM RED MEAT ABATTOIRS IN A DEVELOPED COUNTRY

Resource consumption/waste generation (per ton HSCW)	Average	Range	Benchmark
Water (m^3)	11.8	6-15	12
Energy (MJ)	3 400	1 200-4 800	1 700
Wastewater (m^3)	10.1	6-13	8
Wastewater load			
- Phosphorus (kg)	0.3	0.1-0.5	0.5
- Nitrogen (kg)	1.7	0.9-3.4	1.5
- BOD_5 (kg)	30	8-66	15

Source: Fact sheet 7, an electronic publication of "The UNEP Working Group Centre for Cleaner Production in the Food Industry", URL: http://www.geosp.uq.edu.au/emc/CP/default.HTM.

3. *Environmentally sound technologies in meat and poultry processing*

In general, environmentally sound technologies in meat and poultry processing is focused on the following:

(a) Reduction of water consumption;

(b) Effective treatment and re-utilization of wastewater;

(c) Improved preservation of products for direct consumption;

(d) More effective cooking and other processing means for the production of canned and pre-cooked meals;

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[28] Fact sheet 7, an electronic publication of "The UNEP Working Group Centre for Cleaner Production in the Food Industry", URL: http://www.geosp.uq.edu.au/emc/CP/default.HTM. Quoting Hrudey, 1984.

[29] Plants geared to export and long-term preservation in countries such as Australia, are required to install more rigorous sterilizing units, in turn, increasing water consumption.

[30] Calculated on the basis of hot standard carcass weight (HSCW).

[31] A benchmark of 8 m^3/ton HSCW for red meat has been established by the Australian Meat Research Corporation. See URL: http://www.geosp.uq.edu.au/emc/CP/default.HTM.

(e) Improvements in technology designed to produce higher value-added products from industrial waste.

Table 7 provides summary information on major waste reduction objectives for specific operations in meat and poultry processing as well as possible action to achieve those objectives, some of which will entail acquisition of new technology, with the aim of reducing waste and improving compliance with quality standards.

Reduction of water consumption is being addressed through dry-cleaning methods as well as wastewater reuse. However, wastewater treatment technology used in this segment should be capable of dealing with extremely high BOD_5 values.

Sterilization and pasteurization processes will benefit from new high-pressure steam cleaning methods. Irradiation, on the other hand, will help prolong shelf life, thus reducing waste and attendant pollution and disposal costs.

Conventional cooking methods are still generally in use in this segment. Research and development on new cooking methods including electric pulse techniques, is in progress.

4. *Water conservation and wastewater treatment in the meat and poultry industries*

Efficient water use is dictated mostly by cleaning and washing practices rather than by the type of process or equipment used. Therefore, adoption of methods that enable dry-cleaning by means of spray nozzles on hoses and reuse of wastewater for cleaning in non-critical operations should result in a markedly improved environmental impact.

In poultry processing, more water-efficient equipment, the use of pneumatic waste handling systems instead of water fluming and modern scalding systems prior to de-feathering should also significantly reduce water consumption.[32]

A number of relatively simple means can contribute positively to reducing pollution from meat processing. The following are a few examples:

(a) Efficient segregation and recovery of blood is necessitated by its highly polluting nature: Instituting means of ensuring such segregation considerably lowers pollution loads, by up to 40 per cent;[33]

(b) Installation of screens to recover solids from the wastewater stream;

(c) Use of biodegradable detergents and sanitizing materials;

(d) Collection of manure and intestinal contents without the utilization of water;

(e) Installation of facilities to retain hair and meat trimmings.

Ultimately, biological treatment of wastewater will reduce organic load and to some extent nutrient levels, allowing safe discharge into surface water systems or even its use for irrigation under controlled conditions.

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[32] Fact sheet 7, an electronic publication of "The UNEP Working Group Centre for Cleaner Production in the Food Industry", URL: http://www.geosp.uq.edu.au/emc/CP/default.HTM. Quoting Nielsen, 1989 and Carawan, 1996a.

[33] Fact sheet 7, an electronic publication of "The UNEP Working Group Centre for Cleaner Production in the Food Industry", supported by the University of Queensland, the Queensland Department of State Development, the United Nations Environment Programme and the Queensland Environmental Protection Agency.
URL: http://www.geosp.uq.edu.au/emc/CP/default.HTM

Many of the by-products from meat processing can be processed further into value-added products. For example, pet food from viscera, gelatin from head pieces, meat meal from hoofs, chicken parts, bone and horn, glue from hides and blood meal and small goods from blood. Significant cleaner production gains can be realized by maximizing the utilization of these materials so that they become resources rather than refuse.

An emerging opportunity which may be useful for some of the larger facilities is the recovery of energy from the anaerobic digestion of wastewater. Biogas is produced from the anaerobic decomposition of the organic matter contained in the wastewater and can be used to displace natural gas or LPG in a boiler or to generate electricity.

Using anaerobic generation technology to produce biogas energy from abattoir wastewater is a viable option for the larger meat processing operations.[34]

5. *Seafood processing*

Seafood processing is generally construed as including the handling and processing of all marine plants and animals, as well as by-products such as fish meal, used as an animal feed additive, and fish oil extraction and refining.

A limited amount of fish processing takes place on an industrial scale in the ESCWA member countries. Facilities for fish and prawn cleaning and freezing have been set up in Kuwait, for example. Nevertheless, some of the observations made regarding environmentally sound technologies in fish processing apply to small-scale fish cleaning and preparation carried out in specific locations in fish markets around coastal regions.

Fish processing is an avid user of clean water. It is also a prolific producer of high BOD_5 effluent. Two of the most important considerations to address in this respect are:

(a) Wastewater recycling;

(b) Collection of offal, cuttings, trimmings, bones and spoiled materials for appropriate treatment or for recycling.

Technological inputs applicable in both operations are readily available and may be easily replicated for use in small fish processing plants as well as in large fish markets. Central units in such facilities would include de-watering belts, water treatment plant, high-pressure steam cooking of offal for the production of high value-added foods and inputs to other industries including pet food, fish meal for cattle and poultry feed supplements, protein hydrolysates, chitin, chitosan, and liquid and solid fertilizers.

TABLE 7. PRINCIPAL ABATTOIR AND MEAT CANNING OPERATIONS AND POSSIBILITIES FOR IMPROVEMENT OF ENVIRONMENTAL IMPACT

Process operation	Objective	Possible action
Animal delivery, initial inspection and holding	Waste reduction	- Improve animal induction procedures to reduce stress and mortality - Negotiate with suppliers improvements in feed regimes to reduce manure and paunch manure - Introduce IT in inventory management and adopt just-in-time practices to reduce holding periods

[34] SEDA, 1999 as quoted in Fact sheet 7, an electronic publication of "The UNEP Working Group Centre for Cleaner Production in the Food Industry", URL: http://www.geosp.uq.edu.au/emc/CP/default.HTM. Quoting Nielsen, 1989 and Carawan, 1996a.

TABLE 7 (*continued*)

Process operation	Objective	Possible action
Slaughter, skinning, de-feathering and bleeding	Waste reduction	- Refrigerate or otherwise preserve trimmings etc. for use by other industries, e.g. skins for tanning, other parts for animal feed additives and pet foods - Introduce separate waste streams whenever possible - Process highly perishable parts *in situ* - Optimize temperature and overflow settings in scalding, de-feathering equipment - Segregate blood collection systems to reduce amount of blood lost to effluent stream and improve purity/quality of the blood by-products - Optimize hanging/letting times
Evisceration and cutting	Waste reduction By-product reuse and recycling	- Collect and initially treat viscera, paunch manure, etc., for use in other industries
Carcass and cut washing	Wastewater reduction	- Use high-pressure steam pasteurization
De-boning grinding and formulation	Reduce raw material waste	- Use pilot facilities to perfect formulation and reduce waste - Use grinding and kneading equipment with minimal dead space
Canning and other preservation procedures	Waste reduction	- New canning techniques that reduce waste - Use of irradiation technology to prolong shelf life and reduce waste
Rendering	Waste reduction	- Improve the rendering process (e.g., low/high temperature, dry rendering processes etc.) - Use enzymes to increase the efficiency of rendering, stickwater evaporation and protein de-watering
Miscellaneous solid waste	Waste reduction and higher value-added products	- Ferment to produce flavouring agents for animal feed - Compost or vermi-compost - Introduce IT methods to optimize by-product storage systems and maximize pick-up, processing schedules, temperature
Water recycling and reuse	Reducing water consumption and the volume of wastewater effluent	- Introduce customized as well as general-purpose water treatment plant - Recover rendering and other solids from wastewater - Use polymeric coagulants to increase water treatment efficiency - Reuse treated water in initial cleaning operations
Equipment cleaning	Reducing amount of detergent-laden wastewater	- Separate equipment washing waste streams whenever possible - Treat washing waste stream
Filling, packaging and storage or shipping	Waste reduction	- New packaging methods, e.g., modified atmosphere packaging, reduce contamination and hence waste

Source: "Cleaner Production Fact Sheets; Food Manufacturing Series", the UNEP Working Group, Centre for Cleaner Production in the Food Industry, University of Queensland, Australia. Published on the Internet. URL: http://www.Geosp.uq.edu.au/emc/CP/Fact7.htm

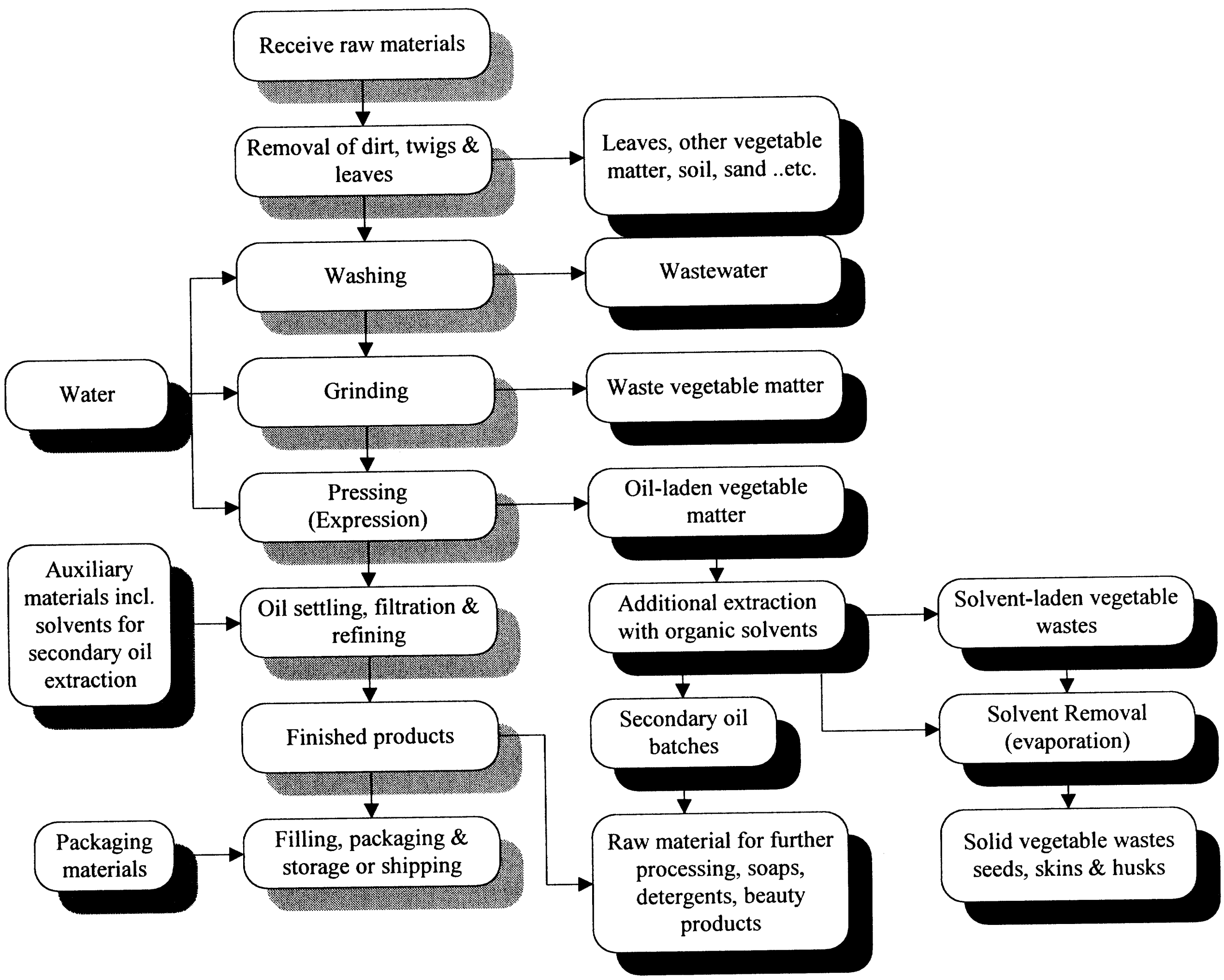
D. VEGETABLE OIL MANUFACTURE

The sequence of operations involved in extracting vegetable oils is presented in chart 4. Succeeding paragraphs will take a brief look at olive oil manufacture and the role that might be played by new technology in rendering it more compatible with environmental considerations.

Vegetable oils are extracted from seeds and fruit parts in most ESCWA member countries. A small number of operations is involved in vegetable oil extraction and processing. Considerable solid waste and wastewater, as well as volatile organic chemical emissions, are produced by this segment. Residual

vegetable matter following oil expression and subsequent extraction may constitute 60-70 per cent of the initial raw materials input.

Chart 4. Process steps, inputs and pollution generated in vegetable oil extraction



Source: "Cleaner Production Fact Sheets; Food Manufacturing Series", the UNEP Working Group, Centre for Cleaner Production in the Food Industry, University of Queensland, Australia. Published on the Internet.
URL: http://www.Geosp.uq.edu.au/emc/CP/Fact3.htm

The practice of using spent oil seeds and other associated vegetable material in animal feed is universally widespread, including also the countries of the ESCWA region. An important point in this connection is to provide intermediate storage conditions that ensure protection from infestation, particularly of toxin-producing fungal growth.[35] Apart from obvious health hazards, failure to do so could result in large amounts of solid waste that can be used only as fuel. Preliminary information from a number of operating facilities in these countries, however, points to inadequate storage conditions and difficulty in ensuring that residual seed shells and seed meal following oil expression remain free from contamination by toxic agents such as aflatoxins. The widespread lack of adequate means of conducting analysis to establish whether the materials are free of such contamination is also observed.

[35] For example, in the case of milk with a high level of mycotoxins.

The emission of volatile organic chemicals is considerable when vegetable matter is subjected to extraction by chemical solvents following the initial mechanical expression stage. Due to the importance of olive oil extraction and processing, succeeding paragraphs deal in greater detail with specific operations in this area.

1. *Olive oil extraction and processing*

Olive oil is manufactured from a number of olive varieties in the ESCWA member countries. The industry is expected to increase in volume and economic importance, particularly in countries such as the Syrian Arab Republic, due to recent considerable expansion of olive groves.

Several technological innovations will help enhance the environmental profile of the industry, in general. The introduction of centrifugal separation, modern water treatment and recycling, and the development of methods that enable the utilization of spent vegetable matter in value-added industrial activities. The introduction of optimized and automated operations is another innovation that promises considerable improvements in terms of environmental impact.

Production methods prevailing in the ESCWA member countries will render the introduction of automated operations somewhat difficult. However, other innovations present considerable opportunities for wider adoption. Local entrepreneurs could play an important part in the introduction of new technology such as water treatment methods based on new membrane technology and further treatment of vegetable waste.

2. *Olive oil processing waste and by-products*

Olive processing waste consists of olive solids and pits after pressing, termed “pomace”,[36] and residual vegetable water, or lees, following oil separation by decantation in many of the smaller facilities. Pomace is often re-processed in larger central facilities using steam and organic solvents to remove further quantities of oil trapped in the organic matter. The fibrous material left over from secondary extraction may be composted or burned. It is commercially valued as a fuel for pottery kilns on account of its steady burning properties and high heat output.[37] It is also used as a fertilizer. Ashes from burnt pomace are mixed with the “green” material for this purpose. The utilization of pomace as animal feed is also the subject of experimentation. Olive pits are reported to be a good smoke source for smoking meat.[38]

TABLE 8. OIL EXTRACTION OPERATIONS AND POSSIBILITIES FOR IMPROVEMENT OF THEIR ENVIRONMENTAL IMPACT

Process operation	Objective	Possible action
Raw material receipt and preparation	Waste reduction	- Composting refuse and vegetable matter for organic fertilization or in animal feed - Use of sun-dried vegetable matter as fuel
Raw material grinding	Dust and particulate emissions	Use: - Well-designed mills/grinders - Air filters and air locks
Expression	Waste reduction by-product use and recycling	Process expressed vegetable matter for use in: - Animal feed components - Further solvent extraction of oil - Other food-related applications - Fuel

[36] Termed “jift” in Arabic.

[37] Firms in Jordan are reported as making charcoal from pomace.

[38] “Disposal of olive processing by-products”, http://www.oliveoilsource.com/olive_waste.htm.

TABLE 8 (*continued*)

Process operation	Objective	Possible action
Straining, filtration and settling	Waste reduction by-product recycling	- Recycle and reuse filter and other auxiliary material - Use of oil-laden residues in other industries, e.g., soap and other detergent manufacture - Recycle and reuse filter and other auxiliary material
Solvent extraction	Reducing VOC emissions solvent recycling	- Retrieve and recycle chemical solvents - Recycle and reuse filter and other auxiliary material
Water recycling and reuse	Reducing: water consumption; volume of wastewater effluent	- Introduce custom-designed and general-purpose water treatment plant - Reuse process water in initial cleaning operations following settling and other minimal measures
Equipment cleaning	Reducing amount of detergent-laden wastewater	- Separate equipment-washing waste streams whenever possible - Recycle cleansing wastewater following treatment
Filling, packaging and storage or shipping	Waste reduction	- Automated filling machines may reduce spillage - Use appropriate packaging material to reduce breakage and spillage

Vegetable water, termed lees, that remains following oil separation presents disposal problems in many parts of the world. Legislation in many countries restricts dumping agricultural waste into city sewers or surface water systems. A certain amount is often sprayed back into olive orchards. Excessive disposal in this manner may endanger groundwater resources. In small amounts this water contains valuable trace elements as well as nitrogenous organic residues. Possible uses of olive lees to produce high value-added goods include extraction of antioxidant constituents for use in health foods.[39]

The amount of organic pollution, measured by the ratio of biological to chemical oxygen demand (BOD/COD), coupled with the variable flow rates/load and seasonal nature of effluent is a central problem for wastewater treatment plants.

Table 9 provides an analysis of olive lees from a Tunisian source.

TABLE 9. CHARACTERISTICS OF OLIVE LEES

PH	4.5-6	BOD_5	65-70 g/I
Water content	83-92%	COD	40-400 g/I
Organic and volatile material	7-15%	Polyalcohols	1-1.5%
Mineral solids	1-2%	Protein	0.5-7.5%
Residual oil	0.3-30%	Pectins and Tannins	1-1.5%
Reducing sugars	1-8%	Polyphenols	5-17 %
Total sugars	2-8%	Suspended solids	35-40 g/I

Source: Data for Tunisian olive oil wastewater; From "Disposal of olive processing by-products". [40]

3. *EST in vegetable oil extraction*

Emphasis in EST developments concerning vegetable oil extraction and processing appears to focus on the following areas:

[39] "Disposal of olive processing by-products", http://www.oliveoilsource.com/olive_waste.htm.

[40] "Disposal of olive processing by-products", http://www.oliveoilsource.com/olive_waste.htm.

(a) More thorough treatment of solid and waterborne waste, with greater possibilities for obtaining higher value-added products;

(b) Replacement of secondary extraction methods based on traditional chemical solvents by less harmful methods such as supercritical solvent extraction;

(c) Improvements in materials and machinery continuing to improve extraction efficiency with subsequent environmental benefits.

E. GRAIN MILLING AND BAKERY OPERATIONS

1. *Grain milling*

Grain milling is not generally regarded as a particularly polluting process. Nevertheless, if inadequately managed, significant quantities of water and air pollution may result from milling operations. Wastewater from equipment and work-space washing operations is generally high in BOD_5. Air that is laden with grain flour poses in-plant health, fire and explosion risks, as well as environmental problems in the plant's immediate surroundings. In addition, inadequate storage conditions can often lead to raw material, and, consequently, end-product contamination. Fungal toxins pose especially serious threats in grain mills and silos. Furthermore, misapplied rodenticide and pesticide preparations, if undetected, can lead to serious health problems. Serious economic losses ensue when contamination is allowed to reach unacceptable levels, since destruction of stocks by incineration is often the only viable solution.

The general sequence of grain milling operations is illustrated in chart 5, with particular reference to resulting waste products. Table 10 lists measures, including the introduction of technology, that need to be taken to achieve set pollution reduction objectives in grain milling operations.

Principal trends in modern grain mills appear to target technological changes as follows:

(a) Greater automation in most production steps;

(b) Application of improved analytical techniques for the determination of grain and grain-flour quality, with particular reference to the detection of possible contamination by agricultural chemicals;

(c) Incorporation of information technology systems in many aspects of mill operations, in inventory management, organization of production and maintaining detailed information on production runs;

(d) Emerging new plant designs into which modular design concepts are incorporated allowing greater flexibility and customized response to clients' needs;[41]

(e) Increased use of new materials, both metallic and polymeric, in the construction of grinding and auxiliary machinery, with wide-ranging objectives including the production of cleaner products, and reduced equipment maintenance, lubrication and cleaning.

The technological developments referred to above are in harmony with the current move towards greater compatibility with environmental standards. Indeed, most were developed with waste reduction and environmental protection as primary objectives in response to stricter environmental regulations in the developed countries.

Grain milling, particularly in the non-Gulf, ESCWA member countries, has traditionally been the domain of the public sector. Most establishments are still using obsolescent technology. Possibilities for

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[41] The fact that many operators in this segment, particularly in the developed countries, tend to be part of vertically-integrated enterprises has necessitated the introduction of a large degree of product variability, giving rise to departure from massive operations and opening the door to the smaller entrepreneurial establishments.

innovation in this segment are expected to improve as the move towards privatization gains momentum and further attempts are made to meet greater competition from exports. It is anticipated that the net result of such moves will be greater compliance with environmental stipulations.

Chart 5. Grain milling operations and the resulting waste products

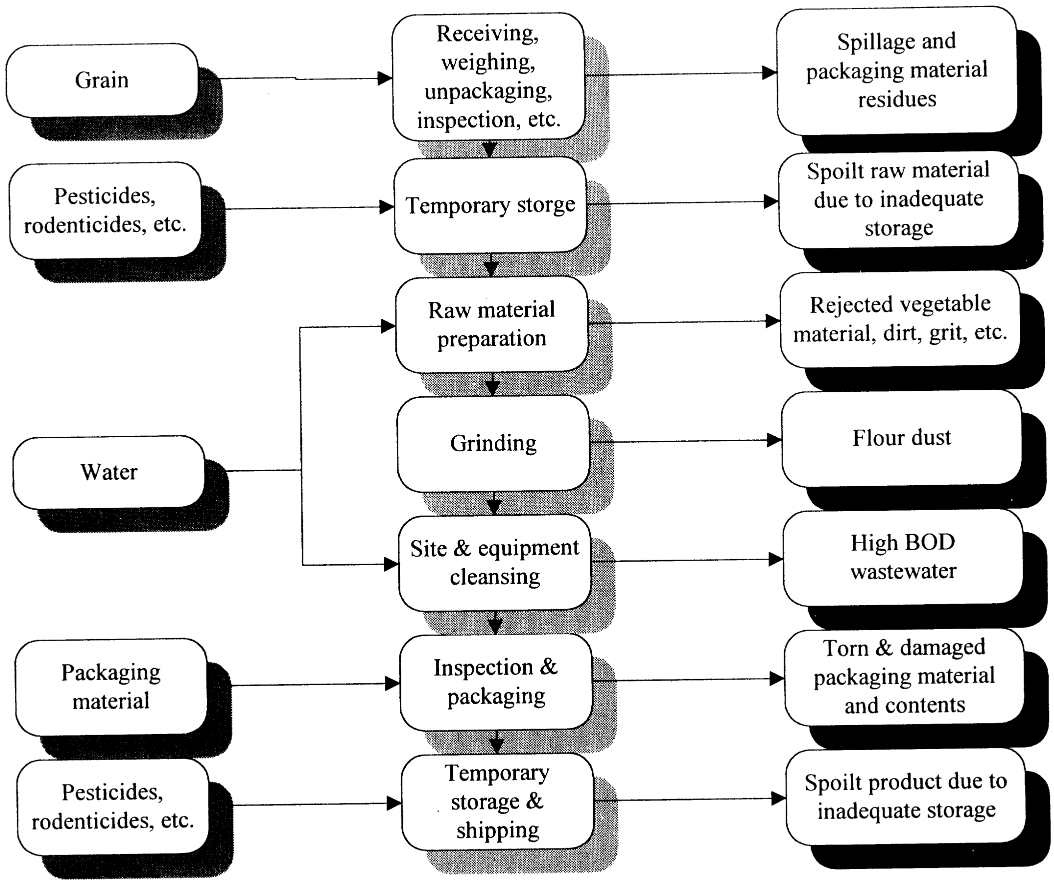


TABLE 10. POLLUTION REDUCTION IN GRAIN MILLING

Operation	Objective	Possible action
Raw material reception, testing, weighing and temporary storage	Process improvement and waste reduction	- Improve raw material selection process using modern analytical techniques - Link reception area to computerized inventory and operations control facilities - Introduce means for collecting soil and other contaminants including vegetable matter for recycling or inclusion in animal feed supplements - Use climate control to reduce pest and toxin build-up and hence reduce waste - Introduce recycling schemes and associated equipment for dealing with spent packaging material

TABLE 10 (*continued*)

Operation	Objective	Possible action
Product grading and preparation	Optimizing use of raw materials and waste reduction	- Adopt IT-based procedures and introduce computerized aids for inventory management - Use improved in-plant conveying means to eliminate product loss - Introduce means to trap grain dust and other particulate matter, e.g., using filter bags in ventilation systems - Collect overflow and spilt grain and divert to other uses or recycle - Collect rejected grain and other vegetable matter contaminants, e.g., husks, dirty leaves and straw, for recycling, composting or inclusion in animal feed preparations - Introduce facilities for recycling water used in grain preparation and work-site cleansing
Milling or grinding, sieving and addition of fortifying agents and other additives	Rational solid waste disposal and reduction of air emissions	- Introduce dust collection devices - Use means of collecting overflow and rejected material due to formulation errors and recycle for alternative uses
Packaging	Rational solid wastewater disposal	- Use automatic loading and packaging devices to reduce waste and spillage
Reuse and recycling	Water conservation	- Treat and recycle water from CIP and process operations whenever possible

Source: "Cleaner Production Fact Sheets; Food Manufacturing Series", the UNEP Working Group, Centre for Cleaner Production in the Food Industry, University of Queensland, Australia. Published on the Internet.
URL: http://www.Geosp.uq.edu.au/emc/CP/Fact6.htm

2. *Bakery processes*

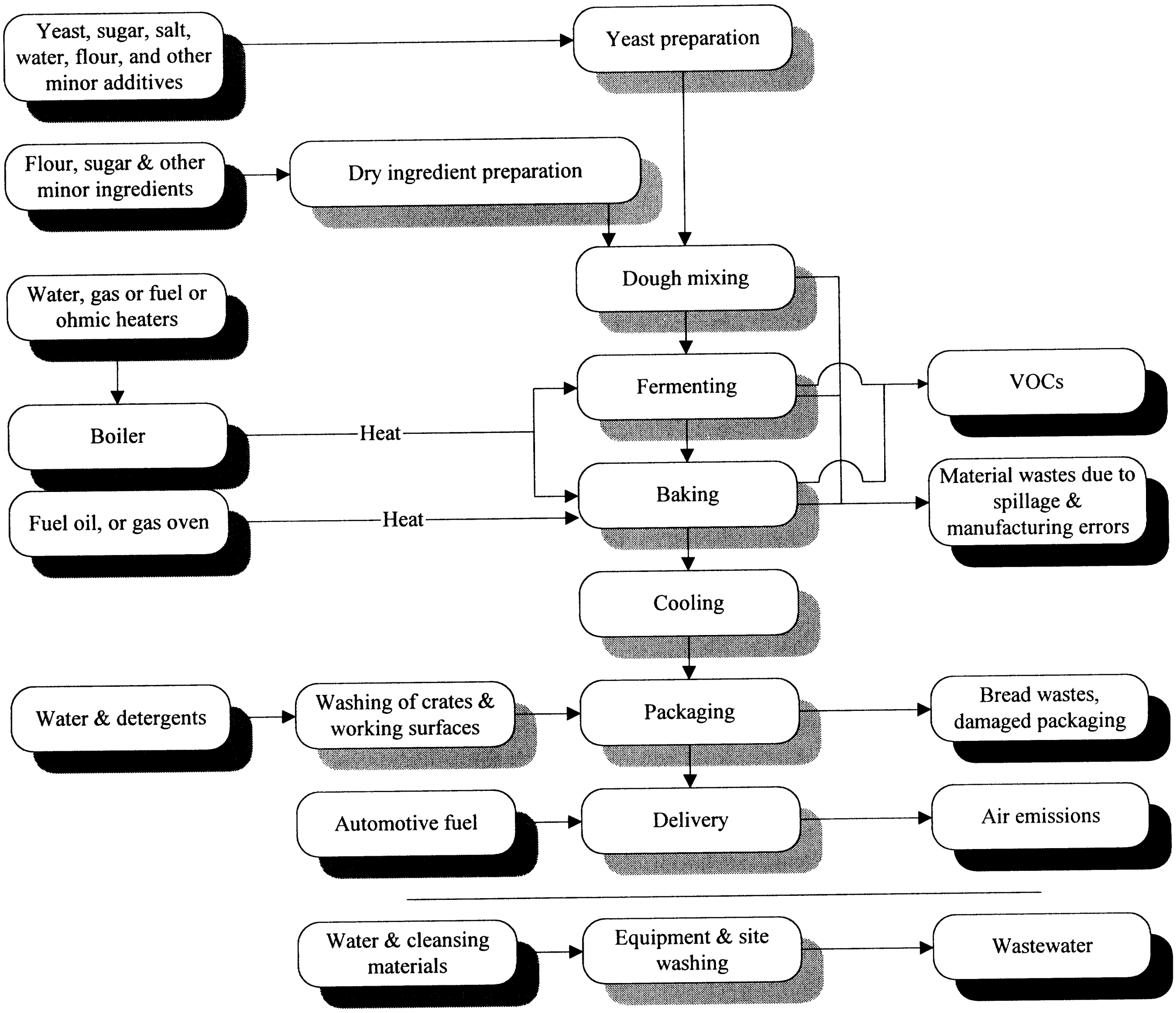
Bakeries are not normally considered large polluters or water wasters; however, their sheer number and proliferation render their water consumption in particular, and the environmental impact of their operations in general, of special significance.

Bakeries vary in size and produce a wide range of products. Despite the fact that several medium and large bakeries are known to have been established in several ESCWA member countries, the small bakery is still very much the norm. As a result, most bakery operations remain manual; and although kneading and possibly forming may be mechanized, the emphasis is still on human intervention in every stage.

Bakery products may be classified into three principal categories:
Bread and bread roll products;
Pastry products (pies, pastries, etc.);
Specialty products (cake, biscuits, donuts and specialty breads, etc.).

The first category is, of course, the largest, worldwide, in terms of output volume. Chart 6 presents a view of the sequence of bread production operations. Processes designed to manufacture products in the other two categories are only slightly different.

Chart 6. Process flow diagram for bakery operations



Source: "Cleaner Production Fact Sheets; Food Manufacturing Series", the UNEP Working Group, Centre for Cleaner Production in the Food Industry, University of Queensland, Australia. Published on the Internet.
URL: http://www.Geosp.uq.edu.au/emc/CP/Fact6.htm

3. *Water use and wastewater in bakeries*

About half of the water used in bakery operations is incorporated into its products. The other half, employed in cleansing and auxiliary tasks, is finally discharged in the effluent stream. This indicates considerable variability in the timing and extent of daily water discharges.

Bakery wastewater is generated primarily by cleansing operations. It is rich in organic material including flour, sugar, yeast, and, in the case of pastry and specialty products, also in oils and shortening as well as cleansing agents and lubricants, principally from kneading and conveying machinery. Table 11 indicates common waste sources in bakery operations.

TABLE 11. OPERATIONS AND WASTE SOURCES IN BAKERY OPERATIONS

Process	Waste source
Ingredient receipt and storage	Damage, deterioration, infestation and spills
Ingredient weighing and preparation	Incorrect weights and missing ingredients
Mixing	Ingredient errors, spills, equipment and utensil cleansing
Fermentation	Equipment and utensil cleansing and batch errors
Forming	Incorrect weights and cleansing operations
Baking and proving	Misformed products and contamination
Cutting and packaging	Cutting errors and damaged packages
Despatch and transport	Overproduction and damage in transport
Washing plant and equipment	Wastewater, organic material, oil and grease from bakery machinery

Flour, sugar, yeast, shortening and oil are the major components of bakery waste. Measurements on wastewater generated by a bakery in an industrialized country indicated that for every ton of dough produced, 500 litres of wastewater are generated, containing 1.9 kg COD and 1.0 kg of suspended solids.[42]

Large, automated bakeries tend to produce low volumes of wastewater per unit product.[43] In contrast, pastry, cake and specialty product operations generate larger volumes of wastewater with relatively low concentrations of COD. This is basically due to the manual nature and small scale of such operations and the fact that cleansing operations tend to be much less efficient under these conditions.

Food grade oils used to grease baking surfaces in specialty breads and as ingredients in other specialty bakery products, find their way into the effluent stream.

4. *Air emissions from bakery operations*

Volatile organic compounds (VOCs) constitute the main ingredients in bakery emissions. Ethanol, a by-product of the leavening process, features among these chemicals.[44] Several types of technology are available for controlling emissions. They include direct flame thermal oxidation, catalytic oxidation, adsorption on active carbon, scrubbing, condensation, biofiltration and biotrickling.[45]

5. *Solid waste*

Waste dough, mainly due to formulation errors or contamination and off-specification products, are the main sources of solid waste. Some of these products may be retrieved and cooked to produce animal fodder.

6. *Environmentally sound technologies in bakery operations*

Table 12 indicates possibilities for improving the environmental impact of bakery operations with emphasis on technology inputs. The impact of automation and modern IT-assisted inventory control is apparent in several areas.

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42 UNEP Centre for Cleaner Production in the Food Industry, 1997.

43 This may indicate a direction for research and development aimed at reverse engineering and more widespread use of such equipment in the ESCWA member countries.

44 Studies in the United States estimate that between 0.3 and 7.0 kg of ethanol are emitted for each metric ton of bread produced, depending on the yeast content, fermentation and proofing time (US EPA, 1992).

45 "Biotrickling reduces bakery ethanol emissions by 85-100 per cent", *Food Engineering*, February 1999. An Internet Publication, URL: http://foodexplorer.com/manu/industry/FE02927.htm.

TABLE 12. POSSIBILITIES FOR IMPROVING THE ENVIRONMENTAL IMPACT OF BAKERY OPERATIONS

Operation	Objective	Possible action
Ingredient despatch and make-up	Process improvement and cutting down waste	- Improve ingredient formulation procedures to reduce batching errors; for example, introduce automatic dispensing, training for staff
Product preparation	Process and control Improvement as well as cutting down waste	- Use improved technology to eliminate sources of product loss; for example, use dough pumps to improve mixing and IT-based inventory and management systems
	Cleaning	- Install new drainage systems in positions where material cannot inadvertently enter the waste stream
	Lubrication	- Change to new alternative lubricants and self-lubricating materials, such as, water, Teflon/ceramic coatings etc. - Install means of catching oil drips and reuse or recycle entrained oil
	Product conveyance	- Install conveyor belts that allow reject removal from the line to avoid unnecessary processing
	Baking	- Introduce multi-pass systems and appropriate insulation in oven systems to improve energy efficiency
Reuse and recycling	Waste reduction and water conservation	- Make use of waste heat generated during oven start-up and shut-down - Re-circulate water wherever possible - Collect and reuse condensate from the ovens - Reprocess waste dough into saleable products, in animal feed
	Energy conservation	- Use bioreactors to process high-strength waste streams into alcohol for fuel or biogas for energy
Waste treatment and disposal	Save resources needed in recycling and waste disposal	- Segregate concentrated wastewater and treat/dispose separately
Product improvement	Reduce waste and improve product	- Introduce long shelf-life bread products

Source: "Cleaner Production Fact Sheets; Food Manufacturing Series", the UNEP Working Group, Centre for Cleaner Production in the Food Industry, University of Queensland, Australia. Published on the Internet. URL: http://www.Geosp.uq.edu.au/emc/CP/Fact6.htm

F. SUGAR MANUFACTURE

Sugar manufacturing, from both cane and beet sources, as well as raw sugar refining, are widespread industrial activities throughout the ESCWA member countries. Sugar production[46] proceeds through two essentially separate processes: raw sugar extraction and sugar refining. Both processes are needed to obtain white sugar from sugar cane, in general.[47] Table 13 presents a brief comparative analysis of the two principal sources of sugar. Chart 7 presents a schematic view of sugar manufacturing operations.

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[46] Around 64 per cent of world production is derived from sugar cane and 36 per cent from sugar beet. See source: Pollution Prevention and Abatement Handbook - Part III Sugar Manufacturing, October 1996. See UNIDO web site at URL: http://www.unido.org/ssites/env/sectors/sectors601.html.

[47] For sugar beet, however, the refining process may not be essential if good juice clarification is carried out.

TABLE 13. COMPOSITION OF SUGAR CANE AND SUGAR BEET
(*Percentage values by weight*)

Constituent	Sugar cane	Sugar beet
Sugar	12-14	15-18
Fibre	10-15	-
Water	75	10-12
Ash	0.5	0.5

Source: Pollution Prevention and Abatement Handbook - Part III Sugar Manufacturing, October 1996. See UNIDO web site at URL: http://www.unido.org/ssites/env/sectors/sectors62ad.html.

Sugar manufacturing from vegetable sources produces considerable quantities of solid waste. Sugar cane processing, for instance, produces bagasse, the name given to crushed cane exiting the sugar mill, is essentially made up of lignin fibers. It is used as follows:

As fuel for boilers and lime kilns;
For the production of paper and paperboard products;
As a component in reconstituted panel board;
For mulching in agriculture;
As raw material for the production of chemicals such as furfural.

Dried filter cake is used as an animal feed supplement, fertilizer, and a source of sugar cane wax. Molasses and filter cake are also produced. The former, is used to produce blackstrap, which is inedible and is used primarily as an animal feed supplement. An edible syrup is also produced from molasses. This is used as an additive in the food industry. Edible molasses syrups are often blended with maple syrup, invert sugars, or corn syrup. Filter cake, on the other hand, is most commonly used in animal feed.

In sugar refining, one metric ton of raw sugar is required to produce around 934 kg of refined sugar. This is to say that around 66 kg of impurities are removed from each metric ton of raw sugar in the refining process.

1. *Process description*

Sugar cane is essentially a variety of tropical grass. It belongs to the same family as sorghum and maize. Varieties currently in use for sugar production are complex hybrids of two or more of the five species of the genus *Saccharum*.

Three major steps are involved in the production of cane sugar from sugar cane: harvesting, cane sugar processing, carried out in special facilities or mills, and sugar refinement.

(a) *Harvesting*

A primary consideration in harvesting is to deliver good quality raw material to the sugar mill. It is essential to realize at this stage that cane tends to deteriorate rapidly due to enzymatic action as well as to a variety of chemical and microbial processes following harvesting.[48]

Refuse from the sugar cane stalks is removed at the harvesting stage. Cane tops and leaves are removed since they contain little sucrose and tend to be high in starch and reducing sugars which decrease sugar yield. Cane leaves are also removed since, due to their high silica content, they tend to increase the rate of wear in the milling rollers.

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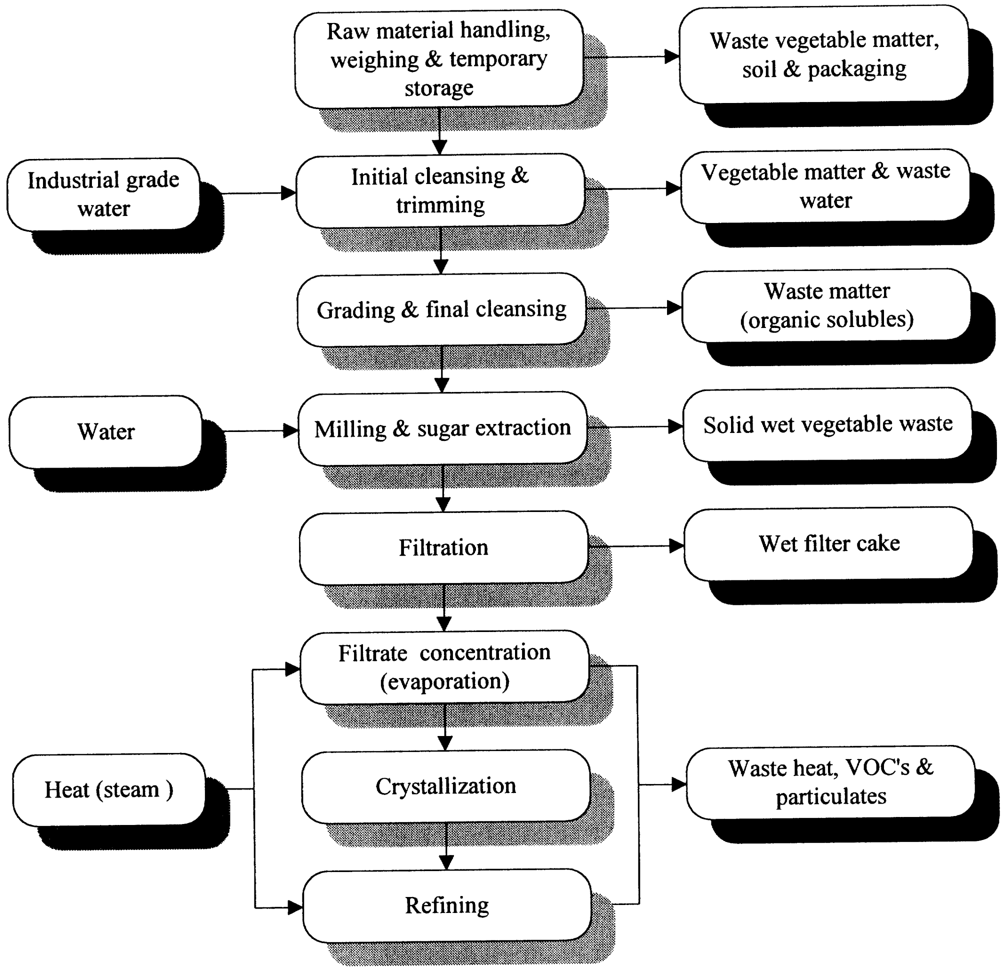
48 Thus unlike sugar beet, sugar cane has to be processed within a short time after cutting.

The practice of removing cane tops and leaves by burning is a cause of unnecessary pollution, especially if carried out under inadequate conditions and without making use of the energy generated, as is often the case. Alternatively, removal of cane tops and leaves by hand allows their utilization as fodder or in composting.

Chart 7. Sugar processing operations, material inputs and waste



Source: "Sugarcane Processing: Final Report", United States Environmental Protection Agency, Emission Factor Documentation for AP-42 Section 9.10.1.1, June 1997.

(b) *Cane sugar processing*

Processing of cane sugar is an industrial activity that is of immense economic importance in Egypt, the country with the highest volume of operating sugar production capacity among ESCWA members. Egypt is also host to the only research institute devoted to R and D in the area of sugar manufacture and refining.

At the mill, cane is mechanically unloaded and cleaned, usually with high pressure water. Milling takes part in two steps:

(i) Breaking the hard structure of the cane using revolving knives, shredders, crushers, or a combination of such tools;

(ii) Grinding or milling crushed cane, commonly using a sequence of roller mills.

Water or cane juice obtained from initial mills is applied to crushed cane to improve sugar extraction of the juice in later milling. A common procedure is to send the juice from the crushing and the initial milling to wet the crushed cane before further juice extraction, a process sometimes referred to as "imbibing". An alternative process is to treat the crushed or shredded cane with large amounts of water to extract the juice and to treat the press water as well as the juice expressed from the crushed or shredded cane. Large amounts of water are needed in this process.

The next step is to strain the juice to remove the larger suspended particles and then to clarify the strained solution with heat and lime; small quantities of a soluble phosphate also may be added.[49] The juice is then heated with steam to about 95°C. The heavy precipitate which then forms is separated from the juice by a gravitational or a centrifugal process. Following initial heating, by passing it through heat exchangers, the clarified juice is then despatched to the evaporator stations. Modern evaporators, termed multiple-effect evaporators, consist of a series of sequential units. Typically, a series of five evaporators is used, each operating at a lower pressure than the previous one, thus allowing the juice to give off its water at lower temperatures.

The evaporator sequence produces a syrup with around 65 per cent solids and 35 per cent water. Further lime clarification is carried out on the syrup. Phosphoric acid, and a polymeric flocculent are added and the strong sugar solution is aerated then filtered before being moved to the vacuum pans for crystallization.

Both batch and continuous vacuum evaporation are used in the industry. The former takes around three pan boilings. The syrup is evaporated till it reaches the super saturation stage and the crystallization process is initiated by "seeding" or "shocking" the solution.

The mixture of liquor and crystals resulting from the evaporation process, known as "massecuite", is discharged to the crystallizer, the function of which is to maximize the removal of sugar crystals from the mixture. Seeding the vacuum pans is carried out with isopropyl alcohol, ground sugar or sugar crystals. The next stage consists of separating crystalline sugar from the massecuite using high-speed centrifugal machines. In these machines molasses moves to the outer shell of the centrifuge and the crystals remain in an inner basket. Washing with water follows, with further centrifugation.

The molasses from the first centrifugation stage is returned to a vacuum pan and further water evaporation is carried out to yield a second massecuite. This is termed "B massecuite", to differentiate it from the first mixture of mother liquor and crystalline sugar which is sometimes referred to as the "A massecuite". B massecuite is treated in the same manner as A massecuite. An important difference between the two stages is that the molasses from the second boiling, also termed "B molasses", is much less pure than the first, A molasses. Nevertheless, further water is removed from this product to yield C massecuite.

Cane sugar from the combined A and B massecuites is dried, cooled and transferred to the packing area before being shipped or stored on site.

The granulator is the most common piece of equipment used in sugar drying. It consists of two drums mounted in series. Sugar is heated in the first drum up to a temperature of about 110°C then cooled in the second. Fluidized bed dryers/coolers have been replacing conventional rotary drum granulators in sugar drying facilities.

The low-grade cane sugar obtained from the impurity-laden C massecuite is used for "seeding" in the vacuum pans. The molasses obtained from the C masscuite, referred to as "blackstrap" in the trade, is a viscous liquid that is used primarily as a cattle feed supplement.

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[49] Lime has the effect of neutralizing the organic acids; the phosphate acts as a flocculant.

(c) *Sugar refining*

Cane sugar is first treated to remove the impurities in the film coating the sugar crystals. A warm, almost saturated syrup is added, followed by a gentle vibration to loosen this film. Centrifugal separation of the cleaned sugar crystals ensues, followed by washing with pure water or a high-purity sugar solution, while still in the centrifuge. The syrup from this crystal washing operation is termed "affination syrup".

The resulting raw sugar is mixed with high-purity sugar solutions from other refinery steps and is steam heated. Screening removes the particulates, and the screened solution is then put through the clarification sequence described above before being evaporated to yield the massecuite.

Clarification of sugar syrup in sugar refining is carried out using two types of processes: pressure filtration and chemical treatment. The former is regarded as labour-intensive, and chemical clarification is generally preferred, although it yields a much larger amount of solid waste. There are two chemical methods to choose from: The first is based on the use of phosphoric acid, the second on carbonates. In both cases lime is used as a raw material. In the first process lime sucrate is produced. A flocculating agent[50] is added to encourage production of a calcium phosphate floc. Air flotation and intermittent skimming separate the floc from the liquor.

The process, based on the use of carbonates, includes adding lime to the raw liquid and then bubbling carbon dioxide CO_2 through the liquid to produce calcium carbonate which readily precipitates. The source of the carbon dioxide is usually scrubbed and filtered boiler flue gas, which contains about 12 per cent CO_2 by volume.

Active charcoal, or bone char and related preparations are used as media for decoloration. The affinity of the carbonaceous structures in the charcoal surface layers for molecules responsible for colouring and flavouring cane sugar is at the basis of this operation. Both fixed and moving-bed systems may be used. Sugar liquor is brought into contact with a series of adsorbent materials immobilized on static beds until the final liquor colour reaches a predetermined level. Excess sugar is retrieved from the adsorbent bed by flushing with pure water. A moving, adsorbent-bed system operates continuously and is a system where the adsorbent is allowed to move countercurrent to the flow of the sugar liquor.

It is useful to indicate that charcoal and bone char adsorbents may be regenerated by drying then heating them in kilns.

Decoloured sugar liquor is treated in much the same way as raw cane sugar, i.e. it is put through a series of evaporators, vacuum pans, crystallizers and dryers, to yield refined sugar. In particular, dried lime cakes may be recalcined by first burning off the organic matter at temperatures above 900°C, the calcium carbonate thus obtained then being converted to calcium oxide at higher temperatures in kilns prior to slaking.

Several other sugar products, in addition to granulated or crystalline sugar, are made in sugar refineries. These include powdered and brown sugar, liquid sugar and edible molasses.

2. *Environmental impact of sugar extraction and refining*

Table 14 provides a list of standards that must be met by the sugar industry.[51]

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[50] Proprietary formulations are generally used, most of which are based on polyacrylamide.

[51] Standards that must be met in all projects financed by the World Bank. Pollution Prevention and Abatement Handbook - Part III, Sugar Manufacturing, October 1996. UNIDO web site http://www.unido.org/ssites/env/sectors/sectors601.html.

TABLE 14. EMISSION STANDARDS FOR THE SUGAR INDUSTRY

Air emissions		Liquid effluent		Noise levels	
Pollutant	Maximum limit	Parameter	Maximum value	Receptor area/Limit in dBA	
		PH	6-9	Residential	
Particulate matter	50 mg/Nm^3	BOD_5	50 mg/l	Day	55
Sulphur dioxide	50 mg/Nm^3	Temp. rise	< 3 deg °C	Night	45
Nitrogen oxide	750-460 mg/Nm^3*	COD	250 mg/l	Commercial	
		TSS	50 mg/l	Day	65
		FOGs	10 mg/l	Night	55
		Biocides	< 0.05 mg/l	Industrial	
				Day	70
				Night	65

Source: Pollution Prevention and Abatement Handbook - Part III Sugar Manufacturing, October 1996. See UNIDO web site at URL: http://www.unido.org/ssites/env/sectors/sectors601.html.

* For solid and liquid fuels respectively.[52]

3. *Waste reduction and material conservation measures in sugar manufacturing and refining*

In essence, a good deal of technological innovation in sugar extraction and refining has focused on energy and water conservation.

(i) *Water conservation*

Machines have been designed to remove soil, etc. from sugar cane using mechanical vibration. Facilities have also been developed to enable the reuse of flume water after screening and settling in sugar beet processing.

(ii) *Water and waste treatment*

Thorough cleaning of wastewater and clay from residual sugar and vegetable matter has also received considerable attention.[53] In particular, the clarification process results in a high sugar content waste stream. To avoid losses and reduce the pollution load in wastewater, the stream can be recirculated to the clarification process. This can also result in energy saving if the clarification process is carried out on a continuous basis.[54]

(iii) *Energy conservation*

In relation to energy conservation, a multiple-effect system has been installed for the evaporation of juice into syrup. Additional energy-saving methods include the circulation of condensates, vapour blending or their reuse for external purposes.

(iv) *Waste recycling*

About 30 kg of molasses are produced per ton of cane. This by-product contains: 20 per cent water, 35 per cent sucrose, 20 per cent reducing sugar and 15 per cent sulphated ash, as well as other minor

52 This is calculated as equivalent to 750 mg/Nm^3 for solid fuels and 460 mg/Nm^3 for liquid fuels.

53 Mud produced at an average of about 30-35 kg/ton of beet treated contains around 80 per cent water and 1-1.5 per cent beet sugar. Treatment of this mud by settling is now carried out by beet sugar processing facilities before final disposal.

54 Sludge from the clarification stage contains a considerable percentage of lime and organic matter. This composition constitutes a useful additive for land devoted to sugar beet cultivation.

constituents adding up to around 10 per cent. Molasses is now increasingly being used as animal food or transformed into ethanol by fermentation and distillation.

(v) *Air emissions*

Pollutants emitted by sugar cane processing plants include combustion products, particulate matter (PM) and volatile organic chemicals (VOC).

Combustion products are determined by the composition of the fuel used to generate heat and electricity at the plant. They generally include nitrogen oxides (NO_x), carbon monoxide (CO), carbon dioxide (CO_2), and sulfur oxides (SO_x).

Particulate emission sources in sugar production and refining are numerous. They include granulators, sugar conveying and packaging equipment, charcoal and char regeneration kilns, lime kilns,[55] carbonation tanks, multi-effect evaporators, vacuum boiling pans, etc. Combustion of fuel, whether oil or bagasse, also generates particulates.

Low levels of VOC emissions are generated in the multi-effect evaporators and vacuum boiling pans as well as in carbonation operations.

(vi) *Removal of particulate emissions*

Exhaust from a variety of industrial operations, for example, granulators in sugar manufacturing and refining is vented to cyclones to remove large particles. Removal of smaller particulates is effected by means of a wet cyclone system. Fabric filters are sometimes used to control PM emissions from grinding and drying operations. They are used, for example, in sugar grinding, and in grain milling and handling operations.

Particulate matter emissions from boilers are usually reduced by the use of cyclones as well as scrubbers.

Table 15 sets out major environmental improvement objectives in relation to the various sugar manufacturing operations, together with possible measures to render these operations more compatible with environmental considerations.

TABLE 15. IMPROVING THE ENVIRONMENTAL IMPACT OF SUGAR MANUFACTURING AND REFINING OPERATIONS

Operation	Objective	Possible innovation
Raw material reception, testing, weighing and temporary storage	Process improvement and waste reduction.	- Use modern analytical techniques to improve raw material selection and grading
Primary washing, grading and trimming	Optimizing use of raw materials and waste reduction.	- Adopt IT-based procedures and introduce computerized aids for inventory management - Use improved in-plant conveying means to eliminate product loss - Install means of retaining spilt juices, sugar solutions and other liquid ingredients for recycling - Collect and treat spent vegetable matter for other uses, as fertilizer following composting, as animal feed ingredients, fuel, etc. - Use automatic controls to reduce water consumption in spillage and leakage situations

[55] Some facilities purchase, rather than generate lime themselves.

TABLE 15 (*continued*)

Operation	Objective	Possible innovation
Milling and sugar extraction	Rational solid waste disposal as well as energy and water conservation.	- Collect and treat spent vegetable matter for alternate higher value-added product manufacture - Use modern effluent control methods to segregate wastewater effluent streams to the greatest possible degree, e.g., CIP wash water from process overflows - Use waste heat from process steam in evaporation and crystallization and for process water heating wherever possible
Filtration, clarification, evaporation, crystallization and refining	Reduction of waste and air emissions	- Remove and treat filter cake and sediments for re-sale as animal feed, fertilizer, etc. - Devise means of reusing, recycling or safely dumping filtration and clarification residues - Retain final blackstrap for use as input in other processing industries - Condense volatile matter from evaporation pans in order to reduce air emissions - Recycle molasses and other by-products or retain for resale to other process industries - Regenerate charcoal and other discolouration and flavour removal aids
Packaging	Waste reduction	- Utilize automatic rather than manual conveying, loading and packaging equipment - Install means of collecting and recycling spillage
Reuse and recycling	Energy and water conservation	- Introduce wastewater treatment and recycling facilities whenever possible - Condense steam to retrieve heat and water whenever possible - Use membrane and other less energy-intensive separations where possible

Source: "Sugar cane processing: final report", United States Environmental Protection Agency; Emission Factor Documentation for AP-42 Section 9.10.1.1, June 1997.

G. BEVERAGE AND FERMENTATION PRODUCTS

This segment of the food industry utilizes a more sizeable proportion of water inputs in its products. The main steps in processing beverages are listed in box 4.

Box 4. The main steps in processing beverages

(a) Raw material handling and processing;
(b) Mixing, fermentation, and/or cooking;
(c) Cooling;
(d) Bottling and packaging;
(e) Clean-up.

Wastewater and solid waste of both vegetable and mineral origin constitutes the principal waste streams in the beverage and fermentation segment. Solid waste results from spent grain and other vegetable sources of fermentation stocks. Auxiliary solid materials used in the fermentation process, e.g. for filtration are also an important item.

In general, the volume of wastewater in soft drink manufacture is lower than that of other food-processing segments. On the other hand, fermentation processes are higher in BOD and overall wastewater volume compared to other food-processing sectors. The following paragraphs take a closer look at two areas of activity that are gradually increasing in volume in some ESCWA countries, with serious consequences for water consumption and vegetable waste generation.

1. *Beer brewing and wine making*

Despite this industry's long history, particularly in the developed countries, the processes of brewing and wine-making processes have changed very little over the years. Although notable changes have been made, particularly regarding the recovery and further processing of by-products, the basic operations in beer and wine production remain the same.

The main items of waste generated by brewing and wine production are:

Malting (particulates and rootlets);
Grape stalks and particulates;
Wort separation (spent grain);
Filtration (filtrate, e.g., kieselguhr, yeast and pomace);
The packaging area (glass, paper, cardboard, plastic and metal);
Bottle washer (paper pulp);
Ancillary operations (paper, cardboard, oil and grease, paints and thinners, etc.).

The main pollutants generated in these processes include wastewater discharges, air emissions and solid waste. Chart 8 illustrates the sequence of operations in beer brewing. Table 16 shows the potential contaminant sources in the brewing process.

Current beer and wine-producing processes generally consist of batch operations, resulting in intermittent waste discharges. This naturally has a decided influence upon waste treatment methods. The following paragraphs provide a brief view of beer and wine production operations.

(a) *Beer production raw materials*

Raw materials used in the brewing industry include water, energy and cereals (barley, corn and rice). Auxiliary materials such as plant parts or plant extracts used in flavouring,[56] kieselguhr for filtration and caustic soda and detergents are also used. It is estimated that the production of one hectolitre of normal lager beer requires about 15 kg of auxiliary materials, including malt. Box 5 provides additional information on auxiliary materials used in beer brewing.

Large amounts of water are consumed in the production of beer and wine. Most of the water used, between 65 and 70 per cent, is discharged as wastewater after being used in various processes such as:

Cooling;
Cleaning of packaging material (e.g., bottle washing);
Pasteurization;
Rinsing and cleaning of process equipment;
Steeping, mashing, etc;[57]
Cleaning of floors and equipment;
Soap lubricant on conveyors in the packaging area;
Vacuum pump for filler;
Flushing of filler.

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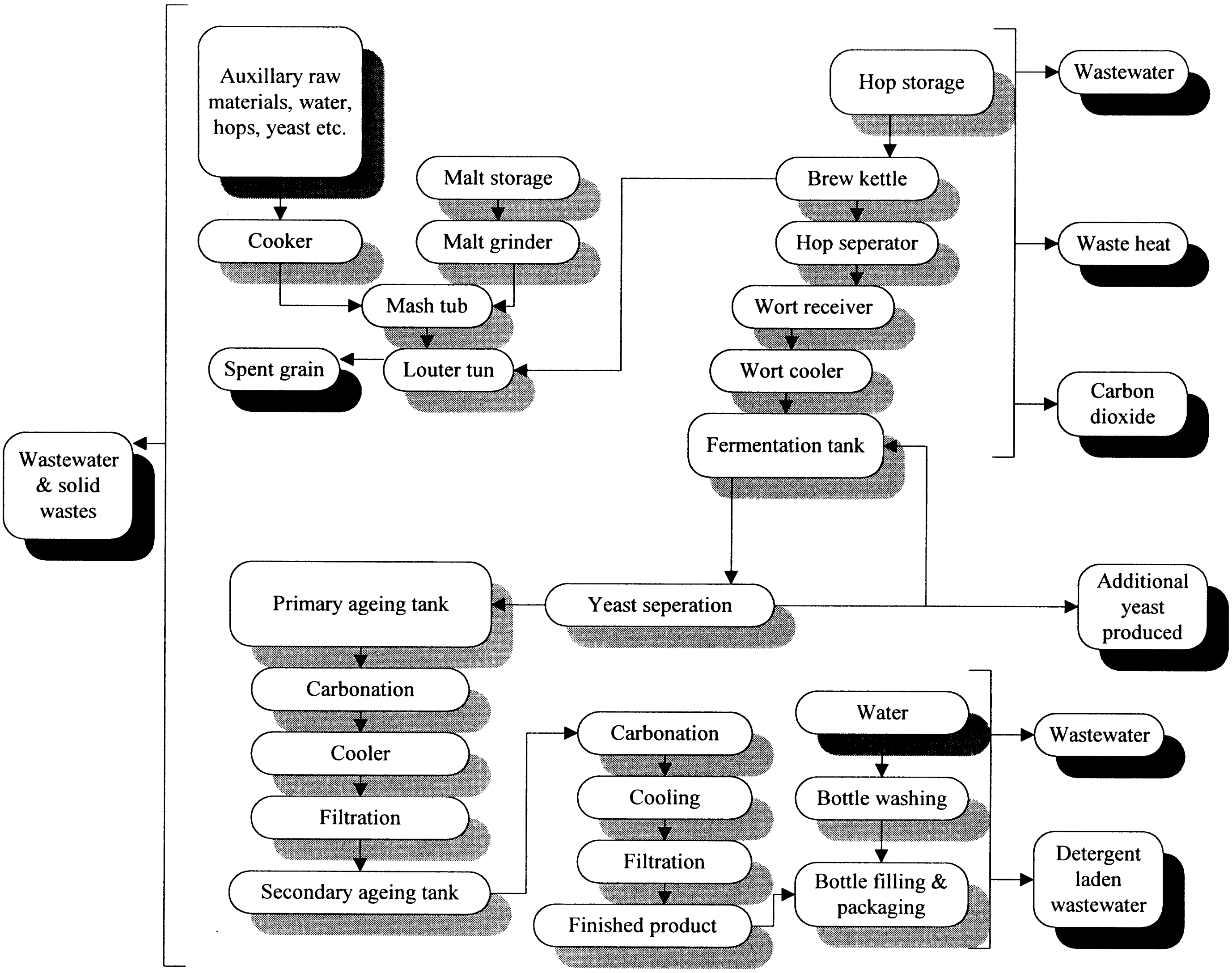
[56] Hops are added to the beer to give it a bitter taste and a pleasing aroma. It can be added in the form of natural hops, or more commonly, as hop extract or powder.

[57] Typically 5 m^3 of water is used to produce one ton of malted barley.

Chart 8. Beer brewing process



Source: Adapted from the "Technical pollution prevention guide for the fruit and vegetable processing industry in the Lower Fraser Basin", Environment Canada, DOE FRAP 1996-20.

TABLE 16. SPECIFIC ENVIRONMENTAL CONCERNS IN RELATION TO STAGES IN BEER AND WINE PRODUCTION

Stage	Environmental concerns
Brewhouse	- High discharge of organic matter - High energy consumption - High water consumption - Dust - Caustic waste from cleansing operations
Fermentation/Beer processing	- High discharge of organic matter - High water consumption - Handling of solid waste - Caustic waste from cleansing operations

TABLE 16 (*continued*)

Stage	Environmental concerns
Packaging	- High discharge of organic matter - High energy consumption - High water consumption - Handling of solid waste - Caustic waste from cleansing operation
Ancillary operations	- High discharge of organic matter - High energy consumption - Handling of solid waste (including special waste) - Handling of chemicals - Caustic waste from cleansing operation

Source: Adapted from "Technical Pollution Prevention Guide for Brewery and Winery Operations in the Lower Fraser Basin", Environment Canada, DOE FRAP 1997-20.

Box 5. Auxiliary materials used in beer production

Auxiliary materials used in beer production include a range of additives such as enzymes, antioxidants, foam stabilizers and colloid stabilizers (finings, silica, tannic acid, etc.). These are, generally, used in small amounts, however. Kieselguhr is used for filtering beer.

Amounts in the range 1 and 3 kg/m^3 are used, depending primarily on initial clarity and yeast cell count; caustic soda is used for cleaning, together with other detergents and acids.

Caustic soda, in particular is used in amounts ranging between 5 and 10 kg (30 per cent NaOH)/m^3. A good deal of the caustic soda may be recovered during equipment cleaning. Failure to do so raises the pH of wastewater produced. The rate of consumption of the other cleansing materials depends on cleaning procedures.

Packaging materials include non-returnable bottles, cans, crown corks, cardboard, plastic stretch and shrink wraps, glue (used for labels and cardboard boxes) etc.

A variety of factors influence the rate of water consumption in brewing processes. In general, 4-10 m^3 of water are used per m^3 of beer produced, depending on the pasteurization process and the age of the equipment. The rate of water consumption is also affected by the temperature of the water used for cooling in certain parts of the process. Distribution of water consumption in a brewery averaging 6.5 m^3/m^3 beer was found, in a 1995 study by UNEP,[58] to be as indicated below:

Raw material, 1.3 m^3/m^3;
Cleaning, 2.9 m^3/m^3;
Cooling water, 0.7 m^3/m^3;
Other (domestic, losses), 1.6 m^3/m^3.

This study also indicated that water consumption may amount to two to three times' the above figure, i.e., up to 20 m^3/m^3 beer, where raw water temperatures are high.

Water that is actually consumed in the beer brewing process, i.e., water that appears neither in the waste stream nor in the product itself, includes evaporated water and water that remains in the spent grain, yeast and filtering media. Nevertheless, this builds up to the considerable rate of 1.5m^3/m^3 beer (UNEP, 1995). A breakdown of water use in sample breweries is presented in table 17.

[58] "Technical pollution prevention guide for brewery and winery operations in the Lower Fraser Basin", Environment Canada, DOE FRAP 1997-20.

TABLE 17. WATER USE IN VARIOUS PARTS OF THE BREWERY

Processing area	Water use (m^3/m^3 beer)	
	Pohlmann, 1980	BPCE, 1986*
Brewhouse	1.8-4.2	1.4-3 (1.75)
Cellars, including filtration	0.8-1.7	1-1.5 (1.15)
Packaging, including pasteurization	0.9-1.9	1.3-1.8 (1.50)
Utilities (engine room, boiler, cooling and amenities)	1.25-3.3	0.7-1.9 (2.25)
Totals	4.75-11.1	4.4-8.2 (6.65)

Source: Adapted from "Technical pollution prevention guide for brewery and winery operations in the Lower Fraser Basin", Environment Canada, DOE FRAP 1997-20.

* Figures in brackets show average values.

Energy is consumed by breweries mostly as heat. It is influenced by process parameters, pasteurization technique, type of equipment and by-product treatment, as well as by packing methods.

Recovering heat from the wort boiling process enables a substantial reduction of two to three times' less heat consumption. An efficient brewery, i.e. one that is equipped with facilities for heat recovery, consumes energy at the rate of 1.5-2.0 gJ/ m^3. The rate of electricity consumption, also in a modern, well-equipped brewery, falls within the range 80-120 kWh/m^3. Rates twice as high are not uncommon, however.

(b) *Process description in beer production*

Malting of grain, milling and mashing, wort cooling and fermentation, packaging, and pasteurization constitute the main operations in the brewing process. Chart 8 depicts the sequence of these operations, with emphasis on their waste output. The following paragraphs present a brief description of the operations.

(i) *Malt preparation*

Malt is derived from cereal grain. Barley is the most frequently used raw material. The grain is germinated for a limited period then dried. During the malting process, starch material in the grain undergoes changes that ultimately convert it to a form that is more suitable for brewing. Some proteins are also hydrolysed and a suitable environment is created for enzymatic action in the later fermentation process.

Malt preparation from barley involves the following steps:

a. Cleaning: to rid the raw material of dust and foreign materials;

b. Sorting: according to size, the smallest kernels usually being sold as fodder;

c. Steeping: to increase the barley water content to about 45 per cent, up to three water changes may be required, and aeration of the grain;

d. Germination:[59] this prepares the grain content for enzymatic action. Steeped grain is placed in boxes with a base of perforated steel plate and a mechanism for periodic vibration of the germinating grain. Germination goes on for 120-190 hours, during which time air is blown through the grain to control its temperature and moisture content;

e. Drying: kiln-drying the germinated grain reduces its moisture content to around 4 per cent. This has the effect of halting the germination process, developing the required flavour characteristics and prolonging storage. Sulfur dioxide may be used to bleach the kernels and lower the pH of the malt during this operation;

[59] Barley grain may start germinating before being moved to the germination boxes following steeping in this process.

f. Polishing: rootlets which sprout during germination are removed in this operation;[60]

g. Storage: dried and polished grain is finally stored in silos for no less than four weeks until the next operation.

(ii) *Milling and mashing*

Malted barley is ground in a manner that leaves husks intact while the grain interior is converted to a coarse starch and enzyme-rich powder. Enzymatic action proceeds as soon as the ground malt comes in contact with water, with the result that starch is degraded to sugar. Sweet wort, as the resulting broth is termed, contains partially degraded starch, sugars, enzymes, proteins and water. Spent grain is strained to obtain pure wort. Strained grain is further sprayed with water to extract additional material for fermentation. These washings are monitored for sucrose content, and extraction is stopped when the sucrose strength reaches the 1° level on the Plato scale.

Spent grain yields range between 125 and 130 kg of wet product per 100 kg of malt. A typical composition is 28 per cent protein, 8 per cent fat and 41 per cent nitrogen-free substances. Spent grain is usually used as animal feed, however some may find its way into the effluent stream. Together with spent hops and other solid waste produced in the process of malt preparation it is a valuable source of protein for animal feed.

The temperature of the wort during straining is maintained within the range 75°-78°C.

Hops or hop extracts,[61] sugars or syrups, and coagulants are added at this stage. Boiling the wort for about 1.5 hours then follows. This results in:

Halting enzymatic action;
Sterilization and concentration of the mixture;
Precipitation of the proteinaceous material.

The wort is then clarified in a hydro-cyclone to remove further proteinaceous precipitates and other insolubles.

(iii) *Wort cooling and fermentation*

The wort is next cooled to about 10°C. Further precipitation of proteins and tannin components occurs at this stage. Areation of the cooled wort is carried out in preparation for fermentation. The fermentation process, which takes place in two distinct phases, converts sugar wort into alcohol, though yeast action may last from 2-16 days. Carbon dioxide, further yeast cells and heat are the main by-products of this process. Some of the yeast thus produced is drawn off and used to ferment the following batch of wort. The rest is sold as a by-product. One of the uses of surplus yeast is for animal feed formulations.[62]

Beer is transferred from the vats in which the primary fermentation phase takes place into storage or maturation vessels. Further fermentation and precipitation of yeast takes place during storage while the product matures, stabilizes, and becomes saturated with carbon dioxide (CO_2). Preparations based on fish collagen are added following maturation to promote flocculation of remaining yeast and proteins. Finally, the mixture is filtered through a slurry of a suitable medium.[63] Filter slurry produced in this operation is a fine, dense material and the source of waste management problems. Beer may be centrifuged and cooled

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[60] Removed rootlets are sold as animal feed.

[61] Hops impart the characteristic bitter taste of the beer and some aroma to the final product. They further help coagulate colloidal proteins.

[62] Dry yeast contains 50-60 per cent proteins, 15-35 per cent carbohydrates and 2-12 per cent fats, rendering it a useful source of protein in animal feed formulations.

[63] Kieselguhr or lucilite.

down to between -1°C to -1.5°C to remove further dissolved and suspended solid material. Sterile de-aerated water and CO_2, may be added to adjust beer concentration and gaseous content. Stabilizers, colourants, additional sugar and foam improvement agents may also be added following filtration.

(iv) *Sterilization and bottling*

Sterilization of the final product is carried out either by passage through a pasteurization tunnel following bottling or using flash pasteurization prior to bottling.

Bottling involves bottle washing to remove residue from previous usage or factory dust. Large volumes of water are used during this stage. Care is taken to isolate beer from air during the filling operation. Main pollutants during bottling are due to spillage, breakages and beer residue in returned bottles.

(c) *Wine-making raw materials*

Chart 9 presents a summary view of steps involved in wine production. Grapes containing 15-25 per cent of fruit sugars[64] constitute the primary raw material in wine production, in addition to sugar, wine yeast[65] and a number of additives. Addition of further sugar to the raw materials used in wine making is essential to increase the final alcohol content in the finished product to the level required to prevent rapid oxidation to aldehydes and acetic acid.

The pH of grape juice usually falls within the range 3.0-3.6. This helps control the growth of most deleterious organisms but allows rapid growth of desirable wine yeast varieties. The acidity of the fermentation medium also promotes extraction of colour from grape skins and helps produce a clearer product.

The fact that grapes possess a very small amount of nitrogen-containing compounds[66] which are essential to yeast nutrition, bacterial stability and flavour, necessitates the addition of nitrogen-containing substances.[67]

Red wine, contains a considerable proportion of tannin, which affect taste, colour, oxidation-reduction potential and ageing characteristics. The pectin in grapes are a source of difficulty in juice clarification due to their low alcohol solubility in alcohol-water mixtures.

It is usual to sterilize the crushed grapes prior to addition of the yeast culture to inhibit or limit growth of undesirable micro-organisms. Sulfur dioxide (SO_2) is used.[68]

The overall water intake in wine production is split approximately evenly between washing and cooling. Specific water input values ranging from 0.8 to 1.2 m^3/m^3 wine processed.[69]

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64 Increasing up to 30-40 per cent in partially dried grapes.

65 Yeast varieties most commonly used include Saccharomyces cerevisiae, S. bayanus or S. oviformis.

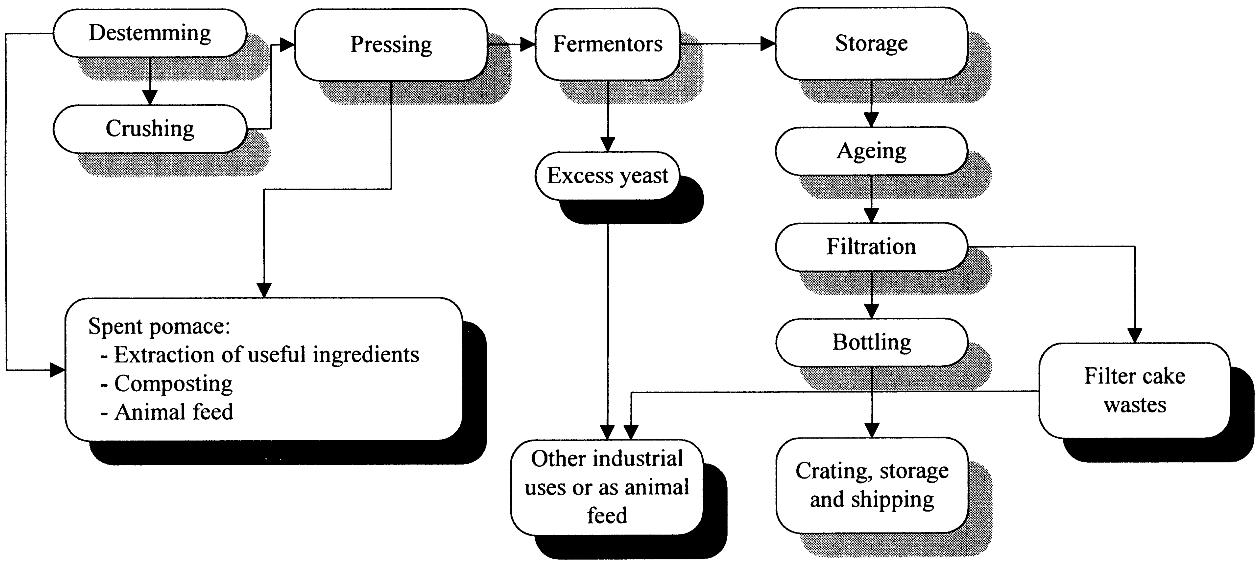
66 Between 0.3-1.0 per cent nitrogen is found in grapes.

67 Common chemical sources of nitrogen used for this purpose include urea and ammonium phosphate.

68 At a rate exceeding 50 mg/l.

69 SRKCE, 1993 and Ontario MOE, 1986.

Chart 9. Wine production process



Source: Adapted from the "Technical pollution prevention guide for the fruit and vegetable processing industry in the Lower Fraser Basin", Environment Canada, DOE FRAP 1996-20.

In the bottling stage the extent of water recycling and the age and efficiency of bottling equipment determine specific water consumption values. Values ranging between 0.3 and 2.1/l bottle with an average of 1.5/l bottle have been reported.[70]

(d) *Process description in wine manufacturing*

Grapes are mechanically crushed and de-stemmed, by centrifugation, passage through rollers or both. The resulting mixture of seeds, skins and grape juice, termed "must" is pumped[71] into fermentation tanks.[72] These tanks may be equipped with stainless steel coils, for cooling or heating. Alternatively, they may be partially or wholly jacketed. Modern wine production facilities are equipped with computer-controlled temperature systems.

Following fermentation, the crude wine is separated from the residue of stems and skins, usually termed "pomace". This is carried out using the conventional screw-type basket press or the continuous press. The latter is the more popular as it tends to be cheaper to operate and produces a higher yield of juice or crude wine, although often a more cloudy liquid than that produced by the former. Chart 9 presents the sequence of wine-making operations.

Periodic equipment cleaning produces considerable volumes of wastewater. Solid waste includes skins, seeds and sediment left in the fermenter. This waste is often treated to recover residual alcohol.

Pulp left following pressing is usually ploughed back into vineyard soil.

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70 SRKCE, 1993.

71 The must may sometimes be strained prior to the initial fermentation step.

72 Fermentation tanks may be made of a variety of materials including: wood, concrete, stainless steel, or iron lined with epoxy resins or a thin layer of stainless steel, the latter being the material of choice in modern wine making. Furthermore, they may be either open or closed.

(e) *Waste materials in beer making*

The following types of brewery waste predominate:

i. Dry and moist solid waste including spent grain and hops, as well as filter cakes containing organic residues from the process, including surplus yeast, kieselguhr, powdered charcoal and broken glass;

ii. Liquid waste, including:

   a. Water-borne waste, caustic solutions used in cleaning and caustic rinses in the bottling area;

   b. Final and intermediate products reaching the effluent stream as a result of leakage and breakage;

   c. Organic loading in wastewater, including particles originating from spent grain and hops;

iii. Solid waste.

Table 18 lists the solid waste generated by a rather large brewery with a capacity of 17,000 m^3/month.

TABLE 18. BREWERY SOLID WASTE

Solid waste *	Waste (per cubic metre of beer produced)
Spent grain (80%)	20 kg
Surplus yeast (90%)	3 kg
Kieselguhr (70%)	6 litres
Ash	17 kg
Malt and grain dust	2.5 kg

Source: Adapted from "Technical pollution prevention guide for brewery and winery operations in the Lower Fraser Basin", Environment Canada, DOE FRAP 1997-20.

* Percentages were calculated on a mass-by-mass basis.

Spent grain: around 140 kg/m^3 wort with a water content of 80 per cent, is normally produced in a well-designed and efficiently-working brewhouse.

Yeast: excess yeast is produced as a result of the fermentation process. Around 20-40 kg of yeast slurry is produced for each cubic metre of beer. This has a very high BOD value, in the range of 120,000-140,000 mg/l.

Trub: this is slurry containing wort, hop particles and colloidal proteins coagulated during boiling prior to fermentation. Typical trub has a dry matter content of 15-20 per cent. Trub has a high BOD_5, around 110,000 mg/kg wet trub.

(f) *Liquid waste from beer manufacture*

Brewing uses up a significant amount of water. It also produces large volumes of wastewater with high biochemical oxygen demand and total suspended solids content. Brewery effluent streams contain: maltose, dextrose, wort, trub, spent grain, yeast, filter slurry and intermediate and final fermentation products. Rinse water represents 45 per cent of the total water use in a brewery. Residual beer lost during

production stages constitutes 1-5 per cent of total production. Most of it can be collected and reused in the brewery process.[73]

The concentration of organic substances in brewery wastewater discharges primarily depends on the amount of beer and organic auxiliary materials, e.g. hops, yeast, etc., in the effluent stream. For example, if trub and spent hops are discharged to the wastewater stream, they can contribute up to 20 per cent of the total daily organic loading.

In general, brewing operations produce a low-flow, neutral pH, concentrated wastewater. The production of non-alcoholic beer increases the proportion of organic substances in brewing wastewater when condensed alcohol is added to the waste stream.

Characteristics of wastewater generated from the various brewery operations are presented in table 19. Wastewater from the malting process has a COD of 800-1,200 mg/l. A study carried out in the mid-1980s estimated that approximately 0.5-1.5 per cent (by weight) of the barley ends up in the wastewater as organics (e.g., pentose, sucrose, glucose, cellulose, protein and minerals). Inorganic chemicals introduced into brewery wastewater include potassium and calcium salts as well as silicates, sulfates and phosphates.[74]

Regeneration of ion exchange units in water treatment plants associated with beer production is also responsible for further discharges of strong acids and caustic materials. Waste from such operations has a wide range of pH values, from 2-12. It is essential, therefore, to collect and neutralize regeneration waste.

Effluent from the brew house emanates from the brew kettle and the fermenter, as well as from cleaning operations. Residues such as trub, spent grain, kieselguhr and yeast are major waste items at this stage. As a result, wastewater from brewhouse operations may have a COD value in the range 3,000-5,000 mg/l, high suspended solids content, relatively high temperatures and high pH values.[75]

Rinsing and cleaning of process and bottling equipment, as well as bottle washing, imposes further waste loading. Bottle washing produces a wastewater with moderate COD values of 2,000-3,000 mg/l and temperatures of 25°-30°C. A high pH is general, however.

TABLE 19. CHARACTERISTICS OF BREWERY WASTE WATER

Source effluent	COD (in kilograms per cubic metre)
Trub from hot wort	3.2
Last runnings:	
- Fermentation vessel to storage vessel	2.7
- Lauter tun	2.5
Fermentation vessels	1.4
Spent filter slurry	1.4

Source: Adapted from "Technical pollution prevention guide for brewery and winery operations in the Lower Fraser Basin", Environment Canada, DOE FRAP 1997-20.

Equipment cleansing produces wastewater with wide variations in pH values, depending upon the cleansing system and chemicals used. In general, the overall pH of effluent from cleansing operations may range from pH 7-12.[76]

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[73] Reported in "Technical pollution prevention guide for brewery and winery operations in the Lower Fraser Basin", Environment Canada, DOE FRAP 1997-2.

[74] References quoted in the Canadian study: Huang and Hung, 1987; de Vegt et al., 1992.

[75] References quoted in the Canadian study: Ontario MOE, 1986; Huang and Hung, 1987; de Vegt et al., 1992; UNEP, 1995.

[76] References from the Canadian study: SEPA, 1991; Cronin, 1996.

Inorganic nitrogen and phosphorus compounds present in brewery wastewater have an adverse environmental impact due to their toxicity to some forms of aquatic life, eutrophication and groundwater pollution. Inorganic nitrogen emanates from nitric acid used for cleaning and the possible use of ammonium salts as yeast nutrients.

Inorganic phosphorus, a derivative of the cleansing agents, may be present in brewery wastewater in concentrations ranging from 30-100 g/m^3.[77]

(g) *Wine production waste*

The principal waste items in wine production are pomace, lees, bottle washings, cooling water, and salt-laden water from ion-exchange processes. Pomace consists of de-watered grape skins, seeds and pulp and may be used as a source of grapeseed oil.

A small plant producing around 8,000 hectolitres of wine per ton of grapes will produce BOD_5 loadings of around 2.2 kg/m^3 and suspended solids loadings in the region of 0.5 kg/m^3. The amount of water used and the waste concentrations vary considerably.

(i) *Solid waste*

One ton of grapes produces 600-700 litres of wine, and 100-120 kg of solid waste. Pomace makes up most of the solid waste produced in wine making: around 100 kg per ton of grapes. An elemental breakdown of this quantity of pomace, with around 50 per cent moisture, includes nine kg of nitrogen, an equal amount of potassium, measured as potassium carbonate, and around 2 kg of phosphorus.[78]

(ii) *Liquid waste*

Wastewater generated in wine production amounts to about 70 per cent of water intake. Wine production wastewater originates from several production processes, including bottle washings, cooling system, saltwater ion-exchange units, pomace and lees pressing.

Wine production pollution loading typically varies from around 2-7 kg of COD/m^3 (table 20). This is mostly due to washing and cleansing operations. Organic loading follows seasonal peaks related to grape and pomace pressing and the filtration of newly-fermented wine.

TABLE 20. WASTEWATER CONTAMINATION FROM WINE PRODUCTION

Parameter	Wastewater produced (m^3 per day)	Specific effluent volume m^3/m^3	Specific pollution load kg/COD/m^3	kg/TDS/ m^3
Range	10 600-28 000	1.47-1.59	2.08-6.85	0.49-3.18
Average	19 000	1.53	4.04	1.10

Source: Adapted from "Technical pollution prevention guide for brewery and winery operations in the Lower Fraser Basin", Environment Canada, DOE FRAP 1997-20.

A major source of organic loadings in wine production wastewater is due to the discharge of sediment[79] that accumulates during the storage of wine (table 21). Other components with high BOD in wine production wastewater include: alcohol; sugars, principally glucose and fructose; organic acids, including acetic, lactic, citric, malic, succinic and tartaric acids and some of their salts; soluble proteins; peptides and some trace metals.

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77 UNIDO 1995 reported in the Canadian study: Ontario MOE, 1986; Huang and Hung, 1987; de Vegt et al., 1992; UNEP, 1995.

78 References quoted in the Canadian study: Ontario MOE, 1986; Huang and Hung, 1987; de Vegt et al., 1992; UNEP, 1995.

79 Also referred to as "lees" here.

(h) *Beer and wine manufacturing: a summary*

(i) *Wastewater*

Beer brewing and wine-making wastewater is characterized by high BOD and total suspended solids (TSS) loadings. Wide variations in wastewater flow and contaminant concentrations have been noted, however. The main environmental concerns associated with beer brewing and wine-making include wastewater BOD_5 and TSS loadings, pH, nitrogen and phosphorus concentrations, as well as the temperature of the wastewater itself.

Discharge of untreated wastewater from brewing and wine-making operations leads to depletion of dissolved oxygen in surface water and generation of noxious odours. Furthermore, nutrients in wastewater stimulate aquatic plant growth and result in eutrophication.

TABLE 21. ANALYSIS OF SOLID WASTE FROM WINE MAKING

Parameters	Lees	Conventional Sage	Lees stillage	Pomace stillage
Total solids (g/l)	186	20	68	13.2-32.0
Volatile solids (%)	95	87.4	86.5	77.0-89.4
Suspended solids (g/l)	152	3.1	59.0	18.7
BOD_5 (g/l)	163	11.0	20.0	2.4
Volatile acids (g/l)	7.8	1.9	2.5	0.4
Total acidity*		3.2	9.9	1.2
pH	4.0	4.7	3.8	6.8-3.7
Total nitrogen (g/l)	9.9	0.37	1.5	0.3
Total phosphorus (g/l)	1.3	11.2	4.3	1.3
Total ammonia (mg/l)	56	2.8	45	4

Source: Adapted from "Technical pollution prevention guide for brewery and winery operations in the Lower Fraser Basin", Environment Canada, DOE FRAP 1997-20.

* Determined in terms of $CaCO_3$.

(ii) *Air emissions*

The main air emissions in beer and wine-making include VOCs, greenhouse gases, odours and dust. A recent study reported by the U.S. Environmental Protection Agency (EPA) and the California Air Resources Board, indicated that breweries were minor contributors to atmospheric VOCs.

Some greenhouse gases are, however, produced in the beer and wine-making processes. They include:

Carbon dioxide (from fermentation and combustion processes);[80]
Nitrous oxide (generated in transportation and energy generation);
Sulphur dioxide (produced during kilning).

Odours from brewing and wine-making activities are a nuisance rather than a health or environmental hazard. Odours are strongest in the vicinity of the malthouse where sprouted barley is being dried, and close to operating fermenters.[81]

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[80] Approximately 16 kg of CO_2 is generated from fossil fuel burning per hectoliter of beer produced. This exceeds by a factor of more than five the amount of CO_2 generated during fermentation (UNEP, 1995).

[81] References quoted in the Canadian study: Ontario MOE, 1986; Huang and Hung, 1987; de Vegt et al., 1992; UNEP, 1995.

2. *Pollution abatement technology in beer and wine production*

The principal focus of environmentally sound technologies in the manufacture of beverage and fermentation products has been on reducing water and energy consumption, improved extraction of by-products and more efficient use of waste vegetable matter.

The use of a variety of in-line sensors in integrated measurement systems has enabled improved energy management. Recirculation of steam and steam condensates following sterilization processes is another measure being adopted to reduce energy consumption. Alternative packaging methods have been introduced to reduce or eliminate the need for steam sterilization.

Methods for the biological treatment of waste produced by the beverage and fermentation products industry have become more common; and they are proving beneficial not only in terms of saleable by-products but also in cleaner waste that may be disposed of on agricultural land or in compost making.

By way of summary, table 22 includes a list of environmental issues and amelioration objectives associated with the various operations in beer and wine manufacture. Possible EST inputs are also listed.

TABLE 22. POSSIBILITIES FOR IMPROVING THE ENVIRONMENTAL IMPACT OF BEER AND WINE-MAKING OPERATIONS

Operation	Objective	Possible innovation
Ingredient despatch and make-up	Process improvement and waste reduction	- Improve raw material selection process using modern analytical techniques
Product preparation and initial processing	Optimizing use of raw materials and waste reduction	- Adopt IT-based procedures and introduce computerized aids for dispensing and inventory management - Use improved in-plant conveyance to eliminate product loss - Install means of catching spilt fruit juices and other liquid ingredients - Collect and treat spent vegetable matter - Use automatic controls to reduce water consumption through spillage and leakage
Fermentation/Beer processing	Rational solid waste disposal and water conservation	- Collect and treat spent vegetable matter and excess yeast, e.g., to extract grapeseed oil - Separate wastewater effluent streams to the greatest possible degree, e.g., CIP wash-water from process overflows - Condense volatile matter in gaseous waste in order to reduce nuisance air emissions - Remove and treat filter cake and sediment for re-sale as animal feed, fertilizer, etc.
Filtration and clarification operations	Rational solid wastewater disposal	- Separate bottle and can-washing wastewater from other wastewater streams, with special attention to segregation of caustic waste used in cleansing operations from other wastewater sources

TABLE 22 (*continued*)

Operation	Objective	Possible innovation
Packaging	Optimizing wastewater treatment	- Investigate the use of alternative packaging to reduce sterilization cost and water consumption - Re-circulate process steam, used for sterilization, for example, and heating water wherever possible
Reuse and recycling	Energy and water conservation	- Install or upgrade water treatment and recycling facilities.

Source: Adapted from the "Technical pollution prevention guide for the fruit and vegetable processing industry in the Lower Fraser Basin", Environment Canada, DOE FRAP 1996-20.

III. NEW ENVIRONMENTALLY SOUND TECHNOLOGIES IN THE FOOD PROCESSING INDUSTRY

A good deal of the development in new, environmentally sound food processing technology has come about as a result of dedicated research and development (R and D) on the part of governmental, non-governmental and industrial laboratories, primarily in response to strengthened environmental protection in the developed countries. Table 23 presents a list of the types of technology that have, in particular, been the focus of such endeavours during the past two decades.

TABLE 23. ENVIRONMENTALLY SOUND TECHNOLOGIES OF PRIMARY INTEREST IN THE FOOD PROCESSING INDUSTRY

Advanced wastewater treatment technology	- Use of wastewater technology based on new membrane technology
Innovative sensors and process control	- Use of advanced techniques to gain better in-line control-specific processing operations thus reducing waste, increasing productivity and improving product quality
Modern packaging materials and techniques	- Using less packaging material in absolute terms and a move towards more environmentally-friendly packaging products
Food disinfection and irradiation	- Use of radiation rather than chemicals to destroy or limit the propagation of pathogenic micro-organisms
New materials in FPI operations	- The use of new materials in the construction of equipment as well as in the extraction of vegetable oils, essences and flavours, provides the industry with superior tools for lowering emissions and improving product quality
Biotechnology applications	- Use of new biotechnology in FPI operations and in wastewater treatment
Innovative design and validation methods	- Use of advanced computer software and high-speed computing in the design and modelling of industrial operations, resulting in time and resource savings
Innovative processing methods	- Use of pulsed electrical, ultra-high pressure and up-to-date steam pasteurization techniques may also be reflected in reduced fuel utilization and longer shelf life

Source: "Food Online" by J. E. Stratton, M.S., Dept. of Food Science and Technology, University of Nebraska-Lincoln.

Of the types of technology listed in table 23, that related to water-use reduction and wastewater treatment are the focus of attention. Concepts behind the drive for new technology in these areas include those of zero discharge and zero emission.

A. ZERO DISCHARGE AND ZERO EMISSION CONCEPTS

The "zero discharge" and "zero emission" systems are the centre of attention of firms in many of the developed countries, particularly in the United States.[82] Both concepts have been developed around the need for better effluent water quality and to diminish the adverse impact on the environment.

The zero-discharge or "closed-loop" approach appears to present an increasingly viable option for many firms in the FPI in industrialized countries. At the core of this approach is the fact that, once part of a food product is lost to a waste stream, it represents a loss in terms of product utilization and an increase in

[82] Several large FPI entrepreneurs in the United States have, for example, declared that they are moving towards such goals.

treatment costs. However, sizeable capital investment and customized treatment plant are required for application of this option.

On the other hand, the zero emissions approach may be significantly more attainable. The "zero emissions" strategy is based on establishing a network of firms utilizing constituents in each other's waste streams. In this approach, waste products do not have to be fully treated *in situ*. Process residues such as sludge are still subject to some form of on-site management but are eventually forwarded for off-site handling and possible ultimate disposal.

A zero discharge or zero emission facility is now the ultimate goal in many industrialized countries. Zero discharge is still an ideal. Due to regulations and restrictions, however, the food processing industry is required to devote more time and effort to reducing effluent and contamination to the lowest economically feasible levels.

An approach based on the zero discharge and zero emissions concepts has become possible as a result of the availability of technological advances enabling cost-effective water treatment and conservation in FPI operations. New wastewater treatment technology has been at the centre of these advances.

B. New separation technology in FPI operations

Separation processes play a central part in all FPI segments. Several recent improvements in food processing have been specifically aimed at reducing polluting effluent in wastewater streams. FPI wastewater has to be treated *in situ* and its level of dissolved solids and biological oxygen demand (BOD_5) drastically reduced before it can be directed towards municipal treatment plants or discharged into surface or coastal water systems. In line with the above concept of zero emissions, it is often possible to reuse dissolved and suspended solids as recycled input into the same or other industrial activities. Thus, proteins, sugars, and enzymes may be usefully recovered from wastewater for reuse.

Several new separation methods will affect wastewater constitution through improved handling of process streams. Thus, reducing the percentage of protein in dairy processing wastewater through their extraction from whey will ultimately improve the quality of wastewater eventually released into the surrounding environment. The same is true of many other processes in abattoirs, sugar factories, fermented beverage production, etc. In general, advanced wastewater processes encompass any treatment methodology that goes beyond secondary treatment.[83] Advanced wastewater treatment practices may also target specific effluent components. Pathogens, suspended solids, dissolved solids, nitrogen, and phosphorus compounds may all be removed in advanced wastewater treatment.

Some of the more promising technology in advanced wastewater treatment is grouped under the generic term "membrane technology".[84] Wastewater treatment utilizing membrane technology is dependant upon the availability of new materials and designs. Integrated systems that utilize different membrane types within the same process are becoming more common. Membranes are also used to effect separation involving the extraction of specific ingredients from a given stream, e.g., the extraction of proteins from whey left in cheese making.

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[83] This is primarily based on biological treatment of wastewater.

[84] The number of food-processing facilities using advanced treatment has nearly trippled in the past 10 years. This trend is expected to continue due to increasing federal and State restrictions on wastewater discharge.

1. *Membrane technology*

Membrane technology has been used in the food industry for over three decades. Its application has ranged from the separation of milk-solids and the concentration of whey protein in the dairy industry, clarification and concentration of fruit juices and the purification of sugar solutions, to water purification and wastewater management. The application of membrane technology in these areas has produced beneficial results reflected in enhanced productivity and cost profiles in a variety of operations.

Energy requirements for generating and applying pressure needed for traditional membrane separations in the past rendered these methods unviable in many other applications, however. In addition, the fact that available membranes had inadequate mechanical properties added to the cost of water treatment based on membrane processes. The advent of new polymeric materials, coupled with cheaper energy prices, has resulted in important changes in this area.

(a) *Membrane basics*

Modern membrane separation methods are, in general, less energy-intensive than evaporation and distillation operations and take up less plant space. The technology enables better control of process effluent and, unlike chemical precipitation, membrane technology does not produce a sludge disposal problem. It does, however, produce concentrated brine or effluent solutions.

In essence, membrane separation utilizes the chemical and physical properties of particles and molecules, both dissolved and suspended,[85] in a given liquid substance, in order to separate or remove specific components from the material being treated.

Materials used in membrane separation are basically thin sheets with pores of varying sizes, attached to supports with larger pores. In their basic form they serve merely as sieves, separating suspended solids or dissolved molecules and ionic species of different sizes from the mother liquors.

Membrane materials used in FPI separations involving substances destined for human food and fodder must meet a number of strict conditions. They must first be approved for contact with food materials; they should also be easy to clean and able to withstand process conditions. Clearly, less stringent conditions may apply in the case of wastewater treatment prior to discharge into surface or municipal water systems.

Membrane separation may be divided into the following categories on the basis of the size of the species retained in the process:[86]

Reverse osmosis (RO);
Nanofiltration (NO);
Ultrafiltration (UF);
Microfiltration (MF).

Table 24 presents the principal characteristics of these separation methods. The last two filtration techniques are more or less straightforward filtration processes. Microfiltration is used for removing particles from 0.05-2 microns in size, UF will separate particles and suspended solids within the size range 0.005-0.1 microns.

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[85] In principle, all separation processes are dependant upon physical or chemical properties. Centrifugation, for example, is dependant upon the differential specific gravity of solids suspended in a liquid phase. Ion exchange, on the other hand, utilizes the electrochemical properties of specific resins to selectively separate or remove specific ionic species from solution.

[86] Article in "Food On Line" by Jayne E. Stratton, M.S., Dept. of Food Science and Technology, University of Nebraska-Lincoln.

TABLE 24. MEMBRANE SEPARATIONS

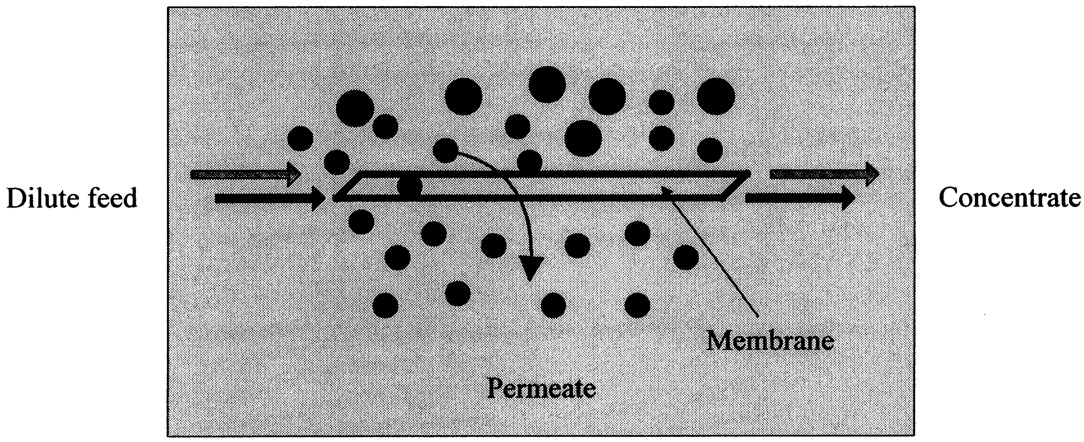
Separation method	Pore sizes	Materials rejected or passed
Particle separation	> 5 micrometres	Suspended particles
Microfiltration	1 000 Ångstroms-10 micrometres	Bacteria and yeast
Ultrafiltration	10-1 000 Ångstroms	Macromolecules and proteins
Nanofiltration	2-70 Ångstroms	Passes divalent cations and monovalent anions
Reverse osmosis	1-70 Ångstroms	Sugars, dissociated acids, metal ions

Source: "Food Online" by J. E. Stratton, M.S., Dept. of Food Science and Technology, University of Nebraska-Lincoln.

Reverse osmosis membranes have the smallest pores and can separate constituents of ionic sizes. RO operations are conducted at pressures ranging up to 1,500 psi. Nanofiltrations, allow a wider range of ionic species to pass and operate at pressures in the vicinity of 300 psi. Ultrafiltration can separate molecules such as proteins and other macromolecules at pressures of 10 to 200 psi. Microfiltration membranes have the largest pore sizes in the above categories and may be used for removing suspended solids and bacteria. They operate in the range of 1 to 25 psi.

Tangential flow filtration (TFF) is used in membrane separation in the food processing industry. In this method the feed stream flows at high velocity parallel to the membrane surface. Flow across the surface of the membrane sweeps the retained substances, or retentate, from the membrane surface to avoid plugging the pores. Figure I presents a schematic of the basic design in this separation method.

Figure I. Tangential flow filtration



Source: "Food Online" by J. E. Stratton, M.S., Dept. of Food Science and Technology, University of Nebraska-Lincoln.

Traditional through-flow or dead-end filtration, involves an arrangement whereby the flow of the feed stream is perpendicular to the surface of the membrane. The material separated is then in the form of a partially- dry cake. TFF methodology is used for both concentration and clarification purposes. In both cases the fraction that contains the solute and the smaller size constituents passes through the membrane. This retentate is re-circulated until the desired concentration or degree of clarification is obtained. Membrane performance is measured by the rate of permeation, referred to as "flux".

In concentration, the membrane retains the desired product, the retentate becoming increasingly concentrated as the permeate is removed. In clarification, the desired product goes through the membrane and is collected as permeate, generally leaving insoluble materials or other undesired components in the retentate.

(b) *Membrane construction*

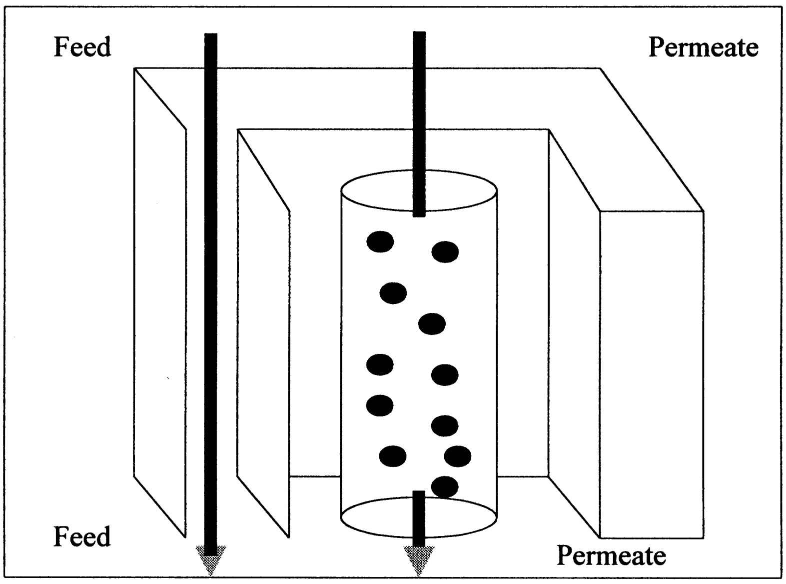
Reverse osmosis and ultrafiltration membranes were initially cellulose-based. Modern polymers such as polyacrylonitrile (PAN), polyvinylidene fluoride (PVDF) and blends of polyvinyl chloride (PVC) with PAN, as well as the more recent polysulfone (PS) or polyethersulfone (PES) polymers, constitute the basis of present-day membranes.

Food industry applications make use of four filtration module designs:

Spiral wound;
Tubular;
Plate-and-frame systems;
Hollow-fibre.

Spiral-wound systems may be used in more than 60 per cent of food industry applications, e.g. dairy fluid processing. They are used in most RO and NO applications. Figure II shows a schematic of the spiral-wound design.

Figure II. Spiral wound membrane module



Source: "Food Online" by J. E. Stratton, M.S., Dept. of Food Science and Technology, University of Nebraska-Lincoln.

A difficulty common to all of these membranes is in the handling of viscous material and material with a high solids content. Tubular systems account for about 10–15 per cent of food industry applications, (figure III). They consist of a porous outer tube that is coated on the inside with a semi-permeable material. A typical module is made up of a number of tubes in series, the shell collecting the permeate and the retentate discharged at the end.

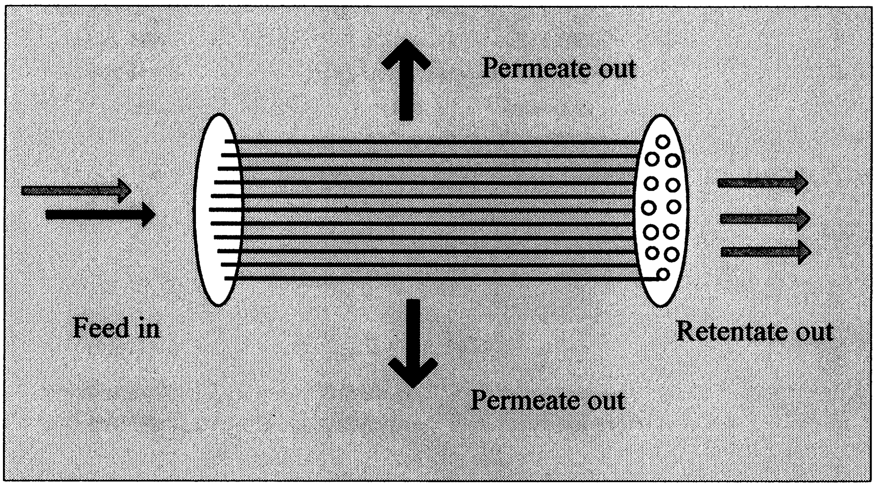
Tubular designs have the following advantages:

Visual inspection is readily carried out;

They are easy to clean;

Can handle liquids with a higher solids content and larger suspended particulates than can other membrane designs.

Figure III. Tubular membrane module

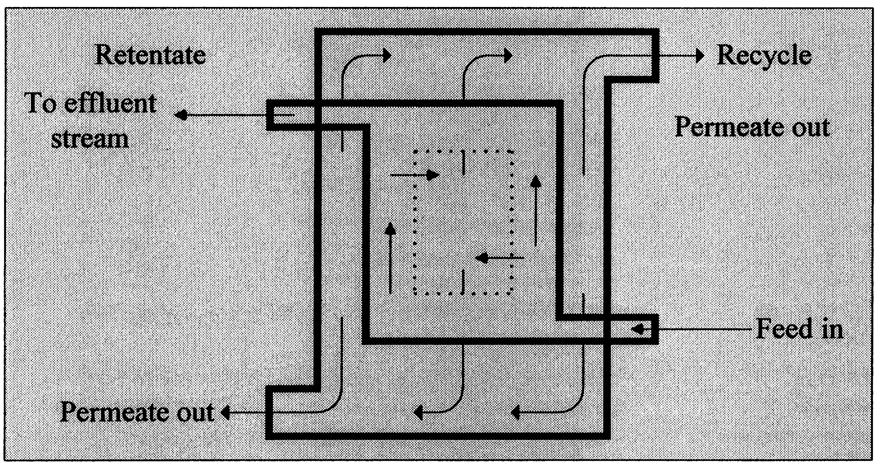


Source: "Food Online" by J. E. Stratton, M.S., Dept. of Food Science and Technology, University of Nebraska-Lincoln.

The membrane area is rather small, however. This combination of characteristics renders tubular designs more suitable for beverage clarification or for reverse osmosis of pulp containing juices.

Plate-and-frame (figure IV) is representative of a sizeable percentage of designs used in food industry applications. Flat-sheet membranes are attached to both sides of a porous plate and held by a suitable frame.

Figure IV. Plate-and-frame, flat sheet configuration



Source: "Food Online" by J. E. Stratton, M.S., Dept. of Food Science and Technology, University of Nebraska-Lincoln.

In the plate-and-frame design, several membranes and their supports can be stacked within one holder to boost the overall membrane surface area. The range of pore sizes used is between 12.5 and 25 micrometres. An obvious advantage of this design is the low cost of membrane replacement. In addition, the initial capital investment for the hardware allows for the additional use of a variety of membranes. Thus, both ultrafiltration and microfiltration processes may be carried out using the same unit. Notable applications of these systems include removal of alcohol from beer, a process that has been put into practice in both Europe and Australia. Plate-and-frame systems have also been used in high-viscosity applications in the dairy industry.

Hollow-fibre membrane systems consist of fibres with inside diameters in the range of 0.5-1.1 micrometres. Flow takes place through the inside of the fibres and permeate collects on the outside. High packing density is achieved by stacking hundreds of fibres in parallel. Back-washing is possible. A disadvantage is the low trans-membrane pressure necessary to avoid damaging the fibres. The entire element has to be discarded if even a single fibre is damaged.

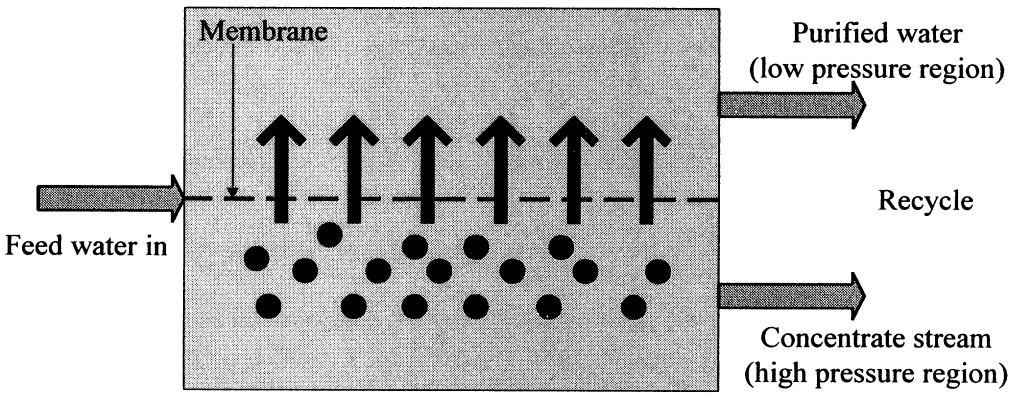
(c) *Reverse osmosis*

Reverse osmosis merits a close look due to its suitability for a wide range of applications. RO systems may be used as follows:

To purify process water;
Concentrate cheese whey proteins or milk in the dairy industry;
Concentrate sugar solutions in the cereal processing industry, and in the manufacture of juices;
To treat wastewater in meat and fish processing industries.

In ordinary osmotic processes, the solvent, normally water, passes through a semi-permeable membrane, separating solutions of different concentrations from the less to the more concentrated. In reverse osmosis, appropriate pressure applied to the more concentrated side forces the solvent to flow into the more dilute solution[87] (figure V).

Figure V. Reverse osmosis process



Source: "Food Online" by J. E. Stratton, M.S., Dept. of Food Science and Technology, University of Nebraska-Lincoln.

Many food products require the removal of large amounts of water for more economical shipping. Removing the water by evaporation requires substantial amounts of energy and is inappropriate if the product is heat sensitive. In such cases implementation of RO technology can provide adequate remedies. The advantages of using RO technology is illustrated by the case of the corn wet-milling industry in the United States. This process consumes about 98.8 quadrillion J/year. The energy required for RO is approximately 110 kJ/kg versus 700 kJ/kg for the most efficient evaporator, resulting in substantial savings.

RO is used for particles, suspended solids, and dissolved solids in the Angstrom range, in effect for large molecular entities of molecular weights exceeding 200 Angstroms. RO systems consist of semi-permeable membranes and a means of applying pressure differentials on both sides of the membrane.

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[87] In natural osmotic processes the move towards equilibrium drives water from the side of the membrane that contains the less dilute, i.e., less loaded or contaminated stream, to the other containing the more polluted, i.e. more concentrated stream. This process equalizes "osmotic pressure" on both sides of the membrane and a state of equilibrium is reached. If mechanical pressure is applied on the more concentrated, contaminated side of the membrane, a reverse process is induced. Pressure is thus applied to reverse the natural equilibrium between the "purified" water and wastewater streams. Thus, water molecules from the wastewater side migrate through the membrane to the clean water stream effecting purification of the wastewater stream.

Basically, the membrane is used in a unit process allowing separate process streams to flow on either of its two sides: one carrying the contaminants, or the material targeted for extraction, the other consisting of pure, or less-loaded, water.

Two of the main problems with membrane separation are the biofouling of the membrane and mechanical failure. These two shortcomings are not unrelated. Toxic synthetic tends to oxidize the surface of membranes, affecting their resilience and mechanical properties. Advanced membrane materials possess superior mechanical properties and resistance to a variety of chemical agents. Stainless steel and ceramic membranes may for instance be used for advanced wastewater treatment in hostile chemical environments.

2. *Ion-exchange separation*

Cationic and anionic resins are widely used in ion exchange systems to remove charged ions of concern from wastewater. The ion exchange process replaces the charged ions within the waste stream, including heavy metal pollutants, with relatively harmless, ionic species detached from the resin. Resins used in this process need to be replaced or treated with chemicals, in a process termed "regeneration". This is generally a simple process carried out *in situ*, often using straightforward salt, acid and alkali solutions. More complex resin systems may have to be regenerated at the facilities of the resin manufacturer. This regeneration process is itself a source of concentrated solutions of brine and, possibly, heavy-metal salts. Care should be taken, therefore, in disposing of spent resin material.

Ion exchange resins are generally sensitive to certain pollutants which may block their ability to capture the desired ions from the waste stream. Furthermore, they operate only within set ranges of pH values, since fluctuation affects the rate of removal of specific ionic contaminants. Thus, removal of ammonium salts becomes highly inefficient beyond pH values of around 9.3. In addition, the fact that ion exchange resins tend to be somewhat selective may mean that a number of ion exchange batteries loaded with different types of resins may have to be used in certain environments in order to achieve adequate separation.

As with membrane applications, ion exchange does not produce a chemical sludge; and, like disinfection, it protects the quality of the receiving water system and decreases the nutrient-loading problems that cause its eutrophication.

3. *Separations based on electro-coagulation*

A recent addition to the range of separation methods is electro-coagulation. This method is viewed as economical for the removal of charged particles from wastewater, utilizing charge separation. Charge separation involves separating ionic contaminants, such as ammonium NH^{4+} compounds as well as nitrates NO^{3-}, nitrites NO^{2-} and phosphates PO^{4-}, from the bulk of the water in the effluent stream. Electro-coagulation is beginning to receive attention as a treatment option, and its use in the food processing industry is expected to increase.

4. *Centrifugal and gravitational separations*

These are essentially the simpler and more traditional of all separation methods. In particular, gravitational sedimentation may be applied to variable wastewater influent, regardless of turbidity, solids loading, etc. Both floatation and sedimentation methods may require the addition of auxiliary materials such as flocculants and foam-stabilizing chemicals.

(a) *Centrifugal methods*

Centrifugal separators may be used to remove contaminants whenever a favourable density differential between the medium and the pollutant in question may be attained. They possess advantages of speed over gravitational separation methods. In addition, they may also be used with viscous effluent streams loaded with solids, for which it might be impossible to use a straightforward sedimentation treatment. Their chief application in the FPI is in vegetable oil extraction and dairy processing.

(b) *Floatation methods*

Floatation methods are fundamentally a special case of gravitational separation. Compressed air is used in air floatation systems to raise suspended solids to the surface in the wastewater stream. This is carried out by means of special tanks and usually the use of surfactants that cause floatation of suspended particles. Skimmers are employed to separate accumulating waste from the surface. Although special equipment is needed, floatation methods are not generally regarded as capital intensive.

Centrifugal and gravity separation processes are often effected ahead of the above-mentioned more-advanced membrane operations. This ensures that cleaner, less turbid wastewater reaches the relatively advanced methods e.g. reverse osmosis and ion exchange, that are dependent for the most part on more delicate separation materials. Recovered fats, oils and grease (FOG) residues constitute a saleable by-product. Use of any of these advanced processes improves the final wastewater effluent quality and also increases the likelihood of recycling a renovated process water.

C. SENSORS AND AUTOMATED PROCESS CONTROL

Automation is increasingly being adopted in FPI operations. In the past, concern about reliability and high capital expenditure were important factors in slowing the acquisition of automated technology for use in food processing. Concern about the image of the industry, based on the notion that human care and expertise were as essential as the wholesomeness of a food item's ingredients in securing consumer acceptability, also played an important role in delaying the introduction of automation.

Despite its belated adoption in the food processing industry, automation had for years been in use in the specialty, beverage and dairy segments in developed countries. Until recently, however, it had not been used to a great extent in the fruit, vegetable, and meat-processing sectors.

Improved technology and cost reduction have now made analytical sensors, PC interfaces, and closed-loop control systems more attractive. These types of automated devices allow the user to improve efficiency, control the process of raw material inputs and the amount of waste generated. In particular, in-line sensors can be used to control process temperature, humidity, pH, flow rates and the level of a variety of contaminants.

New sensors are capable of characterizing the physical properties of processing materials. Subjective properties, such as appearance, taste, aroma and texture, as well as physical properties such as size, shape, texture, and colour, are all possibilities for automated assessment.

The use of process automation further reduces the possibility of human error in manufacturing processes. It improves speed and accuracy in measuring process variables and also reduces labour costs. Automated equipment frees workers for other more pressing aspects of production. In addition, it makes real-time data available to planning personnel without interrupting the production run.

The scope for expansion in the acquisition of automated FPI facilities is considerable. Numerous FPI establishments, even in developed countries, are still using equipment that requires constant human monitoring and intervention. Massive conversion to automation will take place as industry realizes the economic benefits. For the present, new waves of cost-effective automated process equipment continue to become available. The best time to implement this type of technology is, however, when new facilities are being set up; bottle necks and other problems are less likely to occur at that stage. In addition, management is more amenable to the adoption of new technology during a company's design and establishment phases.

D. FOOD DISINFECTION AND IRRADIATION

Destruction of spoilage and pathogenic micro-organisms may be classified as EST for the simple reason that it may reduce the quantity of spoilt foodstuffs that enter the solid waste stream or dumping sites. Advances in both food disinfection and irradiation have been made with significant results in prolonged shelf-life of the product and greater profitability and productivity in many FPI segments. New regulations,

particularly concerning meat, poultry and seafood processing plants, also stipulate that both thorough treatment of their wastewater, high in pathogenic organisms, and disinfection must be carried out prior to discharge into sewers or other public water systems.

1. *Disinfection*

The main advantage of disinfecting products and wastewater is that it improves and protects water quality and aquatic life in the receiving water systems. Sanitary conditions are a primary concern in meat, poultry and seafood processesing. Chlorination has been the quickest means of disinfecting both the product and wastewater in such facilities. However, it has recently come under criticism due to the fact that chlorinated organic chemicals are formed upon its use, certain varieties of which have been labelled as carcinogens, and also by reason of the toxicity of residual chlorine to certain forms of aquatic life.[88] Table 25 presents information on chlorine concentrations in cleansing solutions used in FPI operations.

TABLE 25. CHLORINE CONCENTRATIONS AND TEMPERATURES FOR FPI EQUIPMENT WASHING

Minimum concentration (mg/l)	Minimum temperature	
	pH 10 or less (°C)	pH 8 or less (°C)
25	49	49
50	38	24
100	13	13

Source: Adapted from "Chlorine compounds, food safety and the environment", UNEP, Industry and Environment, January-March 1995.

Ozone and ultraviolet (UV) irradiation treatment are the two principal alternatives to chlorine disinfection of wastewater. As in the case of chlorination, ozone treatment is essentially an oxidation process. The main advantage of ozonation is that it leaves far less residue in treated wastewater. Furthermore, the chemicals produced by ozonation are considered less toxic to both human and animal life.[89]

UV treatment is probably the most environmentally-friendly of the three disinfection methods. However, it requires special equipment and may only be effectively applied to cleaner wastewater. In general, both ozonation and UV irradiation are capital-intensive, require special training in their use and entail higher running costs.

UV light sterilization is also making its mark in the processing of food and beverages. Authorization for commercial UV sterilization of fruit and vegetable juices has been requested from the Food and Drug Administration (FDA) by a United States processor.[90] An advantage of UV light sterilization is that no detectable residue is produced as a result of this procedure, as in the case of chemical sterilization techniques. Furthermore, no degradation of organoleptic properties occurs as in heat sterilization.

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[88] "Chlorine compounds, food safety and the environment", UNEP, Industry and Environment, January-March 1995.

[89] Ozonation may produce a class of chemicals, "peroxides", which are nevertheless considered a health hazard. However, many peroxide species are short-lived and the majority is thought to disintegrate into less harmful oxidation products within a short space of time.

[90] "The sterilizing power of light UV emerging as an effective food/beverage safety tool", Beverage Online, Feature Articles, 19 October 1999. URL: http://www.beverageonline.com/content/news/

UV light is reported to keep harmful bacteria within the limits prescribed by FDA regulations.[91] UV treatment is reported as helping extend product shelf life, thus enabling market expansion. This is especially important for products such as fresh fruit and vegetable juices.

The nature of UV light sterilization permits in-line exposure as the product moves through a special transparent unit. In one model being considered for food application, sterilization is effected by means of intense flashes of light in the UV to near infrared (NIR) range to destroy bacteria, spores and viruses and to deactivate organisms on the surfaces of foods and packages.

An advantage of UV sterilization is that it allows a product such as fruit juice to be immediately cold-filled into plastic bottles. The use of light sterilization is effectively limited to liquid products. Furthermore, it is essential that the medium being sterilized should be relatively transparent to the radiation wavelength being employed. This is important for practical reasons, principally to ensure light penetration through product thickness during acceptable time periods.

Other sterilization methods that appear to be in use for prolonging the shelf life of beverages include the use of hydrogen peroxide vapour systems.[92]

2. *Food irradiation*

Food irradiation involves the application of low-dose radiation to fruit, vegetables, meat and other foodstuffs (box 6). Irradiation destroys food-borne bacteria such as E. coli, salmonella, and other harmful pathogens, as well as certain parasites. The irradiation process prolongs the shelf life of food products and can change rejected meat products into approved ones by destroying the pathogens that caused their initial rejection. Low-dose radiation also inhibits sprouting or ripening of food products, rendering them suitable for shipment to wider markets without risk of deterioration and possible consequent disposal in ways invariably causing an adverse environmental impact.

Among the drawbacks to the use of this technology is public wariness of the irradiation of foodstuffs. Another is, of course, that irradiation does not destroy or break down harmful toxins that are initially present in foods. Concerns about taste and reduced nutritional value have for the most part been shown to be unwarranted. Irradiation carried out at high temperature may, however, taint some products.

Food irradiation decreases the amount of water needed for rinsing and cleansing foodstuffs and reduces the risk of pathogenic contamination. The cost of irradiation is low, of the order of a few cents per kilogram. A relatively short exposure time is needed to destroy pathogens of concern.

There are currently no irradiation chambers in commercial food processing plants. Packaged foods are normally transferred to commercial irradiation sites. Regulations in developed countries that have so far allowed food irradiation stipulate that irradiated foodstuffs must be labelled as such. Most food processing companies are hesitant, however, to market their products so labelled.

Further scientific studies will be needed if irradiation is to be utilized to its full potential. Public opinion in the industrialized countries is not yet favourable to its use, but the forecast for food irradiation is that it will gain in acceptance within the next 10 years.

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[91] The mechanism responsible for sterilization by UV light involves absorption of the UV light by the bacteria's DNA strands affecting their fusion, thus preventing the bacteria from undergoing further reproduction.

[92] "The sterilizing power of light UV emerging as an effective food/beverage safety tool", Beverage Online, Feature Articles, 19 October 1999. URL: http://www.beverageonline.com/content/news/

Box 6. Food irradiation[93,94]

Energy sources used in food irradiation include gamma radioisotopes, usually cobalt-60, and electron beams. The application of gamma energy, or dose, is measured in kiloGray (kGy). The principal uses for irradiation are:

(a) As a substitute for chemical fumigants;
(b) As a food preservation technique;
(c) To delay sprouting in roots and tubers such as potatoes.

A point of special importance in health and environmental regulations governing trade in agro-food products is the fact that the use of irradiation can overcome trade barriers by satisfying different quarantine regulations. The importation of chemically-treated fresh fruit and vegetables is prohibited in some countries.

Food irradiation was first developed and tested in the late 1940s. Irradiated foods have been approved by a number of national and international organizations, including the United States Food and Drug Administration (FDA), the Food and Agriculture Organization (FAO) of the United Nations and the World Health Organization (WHO).

The use of irradiation for food including meats, poultry, seafood, grain, vegetables, nuts and spices has been approved by 39 countries to date. This technology is currently being used by twenty-nine of these countries to preserve and process foodstuffs. Belgium, France, Hungary, Japan and the Netherlands are among countries that irradiate grain, potatoes and other products on an industrial scale. Potatoes, onions and garlic are irradiated in Argentina, Bangladesh, Chile, China, Israel, the Philippines and Thailand. Electron-beam irradiation of mechanically deboned frozen poultry products is carried out in France, and seafood is irradiated in Belgium and the Netherlands. Spices and herbs are irradiated in a number of countries, including Argentina, Brazil, Finland, Norway, the United Kingdom and the United States.

E. IMPROVED PACKAGING

Excessive packaging has contributed to an overabundance of solid waste. Decreasing landfill space, particularly in the industrialized countries, coupled with environmental activism, have caused food-processing manufacturers to re-examine their approach to packaging.[95]

Only in some cases, however, are the benefits of changed packaging reflected in lower costs. In most cases, the costs are either the same or slightly higher. However, strength of public sentiment for the environment in many of the developed countries is such, that food manufacturers who effectively advertise their packaging as more environmentally-friendly quickly gain the advantage over their competitors.

An additional more urgent contributing factor accelerating the introduction of alternative packaging in industrialized countries is the possible future danger of potentially harmful packaging materials leaching from landfills into groundwater. Food-processing companies are therefore gradually changing to more biodegradable packaging products. Excessive packaging has been reduced, and recyclable products such as aluminium, glass and HDPE are being used wherever applicable.

In effect, recent developments in new packaging have targeted the following main objectives:

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93 "Irradiation of foodstuffs", Department of Health and Population Development, the Association for Food Science and Technology and the Association for Dietetics of South Africa.
URL: http://www.sacnasp.org.za/societies/Irradiation per cent 20.HTM

94 "Irradiation Update", M. Byrne, European Editor, Food Explorer
URL: http://www.foodexplorer.com/manu/industry/FI12637.htm.

95 For example, fees for dumping solid waste were previously in the region of US$ 0.75/ton in the United States. Costs today are US$ 100 to US$ 200/ton. They are expected to reach the US$ 500/ton mark in some areas.

Less packaging;
More recyclable packaging materials;
Advanced packaging methods that improve quality and shelf life.

New polymeric materials have played an important part in all of these areas. A particularly important development in the third category above is that of packaging in an inert atmosphere, mainly CO_2 or nitrogen. Another recent development in the same category is the availability of sterilizable plastic containers.

Longer shelf life and reduced energy requirements for the manufacture and transport of goods packaged in plastic rather than in glass or metallic containers is also reflected in greater competitiveness as well as in environmental benefits.

F. SUPERCRITICAL FLUIDS IN FPI OPERATIONS

The use of supercritical fluids to replace traditional solvents, mainly in the extraction of vegetable and essential oils, flavours and colourants from their natural sources, has been the subject of a good deal of experimental work for some time. A number of such commercial enterprises are presently in operation.

Supercritical fluids (SCFs) are essentially gases that are retained in their liquid form through a combination of pressure and cooling. The selection of a material for use as a supercritical solvent depends upon its critical parameters, the combined values of pressure and temperature at which the material will behave as a supercritical fluid, and its dissolving power under such conditions.

Two substances used as supercritical solvents in FPI operations are carbon dioxide and propane. The fact that both substances attain SCF form at around room temperature and at moderate pressure is their chief recommendation for this role. An important advantage, particularly from an environmental point of view, of using supercritical fluids as solvents to extract natural ingredients, is the fact that the residue contains no trace of the supercritical solvent following the extraction process. This is of course due to the fact that the supercritical solvent is completely vaporized at normal temperatures and atmospheric pressure. This obviates the need for the extensive solvent removal operations that must be carried out on materials such as vegetable or seed meal by-products from which the vegetable oil has been solvent-extracted, before they may be put to other uses.

Supercritical fluid extraction also has advantages for the quality of the remaining extracted ingredient. This is mainly due to the fact that the extraction processes is carried out at relatively low temperatures and thus does not expose delicate constituents to chemical damage caused by conventional extraction methods normally carried out at high temperatures

A major disadvantage of using supercritical fluids such as CO_2 and propane is the need for high-pressure equipment. This difficulty will probably be overcome as more design experience is gained in actual applications. In the long run, CO_2 might be preferable to propane due to the flammability of the latter material and the explosive nature of its mixture with air. An additional advantage of using CO_2 is the low cost of obtaining and purifying it.

G. BIOTECHNOLOGY IN ENVIRONMENTALLY SOUND FOOD PROCESSING

Technological inputs resulting from advances in biotechnology are gradually making their mark in FPI operations. In particular, new enzymatic methods for clarification and digestion of ingredients in both foodstuffs as well as wastewater treatment have shown some expansion during the past decade.

Genetic engineering is being applied both to obtain enzymes from abundant micro-organisms and also to modify enzyme protein properties according to specific requirements. One target for new enzyme development is to render these biological catalysts capable of being effective in extreme conditions that their naturally-occurring counterparts would be unable to withstand. Enzymes are also being modified to function in mixed, aqueous and organic solvent media in new applications.

The value of the worldwide market for industrial enzymes was reported at $1.5 billion in 1997. It is projected to reach $1.8 billion by 2002. This reflects an overall average growth rate of around 4.0 per cent annually. The value of the global market for enzymes designed for the food and animal feed segments is expected to increase from about $700 million in 1997 to approximately $830 million in 2002, an average growth rate of around 3.5 per cent annually.[96]

Applications include the manufacture of starch-derived syrups, alcoholic beverages and dairy products, in addition to animal feed supplements. Baked goods, fruit and vegetable processing, protein processing and vegetable oil extraction are other areas expected to benefit from enzyme development (box 7).

Box 7. FPI applications of enzyme technology[97]

Leading the way in the use of enzymes in the FPI are the fruit and vegetable processing and the beverage and fermentation product segments. An increase in their use has been witnessed in a variety of applications, including those of the clarification of fruit juices,[98] the treatment of pulp,[99] and the maceration[100] and liquefaction of fruit and vegetable parts.[101] Thus, both quality enhancement and waste reduction may simultaneously be achieved as a result. Special applications in citrus fruit preparation include clouding agents obtained from citrus peel, cleaning of peel for use in special sweets and marmalade products; recovery of oil from citrus peel; depectinizing citrus pulp washings.

Enzymes are also the basis of microbial conversion of food processing solid residues and by-products into useful chemicals, such as organic acids, that may be used as ingredients in foods.[102]

Enzymes in detergent preparations influence the FPI environmental profile indirectly as enzymes for dishwashing detergents, much used in institutional facilities, restaurants and catering establishments, are also targeted for further improvement and market penetration.

Improved understanding of chemical, biochemical and biological processes involved in composting and vermi-composting and biogas generation are also contributing to improved solid waste treatment and reuse rather than incineration and dumping, two of the more environmentally damaging of the traditional waste treatment methods.

H. Application of Computer Design and Modelling

The use of new design and modelling technology has become more accessible to a wider range of FPI entrepreneurs. Several systems, making it possible for many aspects of new product and process design

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96 "Industrial applications for enzymes", issued by Business Communications Company Inc., URL: http://www.buscom.com/editors/RC-147NA/html.

97 "The use of enzymes in the manufacture of fruit juices", Dean Madden, the University of Reading, 1995, URL: http://www.ncbe.reading.ac.uk/NCBE/FEATURES/menu.html. Web page revised on: 5 February 1997.

98 In the treatment of fruit juices, such as apple juice, for example, pectin is removed in a manner that allows the production of concentrates without gelling and the attendant turbidity.

99 In fruit items such as red grapes, citrus and apples enzymes enable better juice release as well as coloured material extraction. Enzyme treatment of olive pulp, palm fruit and coconut meat also increases oil yield.

100 Notably to obtain nectar bases and baby foods.

101 The basis of this application is to increase the soluble solids content in finished products. Pectinases and Cellulases are used in such applications.

102 Beta-Glucosidase, which may be useful in catalyzing the release of natural flavours from food processing residues, for example, was produced by Aspergillus niger grown on fruit pomace. "Food processing waste technology - Waste utilization technology", Y. D. Hang, Cornell University web site. URL: http://www.nysaes.cornell.edu/fst/market/waste.html.

to be thoroughly examined prior to actual implementation and resource commitment, are now available commercially. In particular, such technology will clearly be useful in the design of processes that comply with wastewater standards and the state of solid waste as it leaves FPI plants.

I. INNOVATIVE PROCESSING METHODS

Innovative processes in their final validation stages or early commercial trials include pulsed electrical field (PEF) and ultra-high pressure (UHP) processing. Both methods appear to be intended for use in the fruit and vegetable juice segment.[103] Tests have established that juice bearing a high microbial load was treated at average field strengths of 35kV/cm and above, with the result that total aerobic plate counts were effectively reduced.[104]

Pilot tests have validated the effectiveness and feasibility of PEF scale-up. PEF-treated apple juice from concentrate had a four-week shelf life at ambient temperatures, i.e., around 25°C. Comparison of ultrafiltration (UF) and PEF, both non-thermal processes for clear liquids, for treating fresh-squeezed apple juice, revealed that the major difference between the two methods was in the in colour of the end product. UF-treated juices tended to be darker.

In ultra-high-pressure fruit processing, pressure creates localized adiabatic temperature rises in the product being treated, at levels below heat damage thresholds. The process is still considered non-thermal. Heat is dissipated as pressure is removed. The UHP process can be computer-controlled and is reported as possessing attractive economic features.[105]

J. EST IN THE ENERGY AND AGRICULTURAL SECTORS

Environmentally sound technologies in the energy and agriculture sectors will exert considerable influence on the overall environmental profile of food processing. As indicated above, it is not the inherent energy-intensive aspect of the FPI that is the cause of concern in this respect. Indeed, FPI operations consume less energy than those of many other sectors. Rather, it is the proliferation of food processing activities worldwide, particularly in expanding urban areas, that renders this link so important.

Likewise, linking the FPI environmental profile to that of agriculture in strategies and plans for the future is essential, due to the fact that most of the industry's inputs are of agricultural origin. Industrial waste with unacceptable levels of pesticide and herbicide contamination influence disposal methods and will certainly prevent FPI operators from seeking alternative higher value-added utilization strategies.

1. *EST in the energy sector*

Energy use is reported to be responsible for over 55 per cent of the emissions causing the greenhouse effect. Technology for exploiting renewable energy sources is of immense importance in many segments of the food processing industry. For a multitude of technical and economic reasons, however, prospects for the replacement of fossil fuels by renewable sources on a significant scale seems rather remote, at least for the next 10-15 years.

Energy conservation technology occupies an important position in all branches of the FPI. Combustion control and insulation are at the forefront of measures that can readily be implemented. There

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[103] "Non-thermal processes for fruit and vegetable juices", C. E. Morris, Editor, Food Explorer, an Internet publication at URL: http://www.foodexplorer.com/MANU/industry/FE02849.htm.

[104] A high-intensity pulsed-light process was reported as cleared by FDA in August 1996 for controlling micro-organisms on food surfaces.

[105] A continuous UHP system with 25-litre capacity units and process costs of about 10 to 16 cents per kg for acidified foods is reported in the process of commercialization. Processing costs are predicted to drop to around 2 to 8 cents per kg in the near future. See "Non-thermal processes for fruit and vegetable juices", C. E. Morris, Editor, Food Explorer, an Internet Publication at URL: http://www.foodexplorer.com/MANU/industry/FE02849.html.

are, of course, situations in which it will be necessary to replace obsolescent equipment. This applies to refrigeration and heating equipment. In such cases, care should be taken that replacement equipment provides for maximum energy co-generation or recycling.

It should be noted that many recent technological developments in the food processing industry, particularly those aimed at better hygiene and consumer safety, have rendered it more energy-intensive than previously. This makes rational energy management an even more important endeavour.

Challenges in the implementation of energy conservation and efficiency programmes in developing countries include difficulties such as the following:

(a) Encouraging energy conservation during periods of plentiful supplies and low prices on the world market;

(b) Acquisition and introduction of energy-efficient equipment due to lack of resources, expertise or both;

(c) Maintaining energy conversion systems in optimal conditions.

The importance of control and measurement technology in the development, production and use of such equipment should be emphasized. In addition, considerable design, research and development efforts are needed to match imported energy conservation and efficiency technology to local conditions.

Clean-fuel technology and some types of solar technology rank next in importance. The most promising solar energy technology to date in the food processing industry is that of the flat-bed collectors for rural and small-industry purposes. Concentrating collectors can be used in larger industries, and wind power devices may be suitable for providing power to remote facilities.

In general, prospects for solar energy EST are still dependent on technological developments that would render its use more economical in comparison to oil and other fossil fuels. Stricter environmental legislation in the industrialized countries might provide the impetus for further development and adoption of this technology.

Regarding EST in the transport sector, the use of catalytic converters to reduce vehicle emissions is expected to become increasingly widespread. The performance of the converters is being improved by the use of new materials and by new discoveries in surface chemistry and physics; and their cost is expected to drop. The continued development of cleaner fuels, both cleaner forms of gasoline and alternative fuels and safer fuel additives, is also expected to contribute positively to the overall FPI profile in the future.

2. *EST in the agricultural sector*

Intensive agricultural methods have greatly contributed to environmental problems, both globally and at local level. Mechanization, for instance, required large treeless areas, widespread use of chemical fertilizers and a variety of veterinary medicines, as well as pesticides and herbicides. Food contamination due to such sources has often been reported, sometimes with disastrous consequences.

Pollution of water systems with pesticides and fertilizers has a negative impact on input water streams used in agricultural product washing and other FPI operations. The use of auxiliary agricultural inputs poses greater problems in the developing countries in general. Examples include inadequate education and training in pesticide use, and failure to observe basic husbandry practices such as that of the mandatory delay before products, principally milk and meat, from cattle treated with veterinary medicines, may be brought onto the market.

Environmentally-friendly agricultural production is still some way off in many parts of the world. Nevertheless, some of the new methods, such as integrated pest management (IPM) and pest resistant or

repellant genetically-engineered species, that help reduce dependence on pesticides, are beginning to make their mark.

In particular, reduced pesticide use as a result of integrated pest management systems will render FPI by-products currently prohibited for use in human food and fodder fit for such purposes. Apart from overall improvement in the agricultural sector, IPM will improve solid waste and the quality of wastewater produced by FPI operations.

The development of more appropriate varieties of plants and animals is an avenue that merits greater emphasis in the ESCWA member countries. In particular, the development of crop and livestock varieties, specifically adapted to stressful agro-climatic and biophysical conditions would be of great value in environmental protection.

Modern disciplines such as genetic engineering, could provide solutions for many crop quality problems in countries of the ESCWA region. There is as yet no information on plans, either at the national or firm level, to introduce genetically-engineered crops into any of the crop groups normally cultivated in ESCWA member countries. However, initial positions discernible from public pronouncements in this regard give no indication of fundamental objections to their introduction. Ultimately, there is great need for development of national and regional strategies that, thus far, appear to be lacking.

In the meantime, traditional practices such as crop rotation and the use of chemicals, with their attendant pollution problems, will remain the more obvious options.

Two equally important considerations deserve close attention when devising an EST agricultural strategy:

(a) Farming technology must be developed with specific regional needs in mind and is best accomplished by building on indigenous knowledge and experimentation, combined with effective new technology, as the need arises;

(b) Technology designed to increase the efficiency of resource utilization should always be given top priority in the development of agricultural EST.

Land, water and bio-diversity are the three crucial natural resources in agriculture. Irrigation water is the resource that is most in demand at present in the ESCWA member countries. Barring the emergence of new and far superior desalination, treatment and recycling technology, this resource will remain the most precious of the three for many years to come. EST, including innovative irrigation technology, which increases the efficiency of water-use in agriculture, is thus of primary importance for the ESCWA member countries. Such technology must be improved upon, further adapted to the local environment and become increasingly widespread

IV. THE FUTURE OF EST IN ESCWA MEMBER COUNTRIES

A. ENVIRONMENTALLY SOUND TECHNOLOGIES IN THE ESCWA FOOD PROCESSING INDUSTRIES

A good proportion of the larger FPI facilities, especially in the non-Gulf ESCWA member countries, e.g. milk and dairy processing plants, abattoirs, grain mills, breweries, etc., date back to the 1960s and 1970s and earlier decades. The technology incorporated in these facilities is, by and large, wasteful of resources, particularly of water,[106] with minimal provision for its conservation and recycling.[107] Indeed, industries that had initially been equipped with water treatment plant chose to sacrifice those facilities first in times of economic difficulty, with the result that they were completely phased out or were inefficient and ineffective thereafter.

This seems to have been the case for both public and private sector establishments. In both cases, reducing the adverse environmental impact of FPI operations, in common with some other industrial activity, was mostly considered a luxury rather than a necessity.

The fact that many FPI facilities were established in an era when water scarcity was less apparent than today might explain the lax attitude towards water resources that previously characterized this industry. Other explanations might be the prevailing view that FPI operations were not serious polluters of water resources; or the structure of the industry, its fragmentation, and its reliance for the most part on small and micro enterprises. A more plausible explanation today is the fact that little if any legislation governing water-use and effluent discharge is as yet in force in most ESCWA member countries. Moreover, even when such legislation does exist, there is difficulty in translating it into workable regulations. Ultimately, the lack, or inadequacy, of enforcement measures must be pointed to for the negative environmental profile of industrial activities, including those of the FPI, in many ESCWA member countries at the present time.

The net result is that numerous rivers, tributary and other surface water systems in several countries of the ESCWA region are almost entirely lost to normal flora and fauna. Others have been transformed into virtual flowing refuse dumps gathering and creating further pollution as they traverse urban and rural areas.

By-product utilization has been considerable since the establishment of FPI plants in the region. For example, grain husk, oil seed mill and bagasse have been used as fuel and animal feed for decades. Similarly, solid waste from abattoirs is the basis of thriving small enterprises that specialize in artisanal production of animal glue, gelatin, leather tanning and other industries. One common feature of all these operations is the general reliance upon obsolescent technology, often precluding the manufacture of higher value-added products from industrial waste. The ultimate environmental quality of these operations themselves also leaves much to be desired.

Few FPI by-products are utilized to their full potential. For example, literally hundreds of tons of processed dairy products, mainly cheeses and strained yogurt, pass through dairy factories, large and small, of the ESCWA region countries, without recuperation of the valuable constituents of their whey. This by-product is simply allowed to flow out into municipal wastewater streams, with the loss of many tons of protein and other substances that could be used for human nutrition and animal feed supplements.

The situation is probably a little better in the Gulf countries. Established during the 1980s and 1990s, with greater awareness of environmental issues and taking into account the inherent scarcity of fresh water resources, FPI plants in these countries appear to have been well equipped, particularly with water treatment and reuse facilities. However, even in these countries, this holds true for only the larger and more modern facilities. Smaller enterprises may still be found wanting, as observed in other ESCWA member countries.

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[106] This seems the case both for countries and locations relatively rich in water resources, as well as for those bereft of them.

[107] This technology in general incorporated design features that pre-dated increased concern with environmental pollution.

Studies carried out at ESCWA to assess science and technology (S and T) policies and research and development (R and D) activities during the past three years reveal a certain degree of interest in the development of an EST capability in the member countries.[108] Greatest interest appears to have been manifested in Egypt, where national S and T initiatives were launched in the early 1990s to deal with industrial pollution in general. Issues targeted include treatment of effluent and solid waste generated by FPI operations in the dairy and sugar industries, respectively. Pollution prevention of the Nile and the greater Cairo region are the focus of these initiatives.[109]

Research projects aimed at tackling the problems of effluent from such facilities have also been included in R and D plans being implemented by several laboratories in the country's universities, as well as in a number of specialized research centres.

Projects with more limited scope and objectives have been initiated in R and D facilities of other ESCWA member countries. Thus, the Industrial Testing and Research Centre (ITRC) in The Syrian Arab Republic has undertaken studies on the extraction of grape seed oil from pomace generated in the public sector and other wine-producing establishments.[110] The outcome of laboratory work in this instance is representative of that in many other cases: Work could not progress beyond the laboratory bench, and the results, although encouraging, could not be acted upon.[111] Reasons given for this and other instances of failure to implement R and D results,[112] include shortcomings of mandates and responsibilities, resources and incentives.

In summary, the situation of EST in the ESCWA member countries is largely one of deficient technological capacity at the enterprise level, coupled with inadequate legislative and regulatory instruments and minimal involvement by national S and T bodies to redress this situation.

B. DEVELOPMENT OF ENVIRONMENTALLY SOUND TECHNOLOGIES IN ESCWA MEMBER COUNTRIES

The status of EST development in the ESCWA member countries is certainly influenced by the lack of science and technology policies, in general. Thus, the fragmented industrial and agricultural structures constituting the bulk of FPI establishments and the lapsed or non-existent EST capability of the larger FPI enterprises, will need to be at the core of EST development efforts. A better future for EST development in the ESCWA member countries is contingent upon the results of current policy initiatives in many of these countries. The importance of rational policy regimes and subsequent plans and initiatives in giving focus to the national S and T contribution and in complementing efforts by governments and enterprises in EST development, installation and maintenance, cannot be overemphasized.

[108] See the studies carried out by ESCWA on "Production and Quality Technologies in the Agro-food Industry in ESCWA Member Countries", E/ESCWA/TECH/1999/6 and the study, also by ESCWA, on "Science and Technology Policies for the Twenty-first Century", E/ESCWA/TECH/1999/4.

[109] See the ESCWA study on the "Assessment of R and D in selected ESCWA member countries", E/ESCWA/TECH/1997/5.

[110] See, for example, the advisory mission's report on milk and dairy processing facilities in the Syrian Arab Republic.

[111] See the report of the advisory mission carried out by ESCWA with a view to revising the ITRC institutional structure and research plans, E/ESCWA/TCD/97/13.

[112] Thus, another R and D project, aimed at extracting lanolin from sheep wool washings at a factory in Hama, The Syrian Arab Republic, appears to have met a similar fate. Work on this project, also initiated and largely performed by ITRC, was, for similar reasons, abandoned following preliminary tests.

The importance of policy regimes dedicated to EST development is attested to by similar steps taken and results achieved by other countries.[113,114] The fact that many of these countries are in fact industrialized must certainly be taken into account when designing analogous schemes in the ESCWA member countries. Indeed, lessons of the industrialized countries in terms of expenditure levels and the actual content of constituent programmes may be of only limited use to countries of the ESCWA region. More important lessons reside in pinpointing missing institutional structures and identifying optimal action modalities.

EST strategies

An integrated approach to waste reduction, with particular emphasis on water reuse and recycling and appropriate reprocessing and disposal of solid waste, does not occur spontaneously, even in the most advanced or developed nations.

The need for national environmental planning was recognized in the developed countries in the 1960s. Several developments are driving the lesson home in many of the developing countries; and greater awareness of the need for a national environmental plan appears to have taken hold in a number of ESCWA countries during the mid-1990s. Thus, concerned government departments in these countries have for the past few years, in cooperation with United Nations specialized agencies and donor organizations, been engaged in drawing up national environmental action plans.

Much can be expected of these plans: They seem to pave the way for the integrated approach necessary to deal with the challenges at hand. Once completed and finally ratified by the appropriate national authorities, these plans should form the basis for extensive legislative and regulatory action ultimately leading to lasting improvements. Massive effort will be essential, nevertheless, for the implementation of these plans.

In many instances, it may be that the development, acquisition, installation, wide distribution and maintenance of EST in food processing operations, and in other industrial segments possibly in greater need of attention, will tax national capacity in even the more prosperous ESCWA member countries. It is therefore essential to develop mechanisms, both national and regional as well as international, that will accelerate and facilitate the move towards more environmentally sound FPI operations.

National strategies aimed at EST development in FPI segments will need to invoke wide cooperation among concerned producers' federations, professional associations and government departments in an effort to adopt, develop, approve and implement technical standards for FPI emissions. Work in this direction, coupled with on-going endeavours to formulate national environmental action plans, should provide the crucial legislative basis and technical standards necessary for further effort in EST development and distribution.

Mobilization of investment and financial resources are also necessary. Governments will need to take the lead in this regard. Note should be taken of the experience of industrialized countries, where incentives to private enterprises to develop and adopt EST had a multiplier effect on initial resources made available by governments. Tax and other incentives for FPI entrepreneurs complying with regulations prior to their coming into force would also have a catalytic effect on the introduction of EST.

Extensive training is needed in all aspects of EST and at all levels, including management and supervisory cadres. In this, cooperation by national universities should be elicited. The need for a variety of skills in order to design, install, develop and maintain EST should prompt national universities to initiate

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113 "Towards a new generation of environmental technology", G. R. Heaton, Jr. and R. D. Banks, *Journal of Industrial Ecology*, Volume 1, No. 2, MIT and Yale University.

114 Soon after taking office, the present United States administration put forward an ambitious national technology policy with the promotion of EST as a central objective. The resulting Environmental Technology Initiative (ETI) addressed several issues, including support for wide ranging R and D and cooperative technology development activities. Still another element was regulatory reform.

graduate and postgraduate courses that cover the applied science and engineering aspects of EST in food processing.

The formulation of EST strategies for ESCWA member countries should integrate and optimize action on all of the above issues. Furthermore, it should not only provide an impetus for the promotion of both the development and acquisition of rational technology but also enhance technological cooperation across the board.

Box 8. New quality systems relevant to FPI

Food processing quality systems being developed to safeguard human health often address environmental pollution issues.

Two such systems have recently gained ground. They are:

(a) The Hazard Analysis and Critical Control Point (HACCP) system;
(b) The Good Manufacturing Practices (GMPs) system.

Both will ultimately replace outmoded inspection methods largely based on sight and smell by others utilizing scientific methods resulting in effective reduction of harmful pathogens and bacteria.

In particular, although HACCP is being phased in, though slowly, even in some of the developed countries, due in part to the debate on how it might be implemented, the changes will have an impact on the manner in which an industrial enterprise active in food production handles waste and deals with environmental hazards.

HACCP rules require processing facilities to develop a written set of sanitation standard operating procedures (SSOPs) and to conduct daily inspections of their plants to ensure that pre-operational sanitary conditions are met. Poultry slaughter plants, for example, are required to check samples for E. coli every eight-hour shift. Corrective action against failed inspections vary, according to the severity of breaches, from on-the-spot cleansing operations to complete shut-down of operations until the facility meets HACCP requirements.

Clearly, all of these operations will affect water resource uses and influence the manner in which wastewater is treated. Although greater frequency of cleansing operations might mean more water consumption, economic pressure due to increasing water scarcity will force FPI establishments to place greater emphasis on perfecting water in-house treatment operations and ensure adequate inspection of incoming water. Both moves will result in water savings and reduce waste due to contamination.

HACCP regulations are, for example, expected to be fully implemented in the United States within the next two to three years. This implies that the majority of FPI firms in that country will further improve sanitary conditions in their facilities.

International standards developed by the Geneva-based International Organization for Standardization is the latest attempt to create a global environmental management system. The ISO 14000 series of environmental systems standards is designed to assist organizations to manage and evaluate the environmental aspects of their operations without prescribing specific solutions, a task that would be simply impossible to achieve on a central , global scale.

Nevertheless, the International Organisation for Standardization provides FPI as well as firms in other sectors, with a framework for compliance with both domestic and foreign environmental regulations. The ISO 14000 contains sections calling for the implementation of pollution prevention programmes. Many firms in the industrialized world are evaluating the pros and cons of full ISO 14001 certification. In the United States in particular, EPA is considering possibilities for easing reporting requirements for American firms that earn ISO 14001 certification.

The following are some of the factors that may be expected to exert a positive influence in achieving the above objectives:

(a) Enhanced regional and international competition, and the necessity of capitalizing on all available assets, including FPI by-products; and conservation of resources, particularly those that are daily increasingly scarce in many of the ESCWA member countries;

(b) Increased awareness of the value of acquiring ISO 9000 (quality management systems standards) and ISO 14000 accreditation, and of adopting special quality systems (box 8) that ultimately are reflected in improved compliance with environmental standards in the quest for greater international competitiveness and consumer acceptance;

(c) Emerging consumer lobbies and pressure groups and increasing awareness of the link between environmental pollution and health standards.

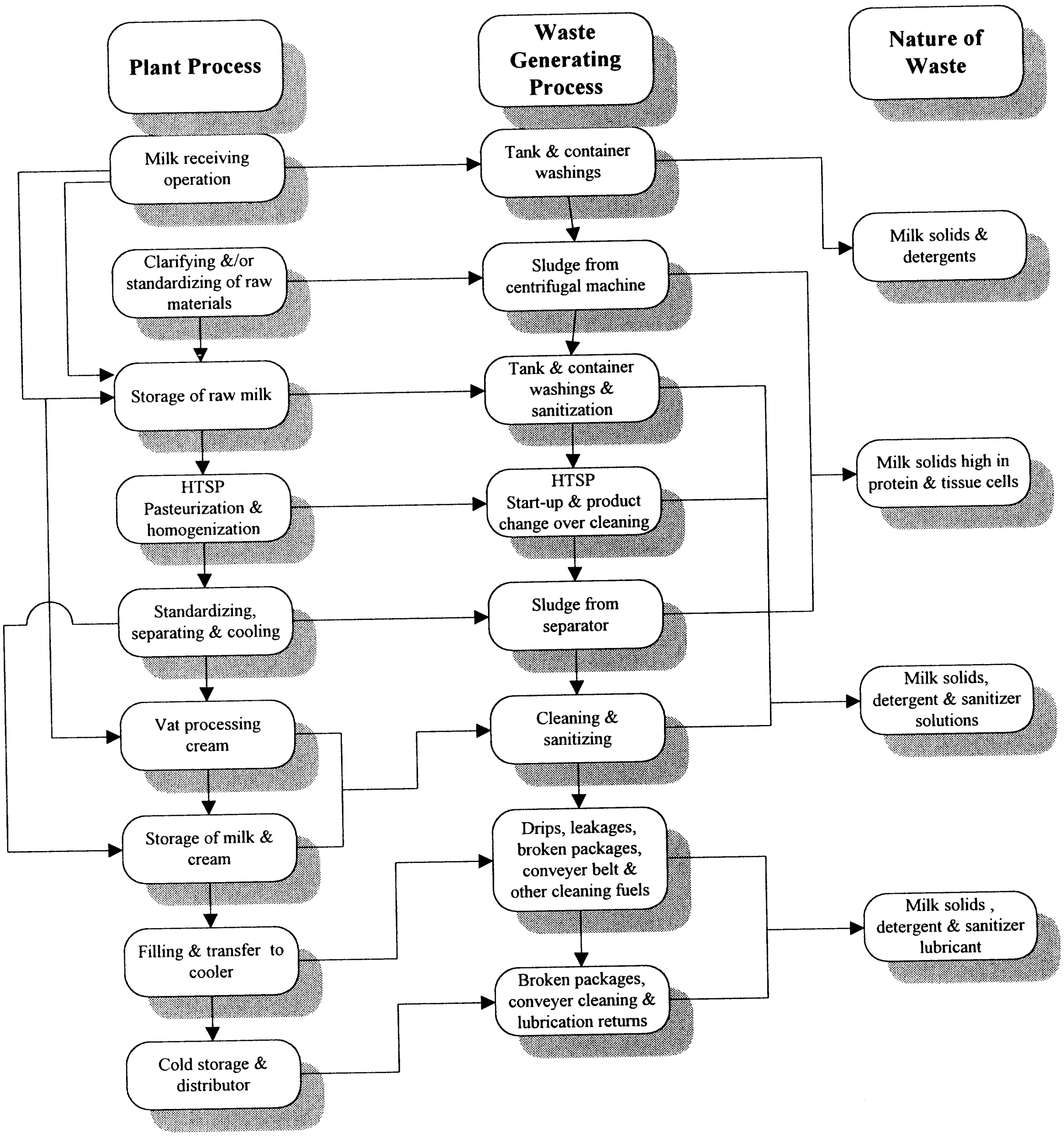
The role of government establishments in rendering EST more accessible to FPI enterprises will ultimately be limited by numerous considerations. Indeed, policy regimes designed to tackle the introduction of EST in developed countries tend to shift the burden of EST initiatives from central government authorities to the private sector, the role of government moving towards counselling and regulation enforcement. Moves in this direction may be tempered in the ESCWA member countries by the fact that enterprises may not yet be as well equipped to play a central role in EST development strategies. This underlines a major goal for these strategies, namely, to enable enterprises to play this central role in the bid to acquire, develop and widely introduce EST.

In performing this role, FPI operators may certainly be assisted by consulting and industrial design enterprises that are gradually making their appearance felt in many of the ESCWA member countries. The latter will undoubtedly need to gain more expertise, a process that may in turn be accelerated through collaboration and networking at the national, regional and international levels. It is particularly in areas related to automating and computerizing FPI operations that such cooperation may be especially fruitful. Other promising areas include cooperation in the production of EST equipment and spare parts. No other area may be more ripe for this type of cooperation than water treatment and solid waste disposal. There has been a great accumulation of international experience in both fields over the past few decades, though some ESCWA member countries have lacked the basic essentials.

In summary, the food-processing industry in the ESCWA member countries will continue to prosper and withstand enhanced international competition only by conforming to new environmental and sanitary standards. New policies, legislation, regulatory regimes, industrial standards and business practices, as well as new institutional forms, will be necessary to incorporate and promote the continuous development of EST in all spheres of industrial activity. Rather than simply creating additional burdens, this may prove to be a source of fresh incentives for wide-ranging technological innovation and consequent gains in profitability and competitiveness across the board.

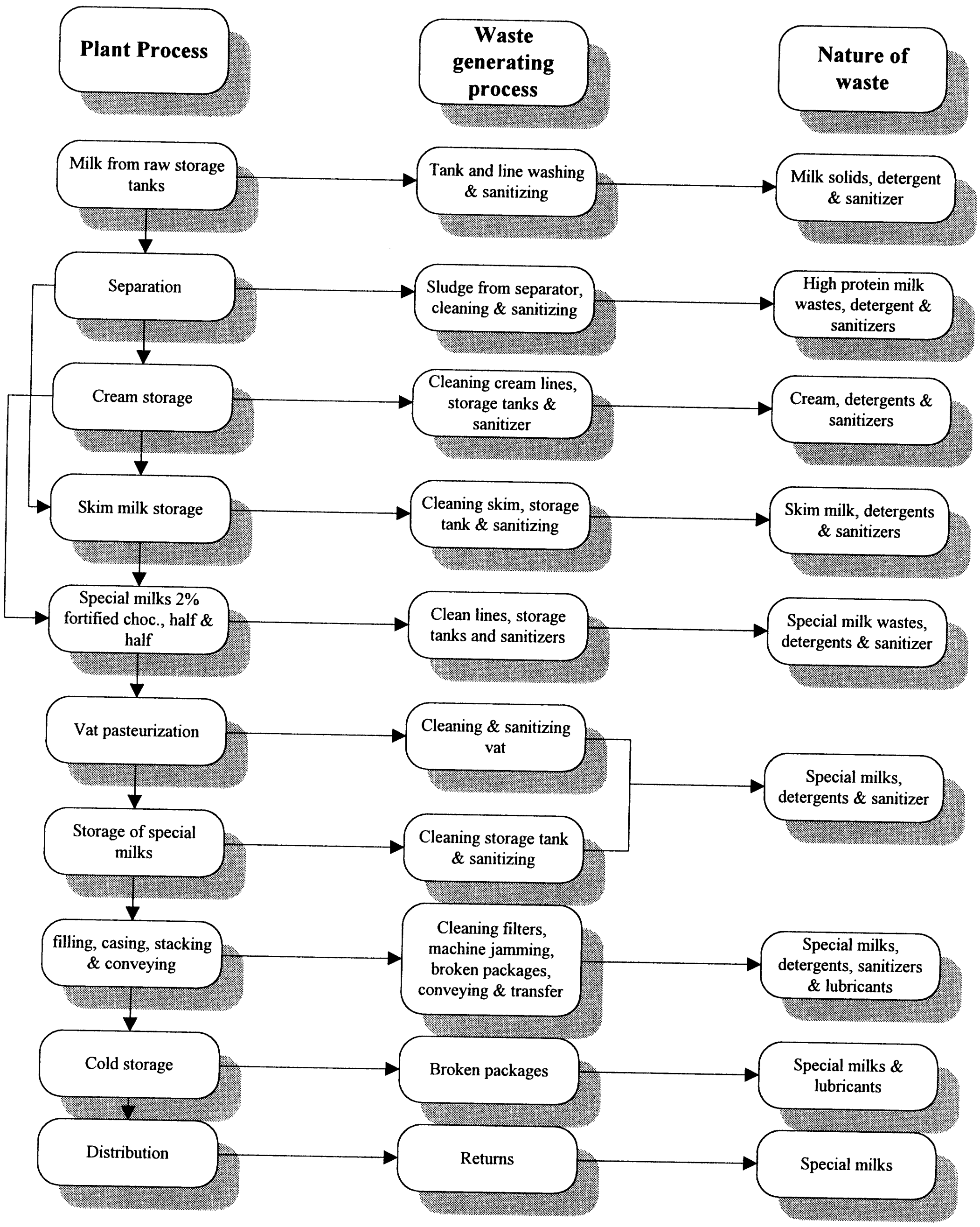
ANNEX

Chart A. 1. Market milk process



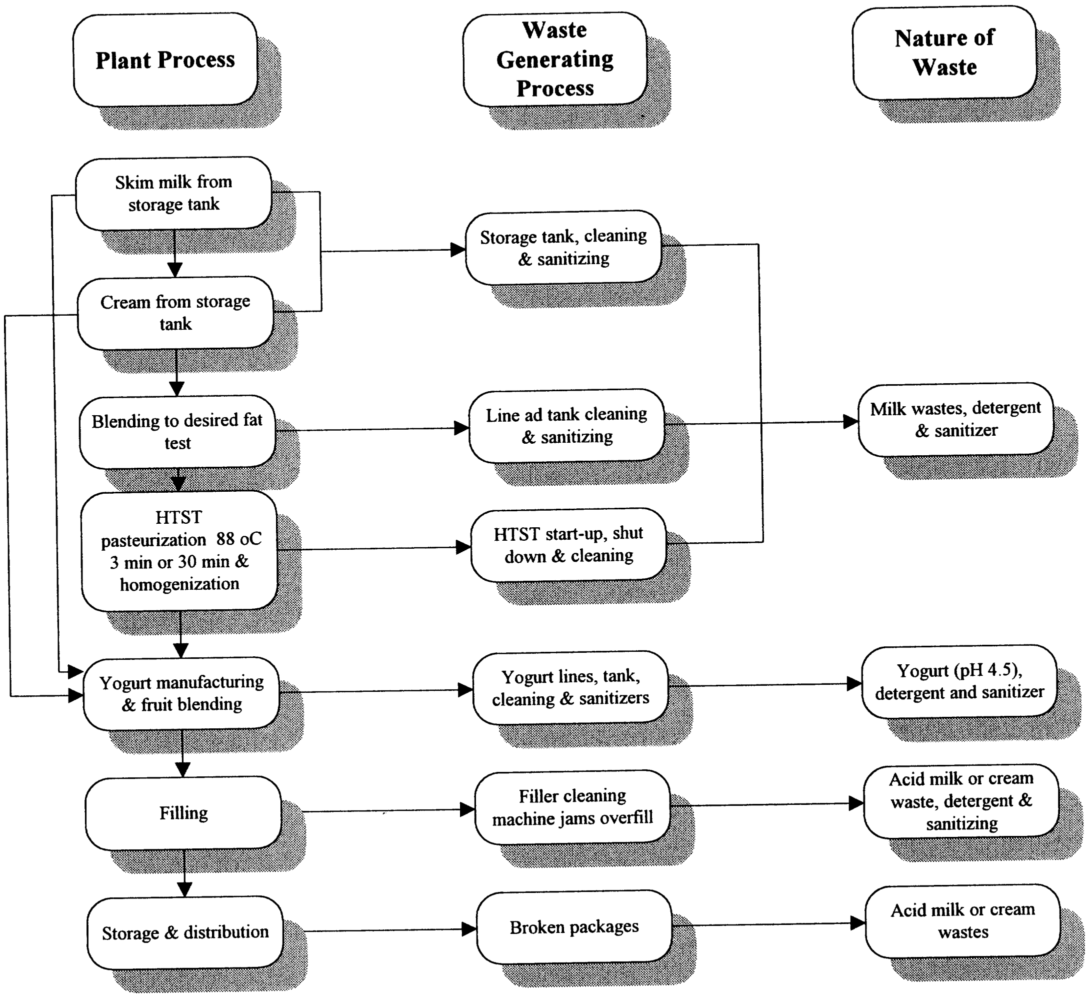
Source: "Technical pollution prevention guide for the dairy processing operations in the Lower Fraser Basin", Environment Canada, DOE FRAP 1996-11.

Chart A. 2. Market milk subprocess: skim milk, creams and special milks



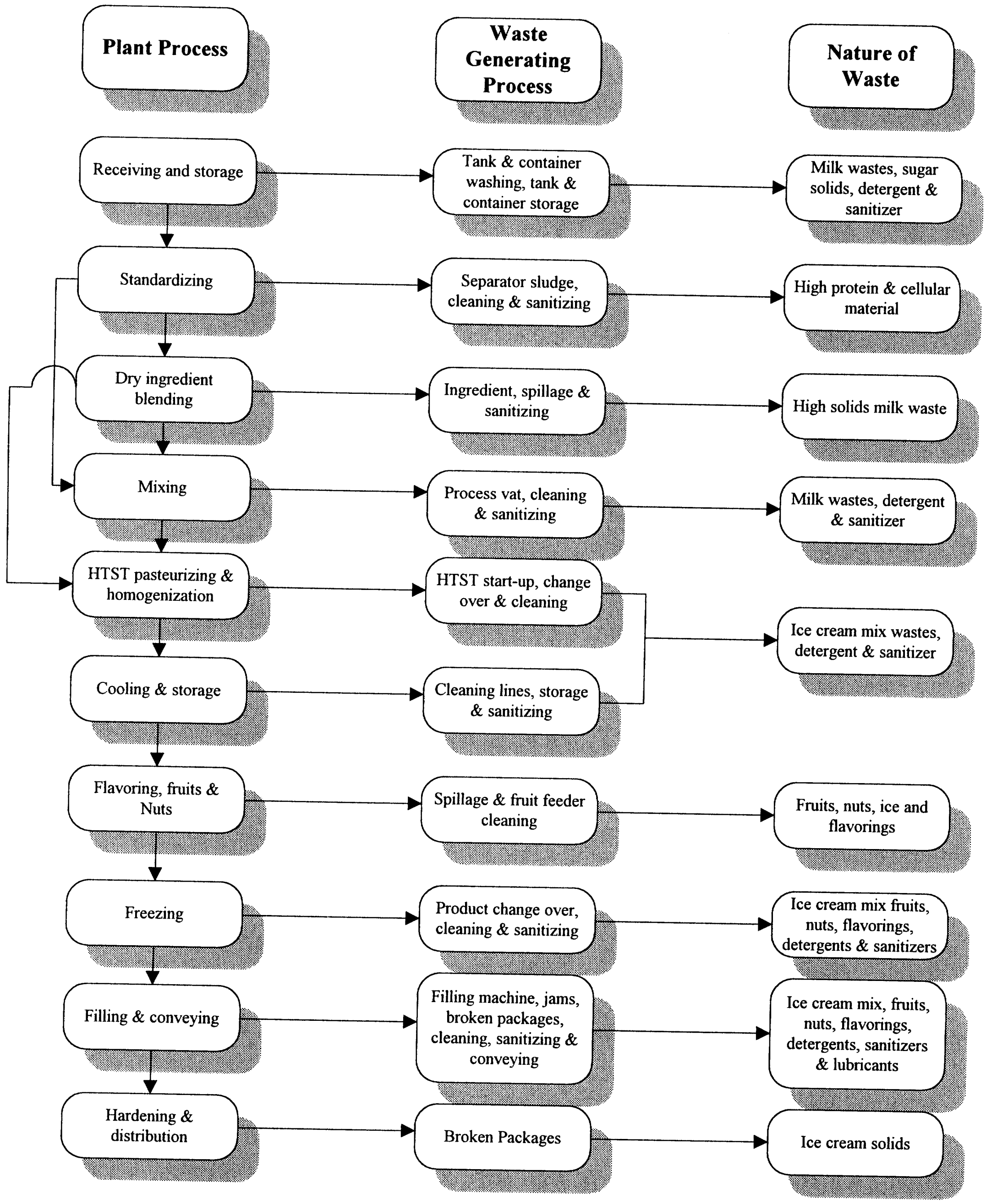
Source: "Technical pollution prevention guide for the dairy processing operations in the Lower Fraser Basin", Environment Canada, DOE FRAP 1996-11.

Chart A. 3. Market milk subprocess: yogurt



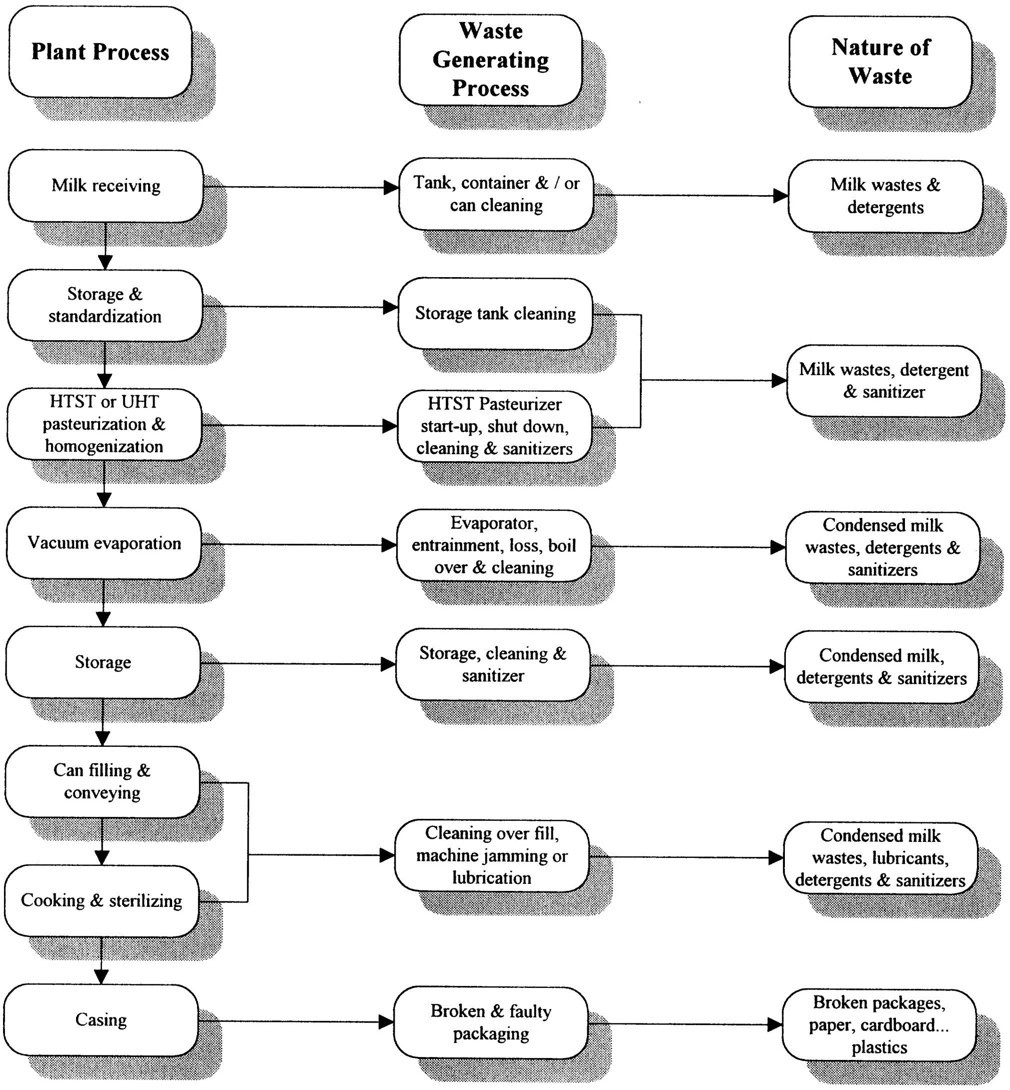
Source: "Technical pollution prevention guide for the dairy processing operations in the Lower Fraser Basin", Environment Canada, DOE FRAP 1996-11.

Chart A. 4. Market milk subprocess: ice cream



Source: "Technical pollution prevention guide for the dairy processing operations in the Lower Fraser Basin", Environment Canada, DOE FRAP 1996-11.

Chart A. 5. Market milk subprocess: condensed milk



Source: "Technical pollution prevention guide for the dairy processing operations in the Lower Fraser Basin", Environment Canada, DOE FRAP 1996-11.