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EMERGING TRENDS IN BIOTECHNOLOGY FOR WASTE MANAGEMENT: AN REVIEW

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Abstract: *In a modern city life we have to deal with enormous waste that we produce through industries and homes. Without proper waste management, our cities will essentially become un-livable. Modern Biotechnology has come up to solve this problem in many ways.*

There are various types of wastes like industrial waste, domestic waste and so on. Modern Environmental Biotechnology can provide proper management for them and help us to become more eco-friendly. The microbes have the potential to break and degrade the waste toxins. Biotechnology is also being eyed to deal with some of our nuclear and radiation waste, like the Deinococcus radiodurans bacterium may be used to manage the nuclear waste. This bacterium is capable of intoxication of mercury which is connected with the production of nuclear weapons. During the treatment of sewage, bacteria can convert the nitrogenous compound to Carbon-di-oxide and nitrogen.

Several industries like chemical industry, food industry, and brewing industries produce a lot of waste which is needed to be properly managed. Modern biotechnology uses biological processes to manage the waste from such factories. Modern biotechnology can use microbes that are suitable to break down these waste products and it converts some of it into useful products.

Vermiculture is a term used to manage the waste, it refers to the culture of earthworms. Earthworm can degrade the waste due to its gizzard system. Eisenia foetida is used extensively to manage waste and it can be used indoors as well as outdoors. Thus the waste is converted into fertilizer which increases the fertility of soil.

Certain bacterias utilize the toxin materials as their food and can convert the toxic materials into the effective compound for the soil. Thauera aromatic has the capacity to intoxicate the toxin properties of toluene and there is another bacterium that can break even the petroleum. Thus it is apparent that with the advent of Biotechnology and genetic engineering we can manage the waste very easily and effectively. We the people of 21st century are concerned with waste management as well as we think about our climate. So avoiding the chemical treatment and taking the biological system for waste management will expose us to a livable world. Modern Biotechnology has come up to solve this problem with stability and this solution is eco-friendly.

Keywords: Waste Management, Biotechnology, Culture, Earthworm, *Bacteria, Toxin, Carbon-di-oxide and Nitrogen.*

Introduction: The increasing generation of food waste and its management constitute a major concern. In the EU, around 100 million tonnes of food, mainly coming from homes but also from food markets, are wasted annually. This amount is expected to rise to over 120 million tonnes by 2020 if the situation does not change [1]. In developing countries the situation is even worst; the main food waste streams come from food market activities/areas, where it is usual to have a high production and a non-efficient waste management.

The management of these waste fluxes must be quick and efficient due to their high degradability, which makes unsuitable their disposal in municipal landfills. The disposal in landfills or dumpsites of these organic wastes, especially vegetable market waste, together with municipal solid wastes, generates different undesirable effects and negative impacts in the environment (bad odours, leachate production and greenhouse gas emission into the atmosphere, etc.) that affect the health of the population of the area of influence [2]. However, the high concentrations of organic matter and nutrient contents of food market and urban gardening wastes favour their recycling by composting, which allows to manage and recycle these materials, obtaining end-products (compost) for agricultural purposes. Composting is defined as the biological decomposition of organic matter under controlled aerobic conditions to form a stable, humus-like end product [3, 4]. Among the major waste management strategies developed, composting is gaining interest for organic waste disposal as a treatment with more economic and environmental profits, leading to a stabilized end product [2]. On the one hand, from the economic point of view, compost can be distributed in a wide variety of markets, especially when the demand for fertilizer is strongly correlated with high agricultural commodity prices [5]. As an example [6] demonstrated the role of composted green waste as a substitute for peat in growing media in state nurseries in Beijing (China). On the other hand, at an environmental level, composting not only avoids landfill for waste disposal, mitigating the formation of leachate and gases [7], but also implies the obtaining of a finished product that can enrich the soil and aid with water conservation [8]. However, although food waste and/or green waste composting may constitute a growing solution to solid waste management, many problems remain: the location of the composting facility, the suitable financial support for the installation and maintenance of the composting facility and/or the necessary technical knowledge, being the latter aspects especially problematic in developing countries, such as Ecuador. In this sense, composting is a technology with an easier implementation and lesser costs in relation to other technological options. Therefore, in countries with similar conditions to those as Ecuador, such as the lack of low-cost technological options for an efficient management of waste streams, it may be a win-win option for the management of clean organic waste streams, such as food market and urban pruning wastes, especially in specific agricultural uses of the composts obtained. However, despite composting can constitute a viable alternative method to manage this type of waste streams, not enough information is currently available on the composting of food market wastes and pruning waste in developing countries, and of the added value of the composts obtained.

Currently, the management of urban waste streams in developing countries is not optimized yet, and in many cases these wastes are disposed untreated in open dumps. This fact causes serious environmental and health problems due to the presence of contaminants and pathogens. Frequently, the use of specific low-cost strategies reduces the total amount of wastes. These strategies are mainly associated to the identification, separate collection and composting of specific organic waste streams, such as vegetable and fruit refuses from food markets and urban gardening activities.

Among the modern technologies that have appeared since the 1970s, biotechnology has famous the most attention. It has proved capable of generating enormous wealth and influencing every significant sector of the economy. It has already substantially affected healthcare; production and processing of food; agriculture and forestry; environmental protection and production of materials and chemicals [9]. Biotechnology has various application fields ranging from waste treatment to medical treatment of cancer. A cleaner environment, advanced methods of diagnosis and medical treatment, better products and alternative energy resources can be considered among the benefits of biotechnology. Nowadays, environmental pollution is one of the most important problems in all world countries. Biotechnology offers many treatment methods to overcome this pollution problem. In this review, removal of wastes by biotechnological treatment is examined in depth and some examples are given to the treatment studies of wastes by biotechnological processes in environmental engineering.

Environmental pollution occurs by deterioration of natural equilibrium of environment via various human activities. Nowadays, environmental pollution is the most important problem for all world countries. Pollution existed since the beginning of industrialization and grew by the parallel of rapidly increasing industrialization after Second World War. Precautions were taken after 1970s for preventing and reducing this pollution. Biotechnology finds application fields in the treatment of wastewaters by biological methods and disposal of solid wastes by composting technique in environmental engineering.

Biological methods are also applied to treatment of air emissions. The methods based on biotechnology in wastewater treatment are activated sludge, trickling filters, oxidation ponds, biofilters and anaerobic treatment. Furthermore, solid waste composting techniques, biotrickling filters and biosorption are the examples of biotechnology applications in environmental engineering. In all these methods, it is essential to find suitable microorganisms that will degrade organic substances and to complete the treatment process in favorable conditions. Some biotechnological applications used in environmental engineering for waste treatment will be discussed below [10].

Environmental biotechnology is concerned with the application of biotechnological techniques to foster and preserve the environment, which means to keep a balance between the physical and biological matters on this planet. The basis for such a balance can be found in the form of the natural cycles of matter. It is therefore of utter importance to find techniques and scientific applications to be able to foster, improve and increase the activities of these natural cycles in order to cope with an increasing human and animal population.

In order to sustain life and improve the standard of living, the general advancement of scientific knowledge of clean technological strategies, which support the natural cycles of matter. Sustainability can be obtained together with a higher health and living standard, if appropriate technologies are applied according to the climatic region and local society. This article together with those within this Topic will demonstrate that it is possible to return to a balanced environment with better health and living conditions.

In order to be able to use these specific biotechnological techniques, this article firstly demonstrates how nature itself copes in recycling its natural wastes most efficiently. Attention is drawn continuously to those areas of the various cycles where human activities have interfered causing an imbalance of dangerous proportions in the cycles. To sustain life and improve the standard of living has to become also a concern of each and every community, society and individual. Only with their concerted effort can we finance and establish a balanced cycling of matter. Since these efforts require strong societal input, the term socio-economic is being used and a suggestive scheme of community involvement is being presented.

A socio-economic strategy for sustainability has to take these demands into consideration. It must therefore be the aim of environmental biotechnologists to improve more rationally food and feed production through a multi-product agricultural system exploiting more thoroughly our available natural renewable resources. Examples are given for agricultural farming and agro-industrial manufacturers employing starch, carbohydrate and lignocellulosic materials. At the same time, increasing wastes can be handled with an improved methanogenesis connected to additional food, energy and fertiliser production reducing increased carbon dioxide levels in the atmosphere. Biofertilisation and energy are very important since the soils have to be replenished as is shown in the nitrogen cycle. The examples also indicate, that biofuel can be part of the strategies [11].

Microbes and hazardous waste: Microbes are living organisms and are found everywhere in the environment. Microbes can include bacteria, fungi, algae and many other types of living things. Single microbes are too small to be seen with the naked eye, but can play an important part in cleaning up hazardous chemicals, such as pesticides, oil, and heavy metals. Some microbes can use these materials as a food source. By spreading specific microbes at a site contaminated with dangerous waste products, the waste can be broken down into harmless substances. This process is known as bioremediation. Other approaches stimulate the growth or activity of microbes native to the site to breakdown the contaminant more quickly.

Waste management—human and industry waste: Certain bacteria and microbes can adapt to, and live in, various environments, where they break down materials for their own use, including mine waste and solid waste. Using gene technology, researchers have the potential to enhance these properties and create new waste solutions. Queensland researchers are investigating the development of valuable bioproducts from waste. The project specifically targets small and medium scale biosolids producers, including feedlots, meat processors, other food processing industries, and communities less than 100,000 persons. The project aims to turn products from waste into useful products such as fish and livestock feeds, fertiliser, recycled water and biogas. Researchers in the world are also developing new technology to address algal blooms by removing high levels of nutrients such as nitrogen and phosphorous from agricultural wastewater. This research has implications for industries such as the meat processing industry and its abattoir wastewater treatment systems.

Biomonitoring: Globally, researchers are investigating the use of plants as 'sensors' for changes within an environment. Such research may have implications for agriculture, the environment, and military and humanitarian operations. Researchers aim to understand and modify plant responses to environmental triggers such as microbes, insects, soil, drought and chemicals, so that they can genetically modify plants to signal, for example by glowing, when a problem exists. Some applications developed focus on the detection of:

- Radioactive pollution of soil and water
- Heavy metal contamination of soils
- Herbicide contamination of soils
- Water and pathogen stresses in plants and crops.

Military and humanitarian operations, may also find such technology useful, for example modifying plants to detect or signal the presence of land mines, chemical warfare agents or pathogens such as anthrax.

Pest Animal Management: Introduced pests cause a myriad of problems for the environment, such as erosion, and loss of native vegetation and wildlife. Researchers in the world are investigating control options for carp using gene technology, and research is underway in New Zealand to control possums biologically.

Cleaner Industrial Processes: The production of components for detergents, nylon, glue, paints, lubricants and plastics from plants is being investigated around the world as a cheaper, biodegradable alternative to current methods. Raw materials used to make industrial chemicals and polymers such as plastics are modified fatty acids, and these fatty acids are often produced from non-renewable petroleum sources. CSIRO scientists are researching plants as 'bio-factories' by modifying the fatty acids within a plant. This has the potential to reduce the chemical processing and polluting waste normally associated with the production of industrial products. These genes may now be transferred to oilseed crops to create cheap, biodegradable and renewable sources of the raw materials required for products such as araldite, lubricants and high quality surface coatings.

Transgenic Technology: In Golovan's group, those researchers discovered and developed the new technology which can change the pig's gene called transgenic pigs". There are special phytases in transgenic pig's saliva, and those special phytases will help the pigs to decompose phosphate in the feeds when they eat. Therefore, we don't need add the inorganic phosphorus in the feed, and it can automatically reduce the phosphorus contents of swine wastes around 75%. A pig usually needs 2.5kg calcium phosphate throughout its' life; in the opposite, a transgenic pig does not need any calcium phosphate throughout its' life. As this result, we can decrease the pollutants in our environment by reducing the swine waste. Also, producing phytases from the transgenic pig that can decompose the phosphate. It shows that the new molecular biotechnology can really help to decrease the pollution in our environment on the animal husbandry. Furthermore, it cannot only reduce mining the phosphate source but also can prevent the pollution by the following after mining [12].

Green Energy: Green energy is a term to describe what is environmental and efficient resources of power and energy. Typically, it means to the renewable and non-polluting energy sources. Green energy includes natural and energetic processes that only within little pollution. Anaerobic digestion, geothermal power, wind power, small-scale hydropower, solar power, biomass power, tidal power and wave power are all under the previous category. For example, methane production from the waste is one type of green energy. Ethanol is a renewable fuel source that can be derived from a variety of biomass sources. In the United States, most fuel ethanol is derived from corn. When corns were produced the ethanol, we can still use their sludge to make the methane by the anaerobic digestion.

Environmental biotechnology has applications in waste treatment and pollution prevention. Compared with conventional methods, these applications can more efficiently clean many wastes and significantly reduce dependence on land-based disposal methods. The broadest application of environmental biotechnology is bioremediation, using bacteria to transform waste into harmless by-products. It is an area of increasing interest. Enzyme reactors have been developed to pre-treat waste components (industrial and food), facilitating their removal through the sewage rather than solid waste disposal systems. Waste can be converted to biofuel, and microbes induced to produce enzymes to convert plant materials into building blocks for biodegradable plastics. The by-products of micro-organisms in bioremediation can be useful. For example, methane produced by bacterial degradation of sulphur liquor, a waste product of paper manufacturing, can be used as a fuel [13]. Some of the risks associated with agricultural and industrial biotechnology, identified in the previous sections of this report, also apply to environmental biotechnology.

Pollution Control: Biotechnology has several applications for pollution control, including solid and liquid waste treatment, hazardous waste management, slime control (e.g., manufacture of paper), and grease decomposition (e.g., meats and certain foods, and waste water collection) [14]. Current commercial applications of biotechnology rely on conventional techniques of genetic manipulation and microbiology; the use of recombinant DNA (rDNA) to develop microbes with special capabilities for waste degradation has been limited. As of 1988, 65 companies were involved in some aspect of biotechnology for waste management [15].

Composting: The composting process is a controlled biological exothermic oxidation of organic matter, followed by a maturing phase, carried out by a dynamic and rapid succession of microbial populations. The organic matter is transformed into a final stable humus type product (compost) through its mineralization and humification (20 or 30% of the volatile solids are converted in CO_2 and H_2O). This product is a hygienic material, free of unpleasant characteristics, according to the following reaction.

Organic Microorganisms Biodegradable + O_2 $\rightarrow$ Stabilized organic residuals + Microbial biomass + CO_2+H_2O + Heat

Residual: As the decomposition of organic matter contained in the sludge is produced, the compost heats up to temperatures situated in the interval of pasteurization (50–70°C), which allows the destruction of pathogen organisms and no biodegradable organic compounds. Aerobic composting is carried out in static piles, in rows or in reactors. The latter 2 methods correspond, respectively, to large amounts of sludge to be treated and to the building of a reactor. The static pile, in its most simple form, needs a safe aerating system by tubes in the base of the pile, injecting or sucking air under pressure or by natural ventilation and turning over the pile regularly. The principal use of the produced material is agronomic and so allows nutrient minerals to reintegrate into the soil which otherwise would have been lost. The compost has also been tried for other uses unrelated with agriculture. Shows a pilot system diagram (Figure 1) for composting in their study concerning waste sludge composting from gelatin-grenetine industry [16]. Nowadays, composting is also viewed as a cost-effective option for treating organic wastes and soils contaminated with toxic organic compounds, such as PAHs [17].

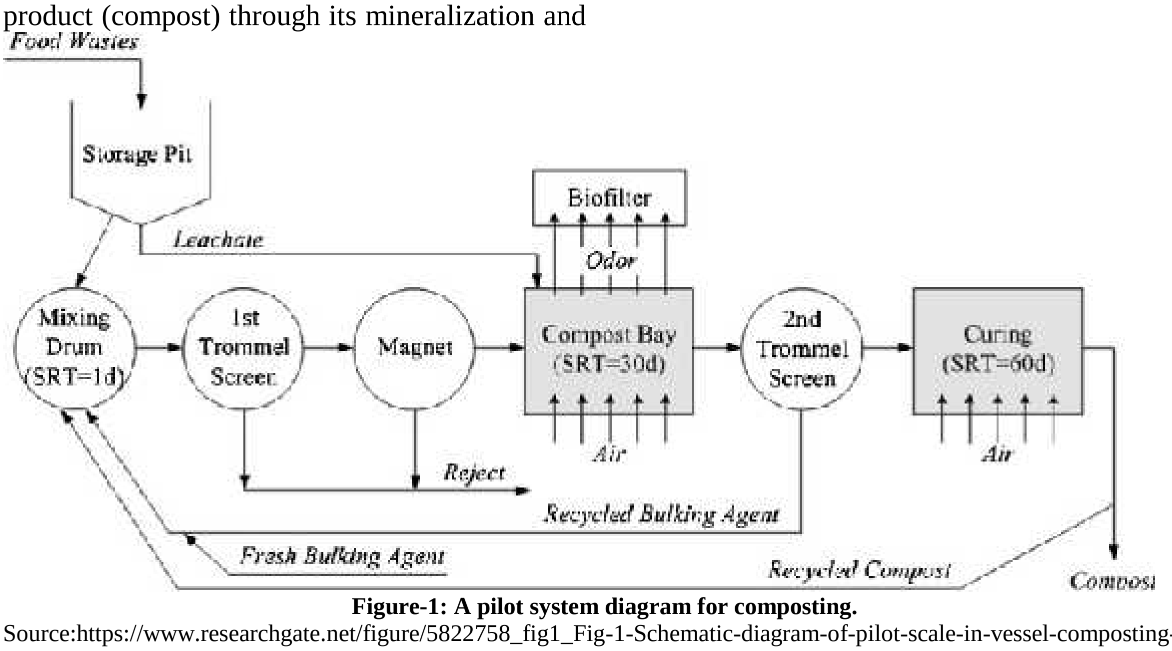

Figure-1: A pilot system diagram for composting.

Source:https://www.researchgate.net/figure/5822758_fig1_Fig-1-Schematic-diagram-of-pilot-scale-in-vessel-composting-plant.

Biosorption: The uptake of both metal and non-metal species by bio-mass, whether living or denatured, is commonly termed biosorption. This technique can be an alternative to conventional waste-treatment facilities [18]. Biosorption encompasses physico-chemical mechanisms by which metal species, radionuclides and so on, are removed from aqueous solutions by microbial biomass or products [19]. A variety of microbial and other biomass types has been shown to have good biosorption potential and several have been proposed as the basis for treatment of metal-bearing wastewaters [20-21]. Compared to techniques such as precipitation and ion exchange, biosorption as a polishing or adjunct process offers the advantages of low cost, good efficiency and it does not produce sludge of high metal content [22]. In biosorption, the metals are not only removeed from wastes, but also recovered to reuse for different purposes.

Reduction of Metals: Most of the heavy metals must be found at metabolic processes as trace elements, but they are also harmful components except iron and manganese. Particularly, their harmful effects increase in high concentrations. For example, mercury and cadmium have important harmful effects on individuals. They can not be degraded biologically or chemically and they accumulate in living organisms. Therefore, these types of metals must be removed from wastewaters. A process scheme for the treatment of metals by biosorption from wastewaters is given in Figure 2. According to the literature 5-20% of metals are removed by sedimentation in primary treatment, 30-90% of metals are removed by microbiological processes from aqueous media. Some of metals recovered by anaerobic culture are Cu_2+, Ni_3+, Cr_3+, Zn_2+, Hg_2+. These metals can be recovered with an efficiency of 75 - 99% [23]. The waste that remains from metal recovery processes can be used as fertilizer and burning material. If it is used as fertilizer, it must be pay attention to the risk of transition of harmful metals to the foods. Therefore, before the use of fertilizer, the metal concentrations in the waste must be controlled and compared with the permitted values.

Besides the treatment studies mentioned above, denatured biomasses can be used for the removal of various metals from wastewaters. There are a lot of treatment studies in the literature concerning biosorption. Use green coconut shell powder for removing cadmium [22]. Another treatment study was made [24] to treat lead ions from storage battery industry wastewaters by using biomass Rhizopus Arrhizus. Also conducted a study for removing nickel ions [25] from wastewaters by R. Arrhizus immobilized on rice bran [26].

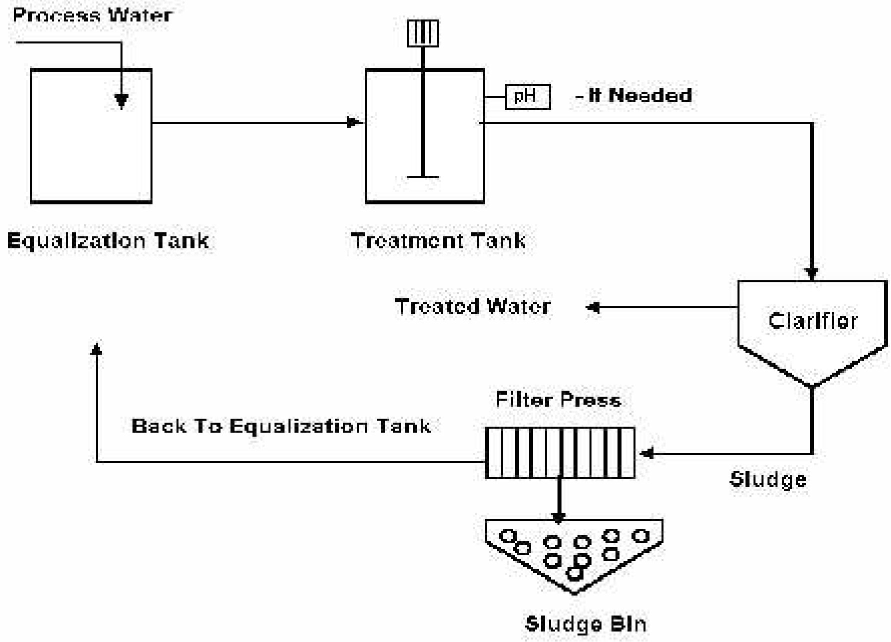

Figure-2: Removal of heavy metals from waste streams

Activated Sludge: An activated sludge wastewater treatment system has at least four components; an aeration tank, a settling tank (clarifier), a return sludge pump and a system of introducing oxygen into the aeration tank. Wastewater, sometimes pretreated and sometimes not, enters the aeration tank and is mixed with a suspension of microbes in the presence of oxygen. This mixture is referred to as "mixed liquor." The microbes metabolize the organic pollutants in the wastewater. After spending, on average, an amount of time equal to the hydraulic residence time in the aeration tank, the mixed liquor flows into the clarifier, where the solids (Mixed Liquor Suspended Solids-MLSS) separate from the bulk liquid by settling to the bottom. The clarified effluent then exits the system. The settled solids are harvested from the clarifier bottom and a fraction of the settled solids is recycled to the aeration tank whilst the remainder is discarded. The result is the ability to control the average time micro-organisms will remain in the reactor, called the sludge age (SRT) or mean cell retention time (MCRT). Those MLVSS (Mixed Liquor Volatile Suspended Solids) solids that are returned to the aeration tank are microbes in a starved condition, having been separated from untreated wastewater for an extended period and are thus referred to as "activated." This process of returning microbes from the clarifier to the aeration tank enables buildup of their concentrations to high levels (1,800 to 10,000 mg/L) and that, indeed, characterizes the activated sludge process itself [27].

The growth of the microorganisms in flocs is responsible for the metabolism and removal of organic matter from the liquid. Typical products of this metabolism are carbon dioxide (CO_2), nitrate (NO_3-), sulphate (SO_4^{2}) and phosphate (PO_4^{3-}). The nature of the floc is important as it determines the separation of sludge from the treated water and hence the efficiency of the overall process [28]. Although the presence of a certain number of filaments is important for proper floc formation, the occurrence of large filamentous bacterial populations is detrimental for sewage treatment as it causes foam formation or settling problems of the activated sludge in the secondary clarifiers [29].

In a conventional activated-sludge plant, a return of activated sludge at a rate equal to about 25% of the incoming wastewater flow is normal; however, plants operate with recirculation rates from 15 to 100%. The mixture of primary clarifier overflow and activated sludge is called "mixed liquor". The detention time is normally 6 to 8 h in the aeration tank. In a conventional plant, the oxygen demand is greatest near the influent end of the tank and decreases along the flow path. Plants built before the process was well understood provided uniform aeration throughout the tank. A conventional plant cannot accommodate variations in hydraulic and organic loadings effectively and the final clarifier must be sized to handle a heavy solids load. Usually aeration units are implemented in parallel so that a shutdown of one unit does not totally disrupt plant operation. Modifications such as step aeration, extended aeration, contact stabilization and oxidation ditches have evolved as the activated-sludge plant has become more widely used [30].

Trickling Filters: Trickling filters have been used to treat wastewater since the 1890s. The name is something of a misnomer since no filtration takes place. A very active biological growth forms on the rocks and these organisms obtain their food from the waste stream dripping through the rock bed [31].

Trickling filters are widely used for the treatment of domestic and industrial wastes. The process is a fixed film biological treatment method designed to remove BOD and suspended solids. A trickling filter consists of a rotating distribution arm that sprays and evenly distributes liquid wastewater over a circular bed of fist-sized rocks, other coarse materials, or synthetic media. The spaces between the media allow air to circulate easily so that aerobic conditions can be maintained. The spaces also allow wastewater to trickle down through, around and over the media. A layer of biological slime that absorbs and consumes the wastes trickling through the bed covers the media material. The organisms aerobically decompose the solids and produce more organisms and stable wastes that either become part of the slime or are discharged back into the wastewater flowing over the media. This slime consists mainly of bacteria, but it may also include algae, protozoa, worms, snails, fungi and insect larvae. The accumulating slime occasionally sloughs off (sloughings) individual media materials and is collected at the bottom of the filter, along with the treated wastewater and passed on to the secondary settling tank where it is removed [32].

The overall performance of the trickling filter is dependent on hydraulic and organic loading, temperature, and recirculation. The performance of a trickle bed reactor highly relies on the uniformity of liquid distribution throughout the bed. Liquid distribution critically affects mass and heat transfer efficiency and thus the overall reactor performance. In a catalytic reactor liquid mal-distribution caused non-uniform wetting of catalyst particles, which in turn reduced the contact between liquid and catalyst leading to an inefficient catalyst usage.

Good liquid distribution throughout the trickle bed filter is essential for the full utilization of the bed capacity. However, because of liquid mal-distribution a portion of the packing in the bed remains dry. Non-wetted zones in the bed are not colonized by the micro-organisms rendering a low efficiency of the trickle bed filter. In addition, good liquid distribution minimizes plugging and sloughing problem and liquid channeling [33].

Membrane Bioreactors: Membrane bioreactor technologies are, as the name suggests, those technologies that provide biological treatment with membrane separation. The term is more appropriately applied to processes in which there is a coupling of these two elements, rather than the sequential application of membrane separation downstream of classical biotreatment. Conventional treatment of municpal wastewater (sewage) usually proceeds through a three stage process: sedimentation of gross solids in the feed water followed by aerobic degradation of the organic matter and then a second sedimentation process to remove the biomass. An MBR can displace the 2 physical separation processes by filtering the biomass through a membrane. As a result the product water quality is significantly higher than that generated by conventional treatment, obviating the need for a further tertiary disinfection process [34]. The 2 most common configurations for membrane bioreactors are submerged membranes and external membranes [35, 36]. Submerged type MBRs are preferred more than the external types.

Membrane bioreactors (MBRs) are becoming increasingly popular due to their various advantages in waste- water treatment, e.g., flexibility of operation, ability to attain higher sludge age and consequently, less sludge production and higher nitrification and denitrification rates [37]. Some disadvantages of this system include frequent membrane monitoring and maintenance requirements, relatively high running costs and there is a limitation as to the pressures, temperatures and pH to which the system can be exposed [38].

Besides wastewater treatment, membrane bioreactors are used for the production of amino acids, antibiotics, anti-inflammatories, anticancer drugs, vitamins, optically pure enantiomers and isomers, etc [39]. Many research studies concerning several membrane bioreactor configurations were made to improve and optimize this process for different purposes [40, 41, 42, 43, 44, 45].

Pathological waste: Pathological waste could be considered a subcategory of infectious waste, but is often classified separately – especially when special methods of handling, treatment and disposal are used. Pathological waste consists of tissues, organs, body parts, blood, body fluids and other waste from surgery and autopsies on patients with infectious diseases. It also includes human fetuses and infected animal carcasses. Recognizable human or animal body parts are sometimes called anatomical waste. Pathological waste may include healthy body parts that have been removed during a medical procedure or produced during medical research.

Pharmaceutical Waste, Including Genotoxic Waste: Pharmaceutical waste includes expired, unused, spilt and contaminated pharmaceutical products, prescribed and proprietary drugs, vaccines and sera that are no longer required, and, due to their chemical or biological nature, need to be disposed of carefully. The category also includes discarded items heavily contaminated during the handling of pharmaceuticals, such as bottles, vials and boxes containing pharmaceutical residues, gloves, masks and connecting tubing.

Genotoxic waste is highly hazardous and may have mutagenic (capable of inducing a genetic mutation), teratogenic (capable of causing defects in an embryo or fetus) or carcinogenic (cancer-causing) properties. The disposal of genotoxic waste raises serious safety problems, both inside hospitals and after disposal, and should be given special attention. Genotoxic waste may include certain cytostatic drugs (see below), vomit, urine or faeces from patients treated with cytostatic drugs, chemicals and radioactive material.

Technically, genotoxic means toxic to the deoxyribonucleic acid (DNA); cytotoxic means toxic to the cell; cytostatic means suppressing the growth and multiplication of the cell; antineoplastic means inhibiting the development of abnormal tissue growth; and chemotherapeutic means the use of chemicals for treatment, including cancer therapy. Cytotoxic (chemotherapeutic or antineoplastic) drugs, the principal substances in this category, have the ability to kill or stop the growth of certain living cells and are used in chemotherapy of cancer. They play an important role in the therapy of various neoplastic conditions, but are also finding wider application as immunosuppressive agents in organ transplantation and in treating various diseases with an immunological basis.

Cytotoxic drugs are most often used in specialized departments, such as oncology and radiotherapy units, whose main role is cancer treatment. Their use in other hospital departments and outside the hospital in clinics and elsewhere is also increasing. Cytostatic drugs can be categorized as follows:

- Alkylating agents: cause alkylation of DNA nucleotides, which leads to cross-linking and miscoding of the genetic stock;
- Antimetabolites: inhibit the biosynthesis of nucleic acids in the cell;
- Mitotic inhibitors: prevent cell replication.

Cytotoxic wastes are generated from several sources and can include the following:

- Contaminated materials from drug preparation and administration, such as syringes, needles, gauzes, vials, packaging;
- Outdated drugs, excess (leftover) solutions, drugs returned from the wards;
- Urine, faeces and vomit from patients, which may contain potentially hazardous amounts of the administered cytostatic drugs or of their metabolites, and which should be considered genotoxic for at least 48 hours and sometimes up to 1 week after drug administration.

In specialized oncological hospitals, genotoxic waste (containing cytostatic or radioactive substances) may constitute as much as 1% of the total health-care wastes.

Chemical Waste: Chemical waste consists of discarded solid, liquid and gaseous chemicals; for example, from diagnostic and experimental work and from cleaning and disinfecting procedures. Chemical waste from health care is considered to be hazardous if it has at least one of the following properties. More details on the nature of these risks:

- Toxic (harmful)
- Corrosive (e.g. acids of pH <2 and bases of pH >12)
- Flammable
- Reactive (explosive, water reactive, shock sensitive)
- Oxidizing.

Non-hazardous chemical waste consists of chemicals with none of the above properties; for example, sugars, amino acids and certain organic and inorganic salts, which are widely used in transfusion liquids. The most common types of hazardous chemicals used in health-care centres and hospitals, and the most likely to be found in waste, are described in the following paragraphs.

Formaldehyde is a significant source of chemical waste in hospitals. It is used to clean and disinfect equipment (e.g. haemodialysis or surgical equipment); to preserve specimens; to disinfect liquid infectious waste; and in pathology, autopsy, dialysis, embalming and nursing units.

Photographic fixing and developing solutions are used in X-ray departments where photographic film continues to be used. The fixer usually contains 5–10% hydroquinone, 15% potassium hydroxide and less than 1% silver. The developer contains approximately 45% glutaraldehyde. Acetic acid is used in both “stop” baths and fixer solutions. Wastes containing solvents are generated in various departments of a hospital, including pathology and histology laboratories and engineering departments. Solvents include halogenated and non-halogenated compounds. Waste organic chemicals generated in health-care facilities include disinfecting and cleaning solutions, vacuum-pump and engine oils, insecticides and rodenticides. Waste inorganic chemicals consist mainly of acids and alkalis, oxidants and reducing agents.

Wastes from materials with high heavy-metal contents represent a subcategory of hazardous chemical waste and are usually highly toxic. Mercury is an example of a highly toxic yet common substance in health-care facilities. Mercury wastes are typically generated by spillage from broken clinical equipment, but their volume is decreasing in many countries with the substitution of mercury-free instruments (e.g. digital thermometers, aneroid blood-pressure gauges). Whenever possible, spilt drops of mercury should be recovered. Residues from dentistry also have high mercury contents. Cadmium waste comes mainly from discarded batteries. Reinforced wood panels containing lead are still used in radiation proofing in X-ray and diagnostic departments.

Many types of gas are used in health care and are often stored in portable pressurized cylinders, cartridges and aerosol cans. Many of these are reusable, once empty or of no further use (although they may still contain residues). However, certain types – notably aerosol cans – are single-use containers that require disposal. Whether inert or potentially harmful, gases in pressurized containers should always be handled with care; containers may explode if incinerated or accidentally punctured

Slaughterhouses: At slaughterhouses usually, everything produced by or from the animal, except dressed meat, is considered as by-product. These by-products are either 'edible' or 'inedible'. The variety of by-products is enormous, as can be seen in the diagram in figure 5 which shows a few of the by-products of the meat industry. Offer an extensive introduction to the use of by-products [46]. There is a large number of publications on the use of animal by-products [47-54].

In many countries, all the waste that is unsuitable for human consumption is processed by rendering companies as animal feed, glue etc. In large slaughterhouses, screening devices through which waste water has to flow prior to being treated, remove large solids such as hair, paunch manure, pieces of viscera and meat, dirt, and other materials. Some of these solids have an economic value and are rendered so as to produce a salable product. Materials of little economic value may be dumped at a landfill, spread out on the land or treated together with the solids from biological treatment processes. It is claimed [55] that in the animal processing industry about 1% of protein is lost to the sewer and that it is of economic importance to recover as much of this protein as possible. If half of the protein were recovered this would be worth about $400 million (1987 dollars).

In developing countries, some or all of these products are dumped as solid waste without any further processing or composting, or they are washed away. This causes pollution in the form of bad smell and potential water pollution, leading to health hazards. If solid waste is dumped, the possibility of using this waste is lost. Solid waste can also be handled by using the waste as fertilizer after composting. During the process of composting considerable quantities of nitrogen are lost in the form of ammonia. According to Kumar (undated), slaughterhouse wastes are ideally suited for fermentation. An important advantage of handling animal waste by fermentation is the low loss of nitrogen if the liquid is handled properly. Kumar (undated) investigated a number of other important avenues (Kumar, undated). Of the produced sludge, the dark solid portion which settles at the bottom (about 10%), was found to be rich in protein, fat fibre and also vitamin B12. It was free from parasites and probably free of salmonella as well. Such part of the slurry can be utilized as feed material or manure.

The remaining part of the sludge, the liquid component, can be used as irrigation water, or for fish and algae cultures. If not used in time a major part of the nitrogen from the liquid will be lost as a result of volatilization

Destination solid waste	Utilization of nitrogen
a: Dumped	100% lost of nitrogen
b: Composting -> fertilizer	Large quantity of nitrogen lost
c: Anaerobic treatment:	
1: solid part -> animal feed	Small nitrogen losses
2: liquid part:	Small nitrogen losses possible if diluted quickly with water
a: irrigation water	
b: fish culture	
c: algae culture	

Sludge: In western countries the larger part of solid waste out of the slaughterhouses consists of sludge from the wastewater treatment plants. In the Netherlands sludge, including the sludge of the slaughterhouses and meat processing industries, may probable no longer be used as fertilizer in the future because of Dutch environmental rules, which however are still heavily debated. One argument is that this kind of sludge is being discriminated as a fertilizer only because in the Netherlands a surplus of organic fertilizers exists.

The environmental rules may lead to (financial) problems because the sludge has to be considered as waste to be disposed of which has the consequence that after obligatory dewatering, it must be brought to a dumping-ground. In principle there are no objections against using the sludge from slaughterhouses as fertilizer, provided it does not contain toxic compounds.

Treatment of Wastewater

Main Wastewater Problems: The problems of the wastewater from the slaughterhouses, tanneries and dairies result from the discharge of:

- Large amounts of BOD (slaughterhouses, tanneries and dairies). BOD-problems can be handled, as already mentioned, by biological wastewater treatment.
- High values of N_{Kj} (slaughterhouses). N_{Kj} can be lowered by oxidation of organic compounds (proteins) followed by nitrification: conversion of ammonium (NH_4^{+}) into nitrate (NO_3^-). To reduce the eutrophication potential of the wastewater,

nitrate must be removed. This can be achieved by denitrification: conversion of nitrate (NO_3^-) into nitrogen (N_2).

- Chromium (tanneries). Chromium can be handled by precipitation reactions, these are simple processes.

There are basically two types of biological wastewater treatment systems: aerobic and anaerobic systems. In Tables 21 and 22 the characteristics and the (dis)advantages of these systems are mentioned.

	Aerobic	Anaerobic
Applicability	low strength:	low, medium and high strength:
(BOD, mg/l)	(100 - 2000 mg/l)	(250 - > 100.000 mg/l)
BOD-removal:	93-99%	90%
NH_3-conversion:	95%	low
NO_3-removal:	90%*	high

**: depends on BOD-load.*

In view of the high BOD-load in the wastewater of tanneries, dairies and slaughterhouses, anaerobic systems seem to be appropriate wastewater purification systems. Simple anaerobic systems may achieve 50% of BOD-purification, while high-rate anaerobic systems may result in 90% of BOD-purification. Anaerobic systems do not remove such nutrients as ammonium-nitrogen. If liquid and slurry are used as fertilizer this does not need to pose specific problems. Nutrient removal systems should be applied only if water authorities set limits for the discharge of nutrients. As in most countries this is not the case, there are no reasons for industry to make high investment costs for tertiary treatment.

	Advantage	Disadvantage
Anaerobic	• Possible production of energy • Low need for land • Power failure or shutdown will not affect the system • No energy consumption • Low production of excess sludge	• Optimal process temperature is about 30°C • Post-treatment for BOD-removal is often required
Aerobic	• Low process temperature • End treatment of waste-water	• Energy need for aeration • High need for land • Power failure or shutdown will affect the entire system • Post-treatment for further nutrient removal is often required • High production of excess sludge

Source: Hulshoff Pol, 1993.

General: The process that may be used for the treatment of wastewater produced by the industries mentioned in this report do not differ very much from each other. In general, these systems are applied to a large extent in developed countries. In developing countries adoption rates are much lower. Especially for these latter countries, treatment methodologies and technologies should be cheap, efficient and easy to operate. Important differences of wastewater treatment in the different industries will be mentioned.

For large dairies in many developing countries, treatment of wastewater is not even considered as an option. Because in developing countries the amount of milk processed industrially is minor, wastewater problems will mainly occur at the plant site and the surrounding surface waters. This implies that dairy wastewater problems in these countries are very local in contrast to those in developed countries. The dairy wastewater problem is larger in developed countries because all milk is processed industrially. For dairies in these countries it is very important that proper wastewater treatment system are installed.

Usually wastewater produced during the day has a variable composition. For the optimal performance of most treatment system it is necessary that the load is rather constant and that the plant is fed with a rather constant wastewater flow. Wastewater is therefore collected in equalization or balance tanks. Most treatment plants follow the following steps.

Preliminary Treatment: This type of treatment includes screening, skimming and settling which can lead to the recovery of by-products, grease and fat and removal of coarse solids. For an optimal performance and to avoid overload of the screening devices, it is important that large amounts of produced solids such as (hog) hair, feathers etc. are collected during the processing itself as discussed in part 2. For developing countries, the salt laden tannery effluent from the soaking process can be collected in solar evaporations pans, possibly pretreated with coagulant, after which salt can be recovered. In case of chrome tanning effluents, the wastewater that contains chromium should not be allowed to become mixed with other types of wastewater: it must be collected separately. Depending on the quality of the composite effluents, neutralising chemicals like lime alum, ferric chloride etc. should be added for an effective precipitation of chromium and removal of suspended solids in the sedimentation process. From this material chrome can be recovered or dumped separately.

Primary Treatment: This involves separation of solids in a settling tank (primary clarifier), or by flotation. The settleable solids and up to 60% of the suspended solids corresponding to approximately 35% of the BOD, can be eliminated during the primary treatment. Subsequently the solids may be treated by anaerobic sludge digestion. This produces biogas and solids that are suitable for soil conditioning and fertilization. Primary treatment is a essential activity that needs to be undertaken for a proper application of various secondary treatment systems. In case of aerobic secondary treatment, a further function of this step is the reduction of electric energy required for aeration.

Secondary Treatment: This usually consists of biological treatments by means of high rate anaerobic treatment systems, anaerobic (lagoons) suitable for high organic loads, or aerobic (lagoons) suitable for low organic loads, activated sludge, oxidation ditch or a combination. Present research is mainly focused on low energy demand and low volume treatment systems and optimum process control. Usually, a combination of high rate anaerobic treatment and aerobic activated sludge is required to meet effluent quality demands. Removal efficiencies reached with these kinds of combination are up to 98-99%. Depending on the operational conditions, removal efficiencies for slaughterhouses range from 70 to more than 99% for BOD and grease and from 80 to more than 97% for Suspended Solids (SS). The process performance depends strongly on the amounts of SS that can be removed in the primary treatment phase.

Tertiary Treatment: This includes chemical-physical methods such as adsorption, stripping, coagulation, sedimentation, chlorination as well as biological methods like slow sand filtration and maturation ponds. This post-treatment serve to remove nutrients such as phosphorus, sulphide, suspended solids, remaining BOD as well as pathogens. Another method of wastewater treatment is that of irrigation on land. Before wastewater is applied on land, toxic compounds such as chromium, salt sulphide, etc. have to be removed. Small amounts of nitrate and phosphate however may serve as fertilizers. The BOD_5 value is usually not allowed to be higher than 300 mg/l.

At present, this kind of wastewater treatment is carried out mainly in developing countries. The method is cheap, rather easy to perform, does not require highly sophisticated techniques and can be apllied because of the usually low pollutional strength of the produced wastewater.

Economic Considerations: The costs of wastewater treatment are a factor of major importance for the selection the appropriate treatment system. Estimates should be made of the investment costs and the expected annual costs. The investment costs are largely determined by construction costs, the costs of land and the required degree of removal of pollutants. The annual costs will depend on the price of the energy and chemicals required for the operation of the plant, the discharge fees and the capital costs on investment. A problem for the estimation of the costs of treatment plants is that prices are rapidly changing. Cost estimates should therefore be referenced to an index. From a comparison of the costs of 6 treatment systems (stabilisation ponds; aerated ponds; high rate anaerobic treatment + ponds; high rate anaerobic treatment + trickling filters; activated sludge process; and oxidation ditch; [56]) it can be concluded that high rate anaerobic treatment + post treatment of the effluent offers a very economic and effective solution.

The relatively high initial costs are compensated for by the low costs of energy and maintenance, which results in low running costs and a limited need for land. Costs of a stabilisation pond, high-rate anaerobic treatment plant + post-treatment in a pond and an activated sludge process for the sewage treatment plant for a town of 50,000 inhabitants (producing ca 550 ton BOD and ca 135 ton N) given as a reference, are: resp. around $3,5.10^6$, 2.10^6 and 2.10^6 USD for investment costs and running cost resp. around 400,000, 300,000 and 430,000 USD on an annual basis. In this calculation it is assumed that electricity costs are 0.10 USD per kWh, sludge disposal costs 10 USD per 1000 kg and that the price of land is 25 USD per m^2. Lagoons will become more economical if land costs are below 10 to 20 USD/m^2. Wastewater from slaughterhouses, tanneries, and the dairy industry are more heavily loaded with pollutants than sewage. This will have the effect that anaerobic processes are more competitive than aerobic processes owing to the much lower energy costs of anaerobic treatment.

Give an overview of relative cost indices and ranking for various treatment systems. According to him, the selection of the treatment system has to be undertaken on the basis of economic costs, environmental considerations, and the technical complexity of the system [57]. Both the initial investment and the operating costs of the system must be taken into consideration. However, environmental and technical aspects cannot be quantified. Therefore subjective rankings must be used. Table 24 indicates that aerobic ponds is the least desirable method of concentrated wastewater treatment in places were productive land is to be used for construction of the ponds. Anaerobic lagoons are the least expensive and are used more often than any other treatment in the management of wastewater from feedlots. However, they are not recommended as a permanent solution.

Treatment Type	**Initial cost index**[b]	**Operating cost index**[b]	**Land area ndex**[b]	**Energy ranking**[c]	**Ecology ranking**[c]	**Index rank**[d]
1: Anaerobic lagoons[a]	1	1	20	1	6	1
2: Aerobic ponds	6	4	300	2	5	20
3: Aerated lagoons[a]	6	13	3	4	4	2
4: Oxidation ditches	8	16	9	3	3	
5: Physical/biological	25	40	10	5	2	6
6: Physical/biological/chemical	50	70	2	6	1	10

[a] Exclusive of land acquisition costs. It is assumed that land used in the construction of the treatment plant is owned by the feedlot.

[b] Index is the ratio of the treatment cost to that of the least cost treatment. Thus, the least cost treatment would have an index of 1. An index of 6 means 6 times more expensive than the least cost treatment in that category.

[c] Ranking is a judgement ranking of the six potential systems ranked in order of preference from 1 to 6. The ranking is not on the basis of cost, nor does a ranking of 6 means it is 6 times less diserable than that ranked 1 in the same category.

[d] Index/rank is a combination of cost rations and judgement rankings reflecting the author's preference based on technical, economic, and ecological feasibility of the system.

Treatment of Polluted Air: Prevention of waste production, as a method mentioned for solid waste and wastewater, is an even more important method for polluted air. Compared to solid waste and wastewater, awareness of air pollution has only recently developed. As a result data of produced polluted air are hardly available and methods for prevention or treatment have as yet not been developed on a wide scale. Research of methods for treatment of polluted air is in progress.

Available reports state that air pollution from red meat processing operations is minor, and that most problems usually involve odours from improper waste treatment. These had better be controlled by correction of deficiencies in the troublesome process than by attempts to treat the odorous air. Also for poultry plants is true that a good design and good operating practices may help prevent odours.

In the dairy industry much energy is required for all kinds of activities and in particular for cooling and heating (pasteurizing, sterilizing, vaporisation). Energy production may lead to excessive discharge of CO_2, NO_x and CO. Reduction of energy consumption leads to an decrease of the discharge of these gases.

Air pollution from tanneries and slaughterhouses may also be caused by such components as NH_3, SO_2, Volatile Organic Compounds (VOC), etc. These can in principle be removed by means of adsorption, absorption, chemical reactions, microbial conversion. These processes often require highly sophisticated technics and entail high costs.

Adsorption is a process in which gasses are adsorbed to solid material such as carbon. In the case of absorption a liquid is used. Usually these physical processes are combined with a chemical conversion process to fixate the polluting compound. Other chemical reactions involve oxidation at high or low temperatures, reduction with hydrogen or methane. Biodegradable compounds can be converted by micro-organisms, suspended in water or fixated on solid material such as compost.

Waste Production and its Consequences: In the three types of animal-product-processing industries (slaughtering, tanning and milk processing), wastewater problems appear to be the most severe ones. Processing activities inevitably produce wastewater, frequently in large quantities. This wastewater is polluted with biodegradable organic compounds, suspended solids, nutrients and toxic compounds (particularly chromium and tannins from tanneries). Via the reduction of dissolved oxygen this pollution directly or indirectly leads to a decreasing suitability of (surface) water for aquatic life, and drinking, swimming or other purposes.

Typical values of wastewater that have been reported are given. Huge variations do occur owing to differences of scale and in house-keeping and management practices of factories or plants. The quantity of water used for the various processes is a major determining factor, high levels of wateruse being related to high emission values.

	expressed per:	**BOD (kg)**	**SS (kg)**	**N_{Kj}-N (kg)**	**P (kg)**
Red meat slaughterhouses	ton LWK	5	5.6	0.68	0.05
Red meat packinghouses	ton LWK	11	9.6	0.84	0.33
Poultry slaughterhouses	ton LWK	6.8	3.5	n.a.	n.a.
Tanneries	ton raw hide	100	200	n.a.	n.a.
Dairies (consumption milk)	ton milk	4.2	0.5	<0.1	0.02

If the density of animal product processing is so low that the concentration of pollutants in the receiving water bodies remains low, the production of wastewater does not necessarily lead to environmental problems. However, when from the comparison of the values of Table 26 with the European target values for urban wastewater discharge (e.g. 25 mg BOD, 10-15 mg N and 1-2 mg P per litre), it becomes clear that, from a wastewater production point of view, that there is a trend towards increasing densities of product processing even at relatively small amounts of processed animal products.

The heavy metal Chromium, occurring in the waste of tanneries, has caused and will in all likelihood continue to cause, serious environmental problems. It is common practice that most of the chromium is released in wastewater. There are no indications of other heavy metals in the waste of the animal processing industry causing environmental problems.

Problems caused by air pollution and solid waste disposal are minor in comparison to those related to wastewater production. The main cause of air pollution is the use of fossil energy, with as major exception the volatile organic compounds in the leather industry.

Particularly in slaughterhouses solid waste disposal may lead to hygienic problems, but in principle these are relatively easy to solve. An exception is the leather waste that contains chromium. This waste must be dumped on special grounds.

For a proper discussion of the environmental impact of slaughtering, tanning, and dairy industry, the effects of related activities such as transportation, spoilage by the consumer, durability of the product etc. also have to be taken into account. These activities are especially important for the discussion concerning the advantages and disadvantages of the various production processes and the scale at which processing is undertaken.

Conclusions: The application of biotechnology on various fields such as industry, agriculture, waste treatment is very important in view of economic and environmental benefits. In this technology, processing of products is less expensive and product quality is enhanced. It is possible to evaluate various wastes around us by microbiological processes. Today, numerous microbiological waste processing projects can be conducted at high scale. For example, solid and liquid wastes containing high organic sub-stances are used for obtaining methane. Consequently, a new energy resource arises. In the treatment of industrial and municipal wastewaters, various microbiological methods such as activated sludge, trickling filters, oxidation ponds, membrane bioreactors are used successfully. One of the important points of waste processing is to think all direct and indirect expenses and to calculate profitability ratio. Wastes belonging to municipality and industries (liquid, solid and gaseous) that constitute environmental pollution and threaten public health must be treated.

While biotechnology holds great promise for developing countries, this promise cannot be realised unless capability is built into the supporting processes. Few developing countries have the R&D infrastructure to undertake biotechnology research as they lack trained scientific personnel and well-equipped laboratories. Even fewer have the industrial capability to develop and exploit research results. Adapting innovation and making structural changes pose unique challenges for the developing world. For example, public and private investment in agriculture and agricultural R&D is critical to adapting new biotech practices; but limitations in a country's political, social, and economic structures may challenge its ability to adopt and support increased agricultural biotechnology successfully.

The global importance of climate change, biotechnology increasingly is seen as providing solutions to address the impacts. In view of this importance, global funding to address climate change has increased drastically, and the Caribbean should take advantage of this opportunity to address regional climate change concerns. Agrobiotech potentially can provide new, high-yielding, disease-resistant and climate-adaptive crops to compensate for predicted decline in food production. Agriculture accounts for approximately 14% of GHG emissions, and annual GHG emissions from agriculture are set to increase in the future. As agricultural land can store and sequester carbon, farmers particularly in poor countries, should be involved in carbon sequestration to mitigate climate change impacts. Sustainable use of genetic diversity and carbon sequestration are among several options farmers can apply to mitigate GHG emissions in agriculture. Carbon markets that provide strong incentives for carbon funds in developed nations to purchase agriculture emission reductions from developing countries could provide investments for rural development and sustainable agriculture in developing countries [58].

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