Chapter 6

Bioproduction Systems and their Environmental Implications

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6.1 Background

Bioproduction is a new term that has been coined to refer mainly to the agricultural processing and animal/fish production systems of the agricultural industry. These two sectors are very critical for many African countries, which depend heavily on agriculture for their daily livelihood and foreign exchange earnings. Although Africa has few agro-based industries, the rapid growth in population places a high demand on the same. This in turn brings in the aspect of environmental degradation, through the potentially high levels of waste production. For purposes of this book, a waste is any material discarded by society because it has fulfilled its useful purpose and is no longer wanted or cannot be utilized. It is a superfluous material with little or no worth that results from production processes. As such, a waste is a pollutant.

Some of the main agro-based industries in the Eastern region of Africa that have significant effect on the environment include the coffee, tea, sugar, lumber, paper, sisal, and tanning industry. However, it is also common to see much agricultural produce especially fruit go to waste in many agro-ecosystems in different parts of Africa. Mangoes, paw paws, bananas, cabbages, milk, cassava and potatoes fall in this category. Processing of such produce is likely to emerge as a perfect initiative towards food security and job creation in rural areas. This will in no doubt be accompanied with increasing volumes of wastes and hence higher risks of environmental degradation.

Africa has the highest number of animals especially cattle and goats. Animal production is done mainly using the traditional systems where the animals are fed in open fields with minimal control and consideration of the environment. However, as land continues to become scarce, the need for more intensive animal production systems is unavoidable. Already most peri-urban residences are characterised by zero-grazing units in cities like Nairobi, Kampala and Dar salaam. Such intensive modern systems optimise production but their impact on the environment is enormous due to high concentration of wastes, use of chemicals and modern equipments. The aim of this chapter is therefore to highlight some of the critical concerns within the bioproduction industry that correlate highly with the environmental issues in the East African region.

6.2 Bioproduction Systems

Both crop and animal production systems are associated with wastes. The waste ends in the environmental sinks (land, water or atmosphere) either directly or indirectly. Agricultural processing and livestock production systems have been chosen to illustrate this concern because of their growing importance in the economies of most African countries, particularly Kenya, Uganda and Tanzania.

Coffee Processing

There are basically two varieties of coffee namely *arabica* coffee, which is indigenous to the Ethiopian highlands and the Boma plateaus in the Sudan and *robusta* coffee,

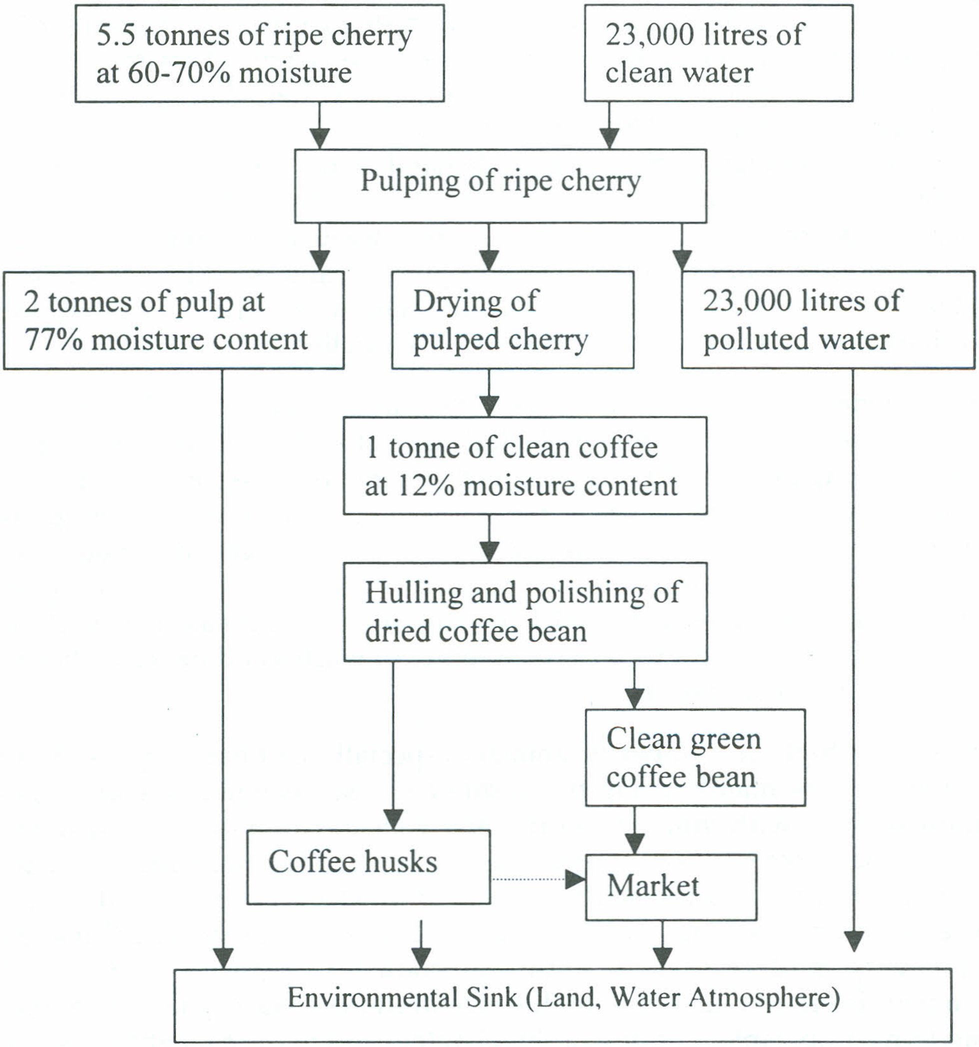

Figure 6.1 Flow diagram for wet processing of coffee and its waste

which is indigenous to Central and East Africa. Coffee (cherry) is harvested at about 65% to 70% moisture content and consists of about 39% pulp, 17% mucilage, 7% parchment, and 37% bean. When dried, the bean forms about 20% of the fruit (cherry). The use of the coffee bean leaves over 60% of the fruit as a waste, which ends in the environment.

During processing (Figure 6.1), coffee bean is removed from the cherry by squeezing (pulping) using pulping machines. This removes the epicarp (red skin) and the adhering mesocarp (pulp). The pulped coffee is then conveyed by water to a fermentation tank where the mesocarp (stick mucilage) on the bean is broken down to soluble compounds by fermentation. The mucilage facilitates the fermentation process since it is rich in sugars (glucose), which is a good medium for the growth of bacteria, yeast and fungi. When the mucilage is fully broken down, it is easily washed off using clean water leaving wet parchment coffee. The wet coffee is then dried naturally or artificially.

Wet processing of coffee, which is practised on large scale especially for the *arabica* coffee, uses large amounts of water. It is however a better method especially for coffee cherries at very high moisture content since it minimises the chance of cherry moulding and rotting before drying. The fermentation process also enhances the quality of coffee and increases the rate of drying of the parchment. However, the use of water requires that the pulping factory be situated near a river, which poses great danger since the used water is returned to the environment directly or indirectly. Artificial drying also involve use of wood or fossil fuel as source of energy thus posing even great danger to the environment due to destruction of trees and release of combustion gases. For *arabica* coffee, the bean is hulled to remove the parchment and the silver skin at about 12%. It is then polished to completely remove the silver skin. Thus the pulp, mucilage, silver skin and the water that is used in wet processing goes to waste by being released into the environment where it causes pollution. The skin and pulp are allowed to fall down a screen onto a ramp. When left for sometime, they ferment resulting in unpleasant smell and attraction of flies. They may also be washed into the river causing further pollution.

In Kenya for example, over 200,000 tonnes of pulp at 77% moisture content and 2,300,000 litres of polluted water is released into the environment everyday. This is equivalent to pollution caused by 1.2 million people per day. A survey of rivers between Nairobi and Thika town in Kenya showed that they were all polluted with coffee waste with BOD[18] level of more than 100 mg/l. The unpolluted rivers had a BOD of 4 mg/l (Wrigley, 1988). A river of 10 mg/l BOD is considered grossly polluted.

[18] The Biochemical Oxygen Demand (BOD) is a measure of the organic pollution in water, judged by the amount of oxygen that would be absorbed by the liquid when discharged into the river. Higher BOD value indicates greater pollution of water.

Management of Coffee Factory Wastes

To minimize the amount of clean water used and thereafter released directly into rivers, recycling of water is recommended. The recycled water is then released into soak pits or stabilization ponds where organic matter is broken down mainly to carbon dioxide and methane. It then filtrates back into the river much cleaner and minus the coffee debris. Recycling also helps to facilitate the fermentation process since the microorganisms from the initial fermentation stage are retained. However, care has to be taken since high concentration of the microorganisms results in the rusting of coffee, hence reduction in quality. Wastewater can also be used for irrigation especially for animal feed crops like Napier grass.

Coffee pulp, which is a waste by-product, can be used fresh, dry or ensiled as animal feed and is acceptable up to 20% in the diet of pigs and cattle. It is also valuable as manure and mulch for annual crops or pastures either after composting or fresh provided it is not left in heaps. Considerable amount of sludge left in the ponds has to be removed and can be used as manure. The pulp after drying can also be used as a source of energy especially in coffee dryers. There are also efforts being made to carbonise the pulp for briquettes production.

Tea Processing

Tea is one of the main foreign exchange earners for the East African countries accounting for over 10% of their GDP. However, long-term mono-cropping adversely affects the soil making it unsuitable for other crops. Tea processing (Figure 6.2) is one of the leading agro-based industries in the region producing consumer ready product. Mainly black tea is produced but diversification is being done to produce instant and green tea.

During cleaning, waste which mainly includes foreign matter like stones, metal, soil, other plants and low quality green tea leaves are removed. The waste is returned to the farm where most of the materials are incorporated in the soil. Withering and drying involve use of hot air, which is heated using diesel or wood furnace. The furnace is therefore the main source of pollution in the factory since it emits smoke and carbon dioxide to the environment. Use of wood fuel also contributed to deforestation thus affecting the environment.

Policy formulation for tea processing needs therefore to focus on the energy use in the factory and its impact on the environment. This is an area, which up to the present time has been given very minimal consideration. Fibres are produced as bi-product and are mainly returned to the farm where they are incorporated in the soil. Being organic in nature, they are highly biodegradable and pose no disposal problem. Water on the other hand is mainly used for cleaning of processing equipments and the floor. It contains no hazardous materials and is therefore directly disposed off.

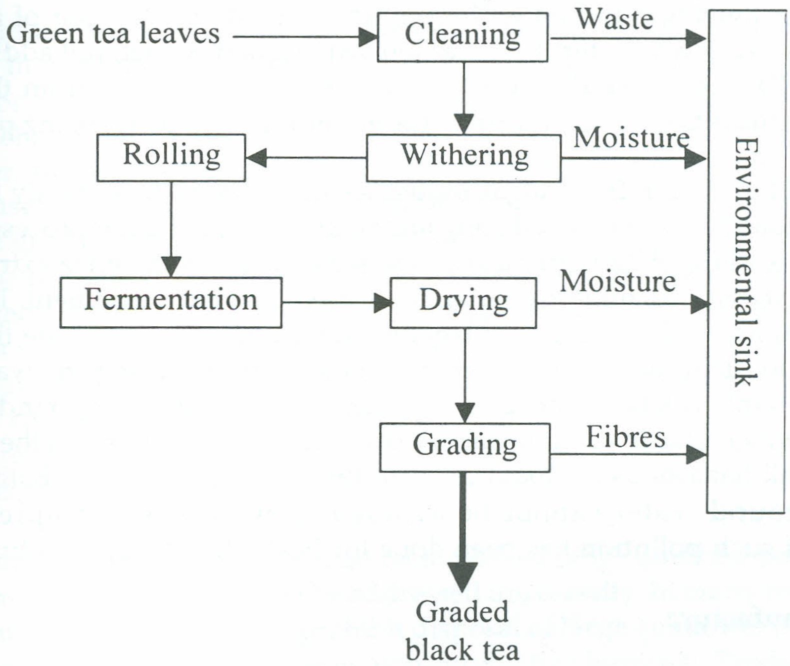

Figure 6.2. Flow chart for black tea processing

Sugarcane Processing

Sugar requirements of the world are supplied from two main sources: sugar cane (*Saccharum officinarum* L.) and sugar beet. While sugar cane has been known for over 2000 years as the main source of crystal sugar, sugar beet is of more recent origin having developed since the beginning of the 19th century (Jenkins, 1966). Whereas sugar beet flourishes well in cooler climates, sugar cane is grown and used as the main source of crystal sugar in East Africa. Although sugarcane has been used for centuries in East Africa for chewing, commercial manufacture of sugar began in the early 20th century. Sugar industry has therefore become one of the most promising agricultural industries in the region providing most of the industrial based jobs in the rural areas. From the sugarcane supplied, the main product is crystal white sugar and the by-products include bagasse, molasses, and filter mud. The basic principles of sugar making from cane are extraction of the juice and its concentration to dense syrup in which sugar separates by crystallization.

Mumias Sugar Company, which is situated in the western part of Kenya, is one of the few industries in the region, which have optimised the use of bagasse for steam and electricity generation. Filter mud on the other hand is used as manure on the farm due to its high organic matter content or in the manufacture of cane wax. Molasses has a wide range of uses making it one of the most valuable by-products from the sugar industry. Known uses include production of alcohols, proteins, yeast, sweeteners, fertilizer, carbonised briquettes, fuel, soil additive and animal feed (Barnes, 1964). Promotion of the use of by-products from the sugar industry minimizes their direct return to the environment thus reducing pollution.

Environmental pollution from sugar industries therefore results mainly from the enormous amount of water used during juice extraction (diffusion process), steam cooling and cleaning. Although most of the water used in the juice extraction is evaporated, excess contaminated water is released to the environment. Pollution is mainly minimized through use of lagoons, which are used to aerate the water and biologically degrade hazardous compounds before releasing the water back to the river. Mainly calcium, phosphorus, potassium and iron compounds will be found in the water. Due to ground leakage of contaminated water and the difficult of removing all hazardous compounds from the water, pollution of both surface and underground water cannot be avoided. However, no comprehensive assessment of such pollution has been done for East African sugar industries.

Lumber Manufacture

Wood is principally lignocellulose and hemicellulose with sugars, resins, gums, pectins, minerals, water, volatiles, fixed carbon and ash. This makes it the most suitable raw material in lumber processing. Lumber processing is one of the largest agro-based industry in the East and central Africa (FAO, 1968). Although the forest cover in these regions hardly exceeds 20% of the land area, the region has some of the largest natural tropical forests in Africa. However, over 80% of the forests are artificial and are the main source of lumber for processing. Lumber processing is carried out on both large and small scale mainly in the rural areas where the forests are located. Large scale processing is mainly carried out in the sawmills, which developed from the practice of conveying logs to a single location where pit sawing is done to obtain the flitches, cants or timber (Willistone, 1988). Due to high rate of deforestation, it has become necessary to maximize productivity and recovery. Ball screws and linear positioners have therefore been introduced to replace the chain-driven setworks on carriages feeding high-strain bandmills. Dry lumber, off-cuts, and chips are the end products of lumber manufacture.

Lumber manufacture has direct adverse effect on the environment starting from the stage of log harvesting where the soil is subject to degradation agents like water and wind. There is also reduced oxygen emission and increase carbon dioxide concentration in the atmosphere due to reduce tree respiration in the affected area. During transportation, large diesel trucks are used which pollute the environment through emission of carbon compounds. Use of diesel driven machines and combustion of wood especially for drying increases further air pollution. Major challenge has been on the storage of bi-products from the mills, which are not easily disposed off especially when produced in large quantities. Off-cuts in most mills are pilled in an open ground from where they are sold for fencing or as firewood. In the mill they can be used in the kilns for lumber drying. Wood debris (bark, sawdust, chips) should be used on a first-in-first-out basis. However, in the East African region they do not find ready use resulting large piles outside the mills. This results in deterioration and fires from overheating and biological actions. In most cases they are burned under uncontrolled conditions resulting in further pollution of the environment through release of smoke. Controlled burning which is common in advanced countries mainly occurs in furnaces so as to generate heat, gas or steam for heating, kiln drying, power generation or steam to power machines directly. The chips are also an eye-saw and are subjected to contamination from rain, soil, fly ash, cinders and many other foreign materials. In other countries more expensive storage methods like chip bins, silos, hoppers and mobile containers used.

Considering the environmental crisis facing developing countries, pollution threats from lumber manufacture must be addressed universally. In many countries today, environmental considerations prohibit disposal of large quantities of sawdust and other wood debris in landfills or by non-productive burning. Productive burning involves use of bed burners, fuel cells, spreader stokers, suspension burners, fluidised bed burners and pyrolysis. In such controlled environment, air pollution is minimized through use of cyclone collectors, granular dry collectors or electrostatic precipitators (Willistone, 1988). Other alternative ways of protecting the environmental include use of the wood debris for making hardboards, and as deep litter in poultry production. No policies have been developed to guide the processing of lumber in East Africa. This therefore calls for urgent measures to be undertaken to formulate such policies. A comprehensive environmental impact assessment of the industry needs also to be carried out so as to help in formulation appropriate policies.

Paper Milling

Paper manufacturing is not a very common industry in the East African region. Each of the three East African countries have only one paper industry with Kenya having one of the biggest mill (Webuye Paper Mill) in the East and central Africa. One of the critical considerations made when siting paper mills is water. This makes paper mills to be some of the main polluters of water. The main stages involved in paper manufacture include pulping, bleaching, beating and drying. Pulping involves the purification of the cellulosic fibres by chemical treatment (Hot sodium sulphite) whereas bleaching removes colouring materials in the fibre through oxidation. In order to develop strength and internal bonding, the fibres are treated in beaters resulting in finished paper (FAO, 1968).

The main pollutants from the paper industry are sulphur dioxide and effluent. Sulphur dioxide has a strong and repellent rotten egg smell which adversely affects even people leaving over 10 km away from the factory. It also reacts with rainwater causing acid rain, which has heavily corroded iron sheet houses near the factory. The acid also ends in drinking water, which is harvest from the roof, thus affecting the health of the people. There are undocumented reports of increase in chest problems from people living near the mill especially factory workers. Although effluent treatment in lagoons tremendously reduces water pollution, concerns are still raised on the suitability of ground water near the lagoons and the water downstream for human and animal consumption. There is therefore great need for a scientific study to be carried to evaluate the effects of paper manufacture on the environment and the health of people. No such recent information is available from any of the three East African countries. There are also no well-set government policies on the environmental impact of paper manufacture in the East African region.

Apart from the pollution resulting from the paper mills, the environment is also adversely affected by the non-sustainable deforestation due to the large amount of wood required. Thus measures are required to develop an economical and sustainable paper milling cycle. Some of the measures that can be undertaken to minimize tree felling include use of alternative pulp sources like bagasse, sabai grass and bamboo. Recycle of wastepaper would also tremendously reduce the pressure on virgin pulp sources due to reduced demand for new paper.

Sisal Processing

Sisal, which originated in Central America, is a vegetable fibre that is extracted from sisal leaves (*Agave sisalana* L.) through decortication. The fibres are long, bold and creamy white besides being exceptionally strong. It is mainly used for making twines, ropes, sacks, carpets, upholstery and as reinforcement for building materials. At the moment sisal is grown on large estates in all the countries in East and Central Africa. However, due to the development of synthetic fibres, the demand for natural fibres has significantly reduced thus adversely affecting sisal fibre production.

During processing (Figure 6.3), the cellular tissues (leaf pulp) are crushed and torn away from the fibres by two drums fitted with beater knives and rotating against a concave breastplate. Water is used to wash the leaves and fibres, dilute the acid juices and to carry away the leaf pulp. Completely decorticated fibres come out as glistering wet tresses draped on the delivery rope. The wet fibres are dried naturally or artificially and then brushed to free individual fibres before being packaged and baled.

Fresh sisal waste is acidic having a pH value ranging from 4.8 to 5.2. It is therefore mildly corrosive requiring great care for susceptible machine parts. The waste is conveyed down wooden flumes, preferably lined with brass sheeting to reduce friction and wear into a waste dump. Although the damp allows the liquid waste to drain underground so that the solid waste can be used as manure, this becomes the main source of pollution since the liquid waste contaminates ground water. Due to the high acidity, the pH value of the surrounding soil is adversely compromised thus affecting the growth of other crops and plants. Although dry decortication results in poor quality fibre, it reduces pollution by over 90%. So as to minimize pollution effects of sisal waste, efforts have been made to use the waste for manufacture of chemicals (Hecogenin and Sodium pectate), wax and in the production of methane gas. However, none of these alternatives has been used in East Africa region making sisal processing one of the most pollutant agro-based industries.

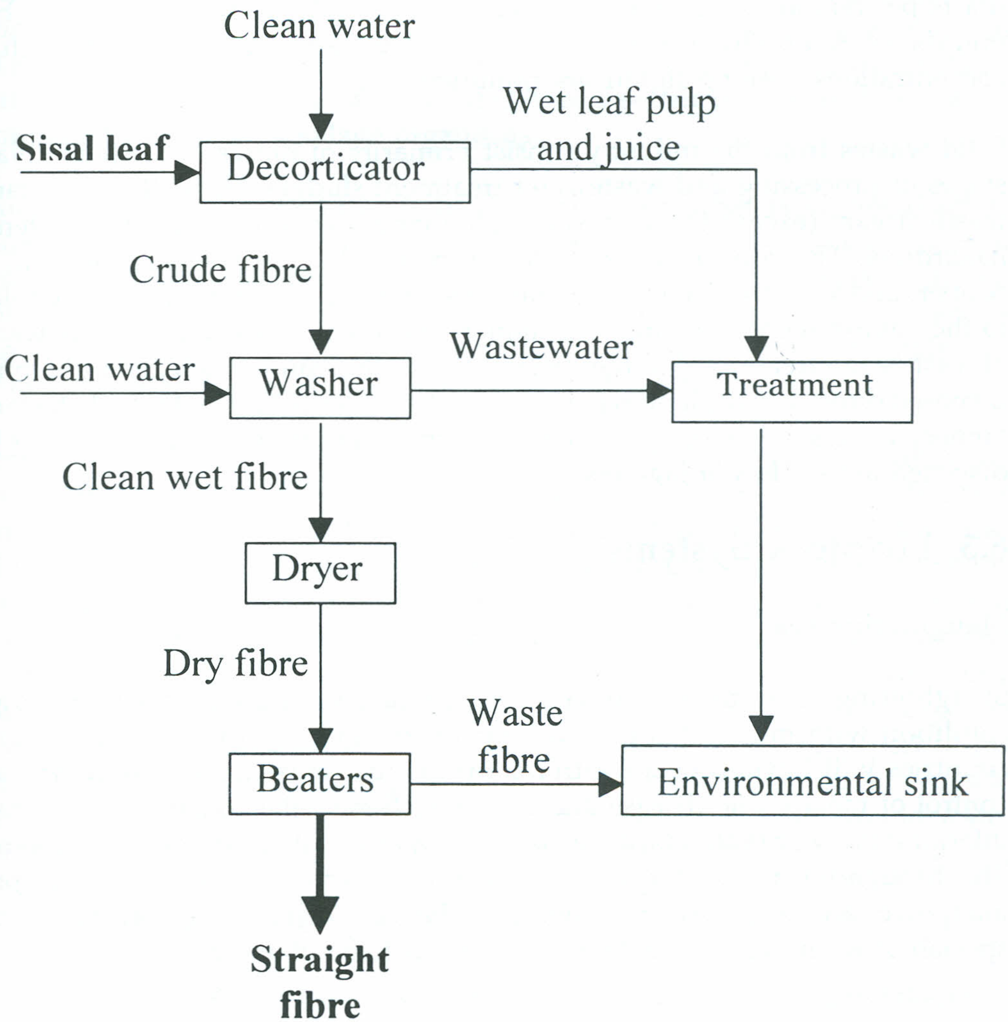

Figure 6.3. Flow chart for sisal fibre processing

Tanning Industry

In tanneries, the treatment of animal hides is a complex manufacturing process, involving the use of ammonium salts, enzymes, organic salts and degreasing agents. Tanning is achieved by the addition of chromium sulphate and sodium bicarbonate; dyes, resin binders and waxes are applied in the final stages. There are a number of potential pollution problems resulting from sulphide waste, chromium discharge, suspended solids, pigments and dyes.
The primary aim of pollution control in a tannery is to remove excess sulphides and chromium discharges. Recycling wash water, spent chromium and dye solutions, reducing suspended solids in settling tanks, and removal of toxic sulphides by oxidation are all recognised ways of achieving this. The tannery can directly be linked to a public sewage system thus minimizing effluent problems. Typical concentrations of chromium from tanneries may be in the range 8.2 ppb (Parts per billion), against a background concentration of 1.1 to 1.3 ppb. Heavy metals such as chromium are potentially dangerous, but in such tiny concentrations pose no significant pollution risk.

Solid wastes from the industry consist primarily of pieces of leather in various stages of processing and wastewater treatment sludges. Virtually every tannery waste stream (except those in vegetable tanneries) is designated as potentially hazardous. The concentration of heavy metals like trivalent chromium, lead, copper, and zinc are usually at hazardous levels and cannot be directly released to the environment. Treatment of tannery wastes is restricted to the dewatering of wastewater treatment sludges. Sludges and other tannery wastes are commonly disposed directly to the land whereas about 60 percent of the potentially hazardous tannery wastes are disposed off in some form of landfill with the remainder being disposed in trenches or lagoons.

6.3 Livestock Systems

Slaughterhouses

Slaughtering of animals in developing countries occurs under poor hygienic condition with minimal considerations of its effect on the environment. Most countries will have a meat control act providing meat inspection aimed at the control of meat borne disease and the protection of the consumer from meat of inferior quality or that, which has not been hygienically slaughtered and handled. The throughput and sanitary conditions of slaughterhouse depends on equipment, manpower and work organization. It is advisable therefore to seek the advice of specialists whenever a slaughtering facility is to be planned.

In areas where few animals are slaughtered, a simple and inexpensive slaughtering facility is desirable. It should consists of a gantry hoist since animals must be hoisted immediately after stunning to assure proper bleeding and then remain in a hanging position during the dressing operation to ensure sanitary conditions. A slaughterhouse should also include floor rings to hold animals, skinning cradles for cattle and small stock, rails for hanging the carcasses, a slaughter slab for handling the products and an adequate and convenient water supply. Improved sanitation and management are possible by using separate bays for cattle and small stock.

For large scale animal slaughtering, a fully equipped slaughterhouse having a large slaughter hall where animals are stunned, bled, slaughtered, flayed and dressed should be provided. In such a system live animals enter one end of the building and emerge as dressed carcasses at the other (FAO, 1980). The slaughterhouses may slightly differ in design based on the animal being slaughtered and final products. For pigs, a water boiler to supply the scaldingvat water at about 80° C is required. The steam from the scaldingvat creates adverse conditions for setting of meat and the scurf accumulated from scraping pig carcasses is heavily contaminated with meat spoilage organisms.

The site for a slaughter facility should be on ground that is higher than its surroundings to facilitate drainage. For sanitary reasons, floors and walls should be easily cleaned, impervious to water and rodent-proof. Concrete floors should be finished smoothly, but not to the extent of being slippery, and sloped towards the open drains along the walls. A clean lairage ensures that the animals will enter the slaughtering area as free as possible from contamination.

Environmental pollution from slaughterhouses can be minimized by not allowing large quantities of blood collected from the bleeding area to enter the main drainage system and cause pollution. All the effluent from the stunning and bleeding area should be collected separately and led to an underground tank situated outside the building. The tank should be built with a tight-fitting, removable cover and be so constructed that the liquid can seep through the sides into the surrounding soil. The blood naturally decomposes requiring the tank to be cleaned only occasionally. To avoid odours, the tank should be equipped with a screened ventilation pipe. In tropical areas; the air in the pipe and the upper part of the tank is warmed sufficiently during the day to cause circulation and air renewal in the tank. The blood tank will operate satisfactorily only if the ground water level is below the level of the tank and the surrounding soil is pervious to water.

Handling of Manure and Condemned Meat

The carcass should be dressed out rapidly and the offal inspected and taken to a separate room where it can be cut up and the stomach and guts opened, cleared of manure and flushed with water. The manure is taken to a manure pit outside the building, while the rinsing water is directed into the main drainage system. Suspected or condemned material is taken to the room set aside for this purpose. It is disposed off together with inedible offal in two concrete pits outside the building. The pits should be equipped with airtight lockable covers. Most of the material slowly decomposes thus the pits may not need to be emptied. Incineration is not recommended as efficient incinerators are expensive both to buy and to operate and simple incinerators do not work satisfactorily and burn out quickly.

Slaughterhouse floors should be sloped so that water and effluent run into open drains placed along the walls. All these drains should be connected by a central drain to a grease and solids trap. From this trap the remaining effluent is led either into an evaporation pan where bacterial action will break down most of the effluent in 20 to 30 days, or alternatively, into a sub-surface seepage field, designed with a series of herringbone patterned trenches filled with stones.

Soakage pits not less than 6m deep and 1.8m in Diameter and covered with a concrete top are satisfactory for only the smallest units. Open drains are recommended for the effluent from the slaughterhouse. To prevent rodents from entering, a screen should be fitted to the open drain where it passes through the slaughterhouse wall in such a way that it can be easily removed for cleaning.

Handling of Manure Waste

Waste generated in animal handling systems is mainly from daily manure production. The quantity of manure produced by the animal depends on its kind and weight, composition and digestibility of feed, the environment and productivity levels desired. Higher quantities of wastes are handled due to the addition of animal bedding, spilled feed, water used in cleaning, runoff from open lots, and water added to reduce odour in liquid manure systems. Manure therefore refers to combination of faeces, urine, livestock and poultry production residues, plus other material, such as bedding, soil, spilled feed, and water. Manures are given descriptive names that reflect their moisture content, such as liquid, slurry, semi-solid and solid. Foreign materials commonly added to manure end up polluting the environment.

Feed consumed by animals is 50% to 90% digested, but spilled feed is undigested. A kilogram of spilled feed results in as much manure equivalents as 2 to 10 kg of feed consumed. Small quantities, about 3%, of spilled feed are common and very difficult to see. Wastage of 5% is common and can be observed. Obvious feed wastage is indicative of 10% or more being spilled (CIGR, 1999). About 20 to 40 litres of fresh water per day for each cow milked are used in a milking centre in which flushing of manures is not practiced. However, if manure flush cleaning and automatic cow washing are used, water use can be 600 litres per day per cow or more. Dairies employing flush cleaning systems use water in approximately the following percentages for various cleaning operations. Parlour cleanup and sanitation: 10%, cow washing: 30%, manure flushing: 50%, miscellaneous: 10%.

Feed processing can add to the quantities of wastes through expired feed, spilled feed, and contaminated feed. Agro-chemicals could also add to the toxicity of wastes. When plants and animals die, they begin to decay resulting in compounds that are organic and non-organic such as nitrates and orthophosphates, or gases, such as nitrogen gas (N_2), ammonia (NH_3), and hydrogen sulphide (H_2S). In water-quality analyses, total nitrogen includes the organic, total ammonia (NH_3 C NH4), nitrite (NO_2), and nitrate (NO_3) forms. The United States Environmental Protection Agency recommends 10 mg/L of NO_3-N for drinking water because of the health hazard nitrites present for pregnant women and infants. Unborn babies and infants can contract Methemoglobine-mia, or "blue-baby syndrome", from ingesting water contaminated with nitrates. In extreme cases, this can be fatal (USEPA, 1986).

Because phosphorus is used extensively in agriculture, the potential for pollution from this source is high. About 73% of the phosphorus in the fresh manure of various types of livestock is in the organic form. The soluble form generally accounts for less than 15% of the total phosphorus in most soils. High phosphorus concentrations results in accelerated eutrophication of water, if other growth-promoting factors are present (USEPA, 1984)

Effects of Manure on the Air and Animals

Livestock production facilities are sources of gases, aerosols, vapours, and dust that individually or in combination, create air quality problems such as odours, health problems for both animals in confinement and people. Under anaerobic conditions, the primary gases are methane and carbon dioxide. About 60% to 70% of the gas generated in an anaerobic lagoon is methane, and about 30% is carbon dioxide. However, trace amounts of more than 40 other compounds have been identified in the air exposed to decomposing animal manure. They include aromatics, sulphides, and various esters, carbonyls, and amines. Odours are associated with all livestock-production facilities. Animal manure is a common source of significant odours, but other sources, such as poor-quality or spoiled feed and dead animals, can also be at fault. Freshly voided manure is seldom a cause of objectionable odour (USDA, 1992).

Some of the dangerous gases associated with animal waste include carbon dioxide, ammonia and hydrogen sulphite. Carbon dioxide can be an asphyxiant if it displaces normal air in a confined facility. Since it is heavier than air, it remains in a tank or other well-sealed structure, gradually displacing the lighter gases. Ammonia on the other hand is primarily an irritant and has been known to create health problems for animals in confinement. Irritation of the eyes and respiratory tract are common problems from prolonged exposure to this gas. It is also associated with soil-acidification processes. Hydrogen Sulphite however is deadly. The gas is heavier and becomes more concentrated in the tank over time. It has the distinct odour of rotten eggs, which makes it to smell and is known to deaden the olfactory nerves (CIGR, 1999). Grazing animals can be adversely affected if animal manure is applied to forage crops at an excessive rate. Studies indicate that grass tetany, fescue toxicity, agalactia, and fat necrosis appear to be associated, in part, with high rates of fertilization from poultry litter on cool-season grasses (especially fescue).

6.4 Fish Farming

Intensive fish farming uses water to carry oxygen to the fish and to receive the waste produced in the system (metabolic by-products and other materials). It also disperses or carries the wastes away so that they do not accumulate in or around the fish farm to harmful and undesirable levels (Bergheim and Asogard, 1996). Technologies and strategies to manage or reduce the wastes generated during aquaculture production are being developed to reduce its demand for water resources and abate its effect on the environment. Increased aquaculture production efficiencies, reduced waste, or reduced water use have resulted from improved feed and feeding strategies, application of aeration and oxygenation technologies, water-reuse technologies, and more widely used effluent-treatment technologies (Summerfelt and Wade, 1997). More stringent water pollution control and systems that reuse water have become more attractive since they reduce the volume of water to be treated and thus the size of water treatment facilities through concentration of wastes for their economical removal. Water-reuse systems typically use clarifiers or filters to remove particulate solids, biological filters to reduce dissolved wastes, strippers or aerators to add oxygen and decrease carbon dioxide or nitrogen gas levels, and oxygenation units to increase oxygen concentrations above saturation. However, not all water-treatment technologies scale up equally well, thus more functional and less costly technologies for treating large flows are being adopted (Beveridge *et al.*, 1991).

6.5 Agricultural Waste Management Systems

Planning for a sustainable waste management programme is based on the following premises:

- Production and processing processes will always result in the production of wastes

- The main objective in waste management is to reduce or eliminate their accumulation and also reduce or eliminate their potential adverse effects.
- The worker, the society, the cost, and the environment must be considered.

A waste management system is a planned system in which all necessary components are installed and managed to control and use by-products of agricultural production in a manner that sustains or enhances the quality of air, water, soil, plant, and animal resources. Waste management systems must be developed using the total systems approach. A total system accounts for all the manure associated with an agricultural enterprise throughout the year from production to utilization. For manure-management system to be practical, it must interface with other systems such as cropping, livestock, irrigation, drainage, nutrient management and pest control systems.

A waste management system consists of six basic functions: production, collection, storage, treatment, transfer, and utilization (Figure 6.4). For a specific system these functions may be combined, repeated, eliminated, or arranged as necessary. Production is the function of the amount and nature of waste generated by an agricultural enterprise. A complete analysis of production includes the kind, consistency, volume, location, and timing of waste produced. Collection is the initial capture and gathering of the waste from the point of origin or deposition to a collection point.

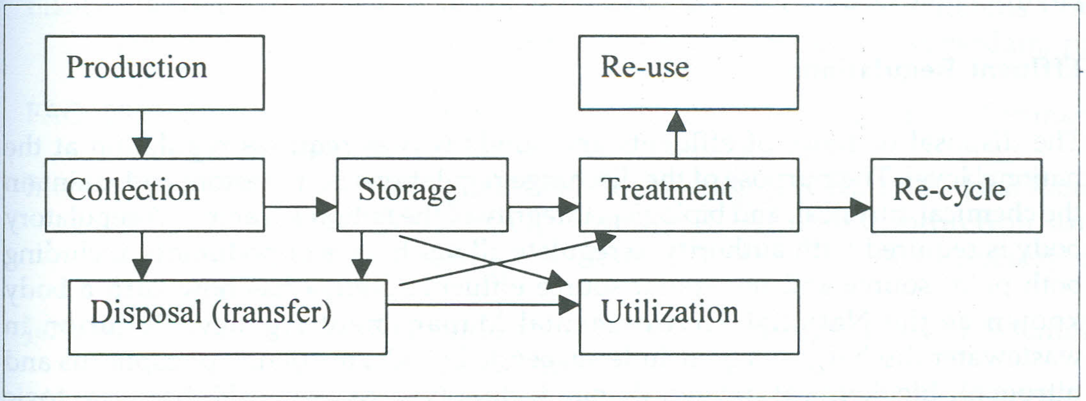

Figure 6.4. Waste generation and management pathway

Treatment of waste is designed to reduce its pollution potential through physical, biological, or chemical treatment. It includes activities that are sometimes considered pre-treatment, such as the separation of solids. Transfer or disposal is the movement and transportation of the waste throughout the system. It includes the transfer of the waste from the collection point to the storage facility, to the treatment facility, and to the utilization site. The waste may require transfer as a solid, liquid, or paste, depending on the total solids concentration. Utilization includes recycling reusable waste products and reintroducing non-reusable manure products into the environment. Wastes may be used as a source of energy, bedding, animal feed, mulch, organic matter, or plant nutrients. If properly treated, it can be marketable.

Conventional methods of waste management in most countries include:

- Land fills
- Lagoons
- Injection wells for hazardous wastes
- Chemical treatment plants
- Secure land fills
- Integrated treatment facilities equipped with incinerators.
- Current strategies are geared towards sustainable practices namely:
- Reduction of waste generation through clean production mechanisms
- Re-use of segregated wastes through recycling
- Using alternative raw materials
- Replacing hazardous products with safer substitutes.

How to realise these broad objectives in production systems associated with financial and technological limitations is what Africa requires. There is need to formulate appropriate policies based on the existing strategies so as to protect the environment in the East Africa region (Chapman, 1998; SADC, 1996).

Effluent Regulations

The disposal or reuse of effluents and solids wastes requires regulation at the national level. The purpose of the discharge regulations is "to restore and maintain the chemical, physical, and biological integrity of the nation's waters." A regulatory body is required with authority to regulate all discharges of pollutants, including both point source and non-point source effluents. Kenya has now such a body known as the National Environmental Management Agency. Pollution in wastewater discharges may include suspended solids, nutrients (phosphorus and nitrogen), biochemical oxygen demand, dissolved oxygen, pH, bacteria, toxic chemicals, volatile organic molecules, metals, pesticides, and other material (Eikebrokk and Ulgenes, 1993). In order to minimize waste output or recycle waste products, policies must be formulated to supports the use of best available technology (BAT) and best management practices (BMPs), the use of effluent for irrigation water, and the use of organic solids for soil enrichment, fertilizer, or animal feed.

6.6 Sample Questions

i. Using practical examples discuss the role of agricultural processing in environmental pollution and degradation.

ii. To pump manure from a storage facility to a treatment facility, its moisture content was to be raised from 60% to 80%. Assuming an initial raw manure weight of 200 kg, determine the amount of water that would be added in litres. Assume that 1 kg = 1 litre.

iii. Using specific examples, critically examine the ways in Kenya's bioproduction systems can relate along industrial symbiotic patterns.

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