CHAPTER 2

REVIEW OF LITERATURE

In this chapter, in order to develop a proper procedure to achieve the objectives of the study, a review of literature was undertaken on the quantity of Biomedical wastes (BMW) generated in various countries, characteristic study of lime, neem (Azadirachta indica) leaves extract and utilization of solar energy as disinfectant of biomedical wastes and the use of anaerobic digestion in decomposing process. Very few research articles are available on treatment techniques of hospital wastes. So treatment options and analysis details of various other wastes were collected and utilized for biomedical wastes treatment options and analysis procedures.

2.1 GENERAL

In the process of health care, waste generated is usually includes sharps, human tissues or body parts and other infectious materials (Baveja et al 2000). As a result of developing healthcare technology, the amount of hospital wastes being generated is increasing due to the use of more disposable products (Omrani 1998). The waste produced in the course of health-care activities carries a higher potential for infection and injury than any other type of waste. Environment and natural resources can be polluted, and consequently human beings, animals and plants can be impacted (Pruss et al 1999).
2.2 CHARACTERISTICS OF BIOMEDICAL WASTE

Biomedical waste is defined as any solid, fluid or liquid waste including container and any intermediate product, which is generated during diagnosis, treatment or immunization of human beings or animals or in research activities or in the production or testing of biological products [Biomedical Waste (Management and Handling) Rules 1998]. Hospital wastes include different kinds of wastes such as infectious, radioactive, chemical, heavy metals and regular municipal wastes (DoE 1998). Biomedical waste can be categorized based on the risk of causing injury and/or infection during handling and disposal. Wastes targeted for precautions during handling and disposal include sharps (needles or scalpel blades), pathological wastes (anatomical body parts, microbiology cultures and blood samples) and infectious wastes (items contaminated with body fluids and discharges such as dressing, catheters and I.V. lines). Other wastes generated in healthcare settings include radioactive wastes, mercury containing instruments and polyvinyl chloride (PVC) plastics. These are among the most environmentally sensitive by-products of healthcare (Remy 2001). WHO (1999, 2001, 2004) stated that 85% of hospital wastes are actually non-hazardous, around 10% are infectious and around 5% are non-infectious but hazardous wastes. In the USA, about 15% of hospital waste is regulated as infectious waste. In India this could range from 15% to 35% depending on the total amount of waste generated (Glenn and Garwal 1999).

2.3 IMPACT OF INFECTIOUS AGENTS ON HUMAN HEALTH AND ENVIRONMENT

Hospital wastes, because of their infectious nature, are one of the most dangerous causes of pollution (Sadeghi 2002). Hospital waste is potentially dangerous, since it may possess pathogenic agents. Some of the pathogenic organisms are dangerous, because they may be resistant to
treatment and possess high pathogenicity. Inadequate waste management will cause environmental pollution, unpleasant smell, growth and multiplication of insects, rodents and worms and may lead to the transmission of diseases like typhoid, cholera, hepatitis and AIDS through injuries from syringes and needles contaminated with human blood (Henry and Heinke 1996).

The inefficient handling of biomedical waste is more likely to cause problems such as blood borne pathogens to the groups at highest risk, namely; healthcare staff, scavengers, and municipal workers (from needle sticks for example, if the biomedical wastes are handled and disposed together with domestic wastes). There is particular concern about infection with human immunodeficiency virus (HIV) and hepatitis viruses B and C, for which there is strong evidence of transmission via healthcare waste (WHO 1999). Transporting of mixed hospital waste to the waste dumping sites causes soil and groundwater pollution, and consequently health hazards for live species (Shirazinejad, 1996). Hence, collection and disposal of waste in the proper manner is of great importance as it can decrease directly and indirectly health risks to people, and damage to flora, fauna, and the environment (Centers for Disease Control and Prevention 2001).

2.4 BIOMEDICAL WASTE MANAGEMENT STRATEGIES

The bio-medical waste (Management and Handling) rules 1198 apply to all persons who generate, collect, receive, store, transport, treat, dispose or handle bio-medical waste in any form. And also it gives guidelines about categories of biomedical waste, colour coding of containers, transportation and treatments such as Incineration, Autoclave and Microwave.

Handling, segregation, mutilation, disinfection, storage, transportation and final disposal are vital steps for safe and scientific management of biomedical waste in any establishment (Acharya and Singh
Meeta 2000). The most appropriate way of identifying the categories of biomedical waste is by sorting the waste into colour coded plastic bags or containers (Patil and Shekdar 2001).

Sahar Mohamed Soliman et al (2006) state that 60% of surgical, medical and laboratory departments store biomedical waste inside utility rooms, followed by 40% of intensive care units. Labour, operating rooms and dialysis units do not store biomedical waste in the department, but the waste is immediately transported to the general storage area of the hospital. The mean period of storage for biomedical wastes in the storage areas of the healthcare setting was 4.6 ± 8.1 days while the study was conducted in five hospitals and ten primary healthcare settings of Egypt. It was concluded that inadequate and inefficient segregation, collection and transportation of biomedical waste contribute to increased risk of exposure of staff, patients and the community to biomedical hazards.

Muhlich et al (2003) conducted a research project sponsored by the EC-LIFE programme to compare waste management in five different European hospitals. A comparison of the regulations governing current waste management revealed different strategies for defining infectious hospital waste. The differences in the infrastructure were examined and the consequences for waste segregation and disposal were discussed under economic and ecological aspects.

Mohammad Karamouz et al (2006) stated that disposal of about 1750 tons of solid wastes per day is the result of a rapid population growth in the province of Khuzestan in the south west of Iran. The framework of a master plan for managing hospital solid wastes in the province of Khuzestan, Iran was proposed considering different criteria for evaluating the pollution of hospital solid waste loads. The effectiveness of the management schemes is also evaluated. In order to rank the hospitals and determine the share of each
hospital in the total hospital solid waste pollution load, a multiple criteria decision making technique, namely analytical hierarchy process (AHP), is used. The results have shown that the hospitals located near the capital city of the province, Ahvaz, produce more than 43% of the total hospital solid waste pollution load of the province. The results have also shown the importance of improving management techniques rather than building new facilities. The proposed methodology is used to formulate a master plan for hospital solid waste management.

Tamplin et al (2004) reported that the re-use of syringes can cause the spread of infections such as HIV and hepatitis. This poses obvious health risks, both in terms of direct exposure and environmental contamination. This study of issues and options for the safe destruction and disposal of used injection materials was undertaken using document analysis and summarize approaches to the inter-related issues of syringe reuse and clinical waste disposal. The authors suggest that holistic approaches to syringe use and clinical waste disposal need to be utilized. The Health Care Without Harm publication Non-Incineration Medical Waste Treatment Technologies (August 2001) and the WHO draft Guidance for the Development of National Action Plans (2002) provide a sound framework for addressing issues of healthcare waste management and used injection materials disposal. This framework needs to be field tested in selected countries. The focus is on technology and procedures that may be adaptable to rural areas in developing countries.

Miyazaki and Une (2005) carried out the waste management practice in Japan. The first rule of infectious waste management was regulated in 1992 and revised criteria for infectious waste management were promulgated by the Ministry of Environment in 2004. Infectious waste materials are divided into three categories: the form of waste; the place of waste generation; the kind of infectious diseases. They summarized as
Infectious waste materials are to be collected and segregated from other wastes, and transported to incinerators where they are combusted by a special waste handling business with which a medical institution contracts. Disposal costs are, however, becoming expensive. Therefore, medical institutions should make every effort to reduce infectious waste generated in their facilities. The revised regulation is expected to encourage the reduction of infectious waste and to protect waste workers from being infected.

Blenkharn (2006) observed the arrangements for bulk clinical waste handling in 26 UK hospitals. Storage of waste carts in areas freely accessible to the public, and failure to lock individual carts was common. Many clinical waste carts and areas dedicated to their storage were in a poor state of repair. Substantial improvement is required in the management of clinical waste in hospitals in order (1) to eliminate the possibility of acquired infection through unauthorized, inappropriate access to clinical waste and to minimize adverse effects resulting from contact with waste pharmaceuticals; (2) to comply with the Duty of Care imposed by UK Health and Safety legislation; and (3) to satisfy concerns regarding the general standard of hospital hygiene.

Patil and Shekdar (2001) concluded that the health-care waste management is not only a technical problem, but is also strongly influenced by economic conditions. On its own, enactment of legislation will not make it more efficient. Sustainable solutions can be effected by involving local bodies engaged in waste management and making sure they follow the principles of effective management. Health-care waste should be subjected to disinfection and mutilation prior to reuse, recycling or disposal. Precautions have to be taken so that disposable items like needles, syringes, IV sets and other plastic items are not reused. Efforts have to be made for minimization of waste: an appropriate plan has to be evolved as per the prevailing conditions. Finally, adequate financial provision needs to be made.
Chandira boss and coworkers (2009) studied the character and quantity of BMW generation in Government General Hospital (GH) Puducherry. Unhygienic disposal of nonsegregated BMW in Puducherry poses a serious health hazard to the population and to scavengers. The current practices of handling, transportation, storage, and disposal of BMW generated at GH need to be strict. Of late, more and more patients from abroad are opting to undergo advanced medical treatment in India, because they can be carried out at a fraction of the cost in India. With this "medical tourism" expanding (Connell 2006, Lee 2007), hospitals need to manage their BMW properly, to minimize risks to the public and to the environment (Mudur 2004). After the BMW guidelines were explained, observations indicate that proper management of BMW has improved and that the segregation of BMW is much better than before (Agrawal and Singh 2005).

2.5 QUANTITY OF BIOMEDICAL WASTE GENERATION

India, a potential economic world leader is experiencing a steady economic growth leading to depletion of natural resources and poses a significant challenge to the country’s sustainable and ecological development. Indian cities generate an estimated 0.115 million metric tonnes of waste per day and 42 million metric tones annually (CPCB 2003). The per capita waste generation ranges between 0.2 and 0.6 kg per day in the Indian cities that is lower than that in developed countries. However, lifestyle changes due to economic growth and fast rates of urbanization have resulted in per capita waste generation increasing by about 1.3% per year. The Energy Resources Institute (TERI) has estimated that waste generation will exceed 260 million tones per year by the year 2047—more than five times the present level (CPCB 2003).

Tsakona et al (2007) examines the existing hospital waste strategy in Greece with a bed capacity of 400-600. Infectious waste production was
estimated by weighing the incinerated waste as 880kg/day. It was concluded that inappropriate segregation practices were the dominant problem, which led to increased quantities of generated infectious waste and hence higher costs for their disposal.

Mehrdad Askarian et al (2004) surveyed 15 hospitals in Iran. The results indicated that the waste generation rate is 4.45kg/bed/day, which includes 1830kg (71.44%) of domestic waste, 712kg (27.8%) of infectious waste and 19.6kg (0.76%) of sharps. Segregation of different types of waste is not carried out perfectly. Two (13.3%) of the hospitals uses containers without lids for transportation of wastes. Nine (60%) of the hospitals are equipped with an incinerator and six of them (40%) have operational problems with incinerators. They concluded that the hospitals under study aren’t providing any effective training courses about hospital waste management and the hazards associated with them. The training courses that are provided are either ineffective or unsuitable.

Jayanthi and her associates (2002) reported the quantity and quality of waste arising from different wards and units of Indian government hospital with a capacity of 360 beds. The quantity of waste arising from the hospital is about 285kg/day. 59% of total waste is general waste and rest 41% is biomedical waste. It was concluded that proper segregation at source is not practiced in the study area, which paved the way for increased medical waste stream due to mixing of general and mixed wastes at the collection points.

Gayathri Patil et al (2005) assessed the waste handling and treatment system of hospital bio-medical solid waste and its mandatory compliance with regulation of Bio-medical Waste (Management and Handling) Rules, 1998, under the Environment (Protection Act 1986), Ministry of Environment and Forestry, Govt. of India, at the chosen KLE Society’s J. N. Hospital and Medical Research Center, Belgaum, India to
estimate the amount of non-infectious and infectious waste generated in different wards/sections and reported as an average about 520 kg of non-infectious and 101 kg of infectious waste is generated per day (about 2.31 kg per day per bed, gross weight comprising both infectious and noninfectious waste).

Mohammad Reza Sabour et al (2007) developed a mathematical model to calculate the generation of (infectious) hospital wastes for any desired year. Utilizing the model, generated infectious hospital wastes has been estimated as 698,937 tonnes for 2008 (short-term) and 3,494,387 tonnes for 2028 (long-term period). If the real infectious wastes are collected separately, then the generated infectious wastes will be reduced by 15.1% of the above-mentioned amount (139,787 tonnes for 2008, and 698,877 tonnes for 2028). Results of physical analysis show the components of the hospital waste as 67.3% infectious, 8.8% medical, 1.8% biological and 22.1% common municipal wastes. An appropriate collection method requires training the staff at hospitals along with preparation of the required facilities.

Patil and Shekdar (2001) analyzed various issues like quantities and proportion of different constituents of wastes, handling, treatment and disposal methods in various health-care units (HCUs). The waste generation rate ranges between 0.5 and 2.0 kg bed\(^{-1}\) day\(^{-1}\). It is estimated that annually about 0.33 million tonnes of waste are generated in India. The solid waste from the hospitals consists of bandages, linen and other infectious waste (30–35%), plastics (7–10%), disposable syringes (0.3–0.5%), glass (3–5%) and other general wastes including food (40–45%). In general, the wastes are collected in a mixed form, transported and disposed along with municipal solid wastes.

Al-Zahrani et al (2000) assess the amount of healthcare risk waste generated by health establishments in Saudi Arabia. A healthcare waste management questionnaire was applied in 27 hospitals, and 16 primary health
centres and clinics. They stated that the mean hospital waste rate of generation was 1.13 ± 0.96 kg/bed/day. The mean primary healthcare centres and clinics healthcare risk waste rate of generation was 0.08 ± 0.08 kg/visitor/day. The estimated mean amount of all healthcare risk waste generated in the Kingdom of Saudi Arabia is 25,207 tons/year. A program is being established to formulate standards for healthcare waste management.

Mohee (2005) examined characteristics of solid and liquid wastes generated in healthcare institutions and to provide a framework for the safe management of these wastes. The project was carried at three major medical institutions, namely, the Jeetoo Hospital, SSRN Hospital and the Clinic Mauricienne. A waste audit carried out at these sites revealed that approximately 10% of solid wastes were hazardous in nature, consisting mainly of infectious, pathological and chemical wastes. The average amount of hazardous wastes per patient per day was found to be 0.072 kg at Jeetoo hospital, 0.091 kg at SSRN hospital and 0.179 kg at the clinic. The amount of hazardous wastes generated as a function of the number of occupied beds was found to follow a relationship of type $y=0.0006x-0.19$, where $y$ was the amount of hazardous wastes generated per bed per day and $x$ was the number of occupied beds. The waste quantifying process also revealed that at SSRN Hospital, 0.654 m$^3$ of water was being consumed per patient per day and the amount of wastewater produced was 500 m$^3$d$^{-1}$. Further analysis revealed that the wastewater was polluting with COD, BOD$_5$ total suspended solids (TSS) and coliform content well above permissible limits.

Chitnis et al (2005) reported that pathology, microbiology, blood bank and other diagnostic laboratories generate sizable amount of biomedical waste (BMW). The audit of the BMW is required for planning proper strategies. The audit in laboratory revealed 8 kgs anatomical waste, 600 kgs microbiology waste, 220 kgs waste sharps, 15 kgs soiled waste, 111 kgs solid
waste, 480 litres liquid waste along with 33,000 litres per month liquid waste generated from labware washing and laboratory cleaning and 162 litres of chemical waste per month. Needle sharps are collected in puncture proof containers and the needles autoclaved before sending to needle pit. The formalin containing tissues cannot be sent for incineration for the fear of toxic gas release and the guidelines by the biomedical waste rule makers need to be amended for the issue. The segregation of waste at source is the key step and reduction, reuse and recycling should be considered in proper perspectives.

Murat Ozbek and Dilek Sanin (2004) reviewed as dental wastes are regulated under medical waste control regulations in most countries. Even though the quantity of hazardous wastes in dental solid wastes is a small proportion, there is still cross infection risk and potential danger for environment associated with mismanaged wastes. They examined the composition of solid wastes coming from eight clinics of the dental school of a University hospital in Turkey. The composition of waste changes from one clinic to the other as expected. However, one can deduce from the data obtained that rubber gloves constitute close to the half of the total solid waste in almost all the clinics. Other major component is paper forming approximately 30% of the solid waste. In general, total waste coming from the clinics is related with the number of procedures conducted on patients at the clinics. Only a small fraction of the waste is hazardous indicating that at Hacettepe University School of Dentistry, hazardous waste collection rules are obeyed in most of the times.

Byeong-Kyu Lee et al (2004) investigated generation volume, sources, composition, treatment and disposal methods for RMWs obtained from three out of the five typical city hospitals in Massachusetts to obtain relevant data on medical waste. Also, this study compared the generation patterns and amounts of RMWs between the hospital and the medical school.
The yearly operational treatment and disposal costs of RMWs based on different treatment and disposal methods were analyzed for one hospital. Finally, study identifies Combine on-site incineration and microwave technologies are the most cost-effective option for the reduction of treatment and disposal costs of RMWs. By careful exclusion of non-RMW from RMW waste streams, hospitals can reduce the RMW volume that requires special treatment and reduce disposal costs.

2.6 BIOMEDICAL WASTE TREATMENT FACILITIES

The Common Biomedical wastes treatment facility (see rules 14, amended in June 2000), which cast the responsibilities on municipal bodies to collect biomedical wastes/treated biomedical wastes and also provide sites for setting up of incinerator. The owners of CBMWTFs are service providers, who are providing services to health care units for collection of BMWs for its final disposal to their site. The components of a common biomedical waste treatment and disposal facility (CBMWTFs) are autoclave, shredder, compactor, and incinerator for anatomical waste, secured landfill facility, laboratory and vehicles for transportation of wastes.

The Tamilnadu Pollution Control Board enforces the Biomedical Waste (Management and Handling) Rules, 1998 as amended in 2000. As part of this process, the Board has so far inventoried 317 Government hospitals and 1,835 private hospitals. The Board has issued directions to the Government and private hospitals to take time-bound action for identifying sites and setting up common facilities for management of biomedical wastes in coordination with the Indian Medical Association.

Mohandasundaram et al (2003) studied the status of Bio Medical Waste disposal in Urban Coimbatore. The total number of hospitals in the private sector in Coimbatore Urban area is 76. The efforts of PCB and the
IMA chapter at Coimbatore along with the Coimbatore corporation establishment have been delivering the benefits. In an order dated 21.5.2003 the TNPCB has authorized Tekno Therm Industries to operate a facility for collection, reception, storage, transport and disposal of Bio Medical Waste of 2.5 tonnes per day in the premises situated at R.S.No.183/1 of Orattukuppai village, Coimbatore Taluk, Coimbatore District.

Klangsin and Harding (1998) investigated medical waste practices used by hospitals in Oregon, Washington, and Idaho. The results implied that confusion around the definition of infectious waste may also have contributed to the finding that almost half of the hospitals are not segregating infectious waste from other medical waste. The most frequently used practice of treating and disposing of medical waste was the use of private haulers that transport medical waste to treatment facilities (61.5%). The next most frequently reported techniques were pouring into municipal sewage (46.6%), depositing in landfills (41.6%), and autoclaving (32.3%). Other methods adopted by hospitals included Electro-Thermal-Deactivation (ETD), hydropulping, microwaving, and grinding before pouring into the municipal sewer. Most hospitals in Oregon and Washington no longer operate their incinerators due to more stringent regulations regarding air pollution emissions. Hospitals in Idaho, however, were still operating incinerators in the absence of state regulations specific to these types of facilities.

2.6.1 Incineration

10th International Congress (2008) focused on: the origin, characterization, and health impacts of combustion-generated fine and ultrafine particles; emissions of mercury and dioxins, and the development/application of novel analytical/diagnostic tools. The consensus of the discussion was that particle-associated organics, metals, and persistent free radicals (PFRs) produced by combustion sources are the likely source of the
observed health impacts of airborne PM rather than simple physical irritation of the particles. Ultrafine particles induced oxidative stress is a likely progenitor of the observed health impacts, but important biological and chemical details and possible catalytic cycles remain unresolved. Other key conclusions were: (1) In urban settings, 70% of airborne fine particles are a result of combustion emissions and 50% are due to primary emissions from combustion sources, (2) In addition to soot, combustion produces one, possibly two, classes of nanoparticles with mean diameters of ~10 nm and ~1 nm. (3) The most common metrics used to describe particle toxicity, viz. surface area, sulfate concentration, total carbon, and organic carbon, cannot fully explain observed health impacts, (4) Metals contained in combustion-generated ultrafine and fine particles mediate formation of toxic air pollutants such as PCDD/F and PFRs. (5) The combination of metal-containing nanoparticles, organic carbon compounds, and PFRs can lead to a cycle generating oxidative stress in exposed organisms.

Lee and Huffman (1996) viewed regulation regarding the disposal of hospital waste. The concern over AIDS and other communicable diseases coupled with right-to-know legislation has resulted in concern by all elements of hospital personnel; hospitals need to be re-evaluated relative to their waste collection and disposal practices. Based on the current technology assessment, environmentally-safe incineration of medical waste is achievable, if: 1. State-of-art incinerators are installed 2. Modern air pollution control equipment is used and 3. Incinerator operators are properly trained.

Satnam Singh and Vinit Prakash (2007) reviewed toxic releases from medical waste incineration comprising organic emissions such as polychlorinated dibenzo-dioxin/furan (PCDD/Fs) and polycyclic aromatic hydrocarbons (PAHs), inorganic emissions and ashes containing toxic metals.
Attempts made by various investigators to reduce/eliminate emissions have also been included.

Martin Pavlas and Michal Tous (2008) deals with the problem of efficient energy utilization in the field of thermal processing of waste (waste-to-energy). The waste combustion (incineration) processes are accompanied by release of large amount of energy, which shall be effectively utilized. In addition to the main purpose of incineration, i.e. treating the specified amount of waste, waste-to-energy systems are able to some extent substitute conventional energy production plants fired by fossil fuel and thus to contribute to solving global environmental problems. A mathematical model based on combination of basic auxiliary operations and simple thermodynamic models of heat engines has been created with the aid of a specific computational tool. Its conception is based on both requirements and experience coming from industry. The most serious problem of effectively running incineration plants consists in economical utilization of energy produced.

Olga Bridges et al (2000) conducted a comparison of the potential risks to human health from municipal solid waste (MSW) incineration and landfill on a generic basis. For this purpose a ‘worst case’ approach is adopted and a number of assumptions regarding the size and activities of each waste disposal method are made. The airborne pollutants measured for an incinerator are different from those for a landfill with or without gas collection. However, based on the available information it appears that as far as airborne pollution is concerned, landfill sites without gas collection pose a potentially higher generic risk to human health than MSW incinerators performing to Environmental Agency (UK) standards. This analysis cannot be used to replace specific evaluations for a particular incinerator or a landfill.
site because local conditions can have a very large impact on the magnitude of risks involved.

Hosny and El-Zarka (2007) performed a survey for medical waste disposal in order to examine the current status of medical waste disposal in some hospitals in Alexandria and to properly assess management of hazardous waste. As Alexandria has about 3911 healthcare facilities providing medical services for people, a huge amount of medical waste are generated daily with about 208 tons generated per month. The results revealed that the most common problems associated with healthcare wastes are the absence of waste management, lack of awareness about their health hazards, insufficient financial and human resources for proper management, and poor control of waste disposal. The current situation of medical waste disposal in Alexandria is depending on incinerators. Some of these incinerators are not working anymore. Incinerations as a system is not accepted at the time being in most developed countries due to the risks associated with it and suitable substitution management system for medical waste disposal is now taking its place.

Kanemitsu et al (2005) performed basic experiments to confirm that bacillus spores are killed by incineration in a muffle furnace. Biological samples containing $10^6$ spores of Bacillus stearothermophilus were placed in stainless steel Petri dishes and then into hot furnaces. The furnace temperature and duration of incineration were 300 °C for 15 min, 300 °C for 30 min, 500 °C for 15 min, 500 °C for 30 min and 1100 °C for 3 min. We confirmed that all spores of B. stearothermophilus were killed at each of these settings. The effect of incineration seems to be equivalent to that of sterilization, based on the satisfactory sterilization assurance level of $10^{-6}$.

Alvim-Ferraz and Afonsot (2005) estimated that the amount of atmospheric pollutants emitted through the incineration of healthcare wastes
using emission factors according to the Portuguese legislation. One controlled-air incinerator without air pollution control devices was used in the research. The main objectives of the study were: (i) to estimate the emission factors for particulate matter, dioxins, heavy metals and gaseous pollutants, according to the type of waste incinerated; (ii) to evaluate the quality of atmospheric emissions; and (iii) to define a methodology for the management of atmospheric emissions, evaluating the influence of type of waste incinerated and of the segregation method used on the emitted amounts. It was concluded that: (i) when emission factors are not associated with the type of incinerated mixture, the utility of the emission factors is highly doubtful; (ii) without appropriate equipment to control atmospheric pollution, incineration emissions exceed legal limits, neglecting the protection of human health (the legal limit for pollutant concentrations could only be met for NOx, all other concentrations were higher than the maximum allowed: dioxins, 93–710 times; Hg, 1.3–226 times; CO, 11–24 times; SO2, 2–5 times; and HCl, 9–200 times); (iii) rigorous segregation methodologies must be used to minimize atmospheric emissions, and incinerate only those wastes that should be incinerated according to the law. A rigorous segregation program can result in a reduction of the amount of waste that should be incinerated by 80%. A reduction in the quantity of waste incinerated results in a reduction on the amounts of pollutants emitted: particulate matter, 98%; dioxins, 99.5%; As, Cd, Cr, Mn and Ni, respectively, 90%, 92%, 84%, 77% and 92%; Hg and Pb, practically eliminated; SO2 and NOx, 93%; and CO and HCl, more than 99%.

David Rogers and Alan Brent (2006) established a protocol for the first quantitative and qualitative evaluation of relatively low cost small-scale incinerators for use at rural primary healthcare clinics. The protocol comprised the first phase of four, which defined the comprehensive trials of three incineration units. The trials showed that all of the units could be used to render medical waste non-infectious, and to destroy syringes or render
needles unsuitable for reuse. Emission loads from the incinerators are higher than large-scale commercial incinerators, but a panel of experts considered the incinerators to be more acceptable compared to the other waste treatment and disposal options available in under-serviced rural areas. However, the incinerators must be used within a safe waste management programme that provides the necessary resources in the form of collection containers, maintenance support, acceptable energy sources, and understandable operational instructions for the incinerators, whilst minimising the exposure risks to emissions through the correct placement of the units in relation to the clinic and the surrounding communities.

Sukandar Sukandar et al (2006) present metals leachability of medical waste incinerator fly ash in Japan on the basis of particle size. Sequential extraction and Toxicity Characteristic Leaching Procedure (TCLP) analysis were carried out in order to quantify the leaching amount of metals in each categorized particle size. The results of sequential extraction showed an increase both exchangeable and carbonate associated chromium concentrations in the bigger particle size fractions. They concluded that Ba, Cd, Ni, Pb, and Zn in the medical waste incinerator fly ash showed high mobility and tended to bind to carbonate and exchangeable fractions with the exception of a range of particle size, 150-106 µm. Leachability of Cd, Cr, Cu, Hg, Ni, Sn, and Zn determined by TCLP method was not statistically different among the categorized particle size. Leachability of arsenic in particle size fraction of ≤38 mm tended to be higher than the other particle size fractions. Ba and Pb showed the highest leachability in the particle size fraction of 150-106 µm and 75-38 µm respectively.

2.6.2 Plasma Techniques

Mosse and Savchin (2006) analysis the composition and the degree of toxicity of medicobiological wastes with the use of the results of
investigations made in different countries. It has been shown that such wastes are highly hazardous to ecology and a universal technology of their management is needed. They developed and tested a plasma chamber incinerator for plasmo thermal treatment of medicobiological waste. To optimize the operating conditions of the facility and prevent chemical and thermal pollution of the environment, they constructed a model of thermal calculation of the plasma chamber incinerator.

Amouroux et al (2005) reported that the European Union is creating strict standards for air and water pollution and waste treatment and implementing aggressive regulations. Compliance with these regulations is impossible without the development of new depollution processes involving plasma or laser technology. Time is one of the major problems in monitoring pollutants with the use of the time-resolution laser-induced breakdown spectroscopy technique, which can perform online analysis without sampling with a high level sensitivity for all the species of the Periodic Table. Plasma-enhanced desorption from fly ashes or polluted soils associated with a mass spectrometer or an optical emission spectrometer allows the monitoring of volatile organic compounds (VOCs) and organochlorine species in a few seconds. The treatment of VOCs by the plasma techniques was presented in order to destroy or trap PAH molecules.

2.6.3 Non Incineration Technologies

EPA Part V (2002) gives the guidelines of Non-Incineration Technologies for treatment of Biomedical Waste (Procedures for Microbiological Testing) The purpose of this guideline is to ensure that non-incineration technologies such as Autoclave, Microwave are capable of sterilizing or adequately disinfecting biomedical waste. This is verified at the commissioning of the equipment at a new site, and further verified at regular intervals by testing the efficiency of the operating equipment. The verification
involves strict procedures and the test results are reviewed before suitable disposal of the treated biomedical waste may proceed.

### 2.6.3.1 Autoclave

Pimshtein and Zhukova (2003) assesses the possibility of the external heating of autoclaves based on results of calculations of the stress state of the monolithic and multilayer versions of these vessels. The variation of mechanical properties of the material as a function of temperature, temperature gradient, internal pressure, and tightness of fit of the layers in the multilayer wall are taken into account in the analyses. The following recommendations for the heating conditions of the autoclaves on the basis of the calculations performed:

1. The heating rate should not exceed 30°C h⁻¹
2. External heating is permissible for monolithic autoclaves. Here, the allowable temperature gradient (DT) is determined as a function of the internal pressure, and the temperature of the inner surface.
3. Operation of rolled-sheet autoclave 1-r with external heating and an average initial interlayer clearance of 0.03 mm is permitted under an internal working pressure of 70 MPa, an inner-surface wall temperature of 338°C, and a temperature gradient of no more than 32°C.
4. External heating of rolled-sheet autoclaves 2-r and 3-r with an average initial clearance of 0.03 mm is permitted only when they are being brought to operating conditions. External heating is prohibited for an internal pressure above 90 MPa.
Williams-linera and Ewel (1984) reported that steam sterilization of a Typic Dystrandept in Costa Rica resulted in a six-fold increase in extractable Mn, to levels often considered toxic. Seeds of eight species, comprised of six successional taxa and two cultivars (soybean, Glycine max and raddish, Raphanus sati-vus) were planted in the sterilized soil and in unsterilized soil after delays of 1, 8, 15, and 28 d. Germination and mortality were not different in the two soils, indicating that steam-sterilized soil can safely be used in seed traps. Six species (including both cultivars) grew better in unsterilized soil, but two of the native taxa (Phytolaeca rivinoides and Bocconia frutescens) grew significantly faster in sterilized soil.

Hee-Jong Lee et al (2000) developed a practical model for an industrial high-pressure poly-ethylene plant. The reactor considered in this work is the adiabatic slim type autoclave with four zones for free radical polymerization of ethylene. A fairly comprehensive but realistic model is described that has the ability to predict the temperature at each reaction zone as well as the effects of initiator flow changes. From the stability analysis they identified the range of operating conditions which can effectively be used to prevent decomposition phenomena (runaway reactions) and to maximize polymer conversion in LDPE autoclaves.

Sadykov (2006) discusses the results of studies of the autoclave technology for processing of zinc concentrates in Kazakhstan (Kazakhmys plant). The autoclave leaching is based on the interaction of components of a crushed concentrate with sulfuric acid and oxygen to give the corresponding sulfates and elementary sulfur. The good agreement between the data for zinc, copper, iron, lead, and sulfur in input and output materials in autoclave leaching indicates that the procedures used for sampling and analysis are reliable.
Guzeev and Dyachenko (2006) investigated that optimal parameters of zircon breakdown with ammonium fluoride and hydrofluoride in an autoclave under isochoric conditions were found. In the case of ammonium hydrofluoride, the 95% decomposition at 300°C is reached within 1.5 h, and a pressure of 45 atm is developed in the system. The overall scheme of the cycle of zircon breakdown with the regeneration of ammonium fluoride and production of zirconyl hydroxide was suggested.

Antoshchak and Gnyp (2000) described structural features of a set of equipment for corrosion-mechanical and electrochemical studies of materials in a high-temperature aqueous medium. The autoclave is used for studying cyclic and static cracking resistance of structural materials. The autoclave equipment, in contrast to the known one, allows one to clear the working electrode in the medium at high temperature under pressure and to investigate the electrochemical processes on the freshened surface. Under laboratory conditions, they designed autoclaves and procedures for performing corrosion-mechanical and electrochemical testing of materials at temperatures of up to 350°C and pressures of up to 18 MPa. Special attention is paid to the features of the methodical approach to the choice of the type of a design and to the implementation of electrochemical experiments.

2.6.3.2 Microwave

Edvard Mikhailovich Barkhudarov et al (2008) described the killing of bacteria on surfaces by two types of UV sources generated by microwave radiation. In both cases, UV radiation is produced by gasdischarge electrodeless lamps (Ar/Hg) excited by microwaves generated by a power supply from a standard domestic microwave oven. For UV lamp excitation, one of these sources makes use of a coaxial line with a truncated outer electrode that allows the excitation of gases and gaseous mixtures over a wide range of pressures at a comparatively low microwave power. In the second
source, UV lamps are placed inside a microwave oven. Ultraviolet generated by the two sources was used to destroy vegetative Escherichia coli bacteria dispersed in thin films and in droplets on surfaces. It was shown that bacterial cells dispersed in films on surfaces are killed more rapidly than cells present in droplets when using the lamps producing ozone and UV radiation. The UV sources described can effect rapid killing and constitute a cost-effective treatment of food and other surfaces, and, the destruction of airborne viruses and bacteria. The lamps can also be utilized for the rapid eradication of microorganisms in liquids.

Angela Gonzalez and Ramon Barnes (2002) used the Waste Extraction Test (WET) in California as a complement to the Toxicity Characteristic Leaching Procedure (TCLP). The WET protocol consists of shaking a sample with citrate buffer and determining the metal content in the solution produced. This procedure requires a 1-to-10 waste-to-liquid ratio and 48 h for extraction. Although the WET protocol proves to be very useful, it is a time-consuming step in the determination of leaching and mobility. Therefore, a microwave extraction procedure was optimized to emulate the relative extraction efficiency obtained by the WET protocol. Lead, arsenic, and copper concentrations were measured by inductively coupled plasma mass or atomic spectrometry (ICPMS or ICP-AES), following a strict quality assurance protocol. Results obtained with this new methodology were statistically comparable to those obtained by the WET protocol. This microwave extraction approach proved simple and fast, reducing sample treatment by almost 280%. A significant reduction also occurs in waste production, materials, labor, and chemical usage. Therefore, the microwave extraction procedure is recommended as a rapid and cost effective monitoring tool for waste samples when combined with or supplemented by the traditional WET protocol.
Wayne Nicholson (2003) reported that thermal inactivation kinetics with extrapolation were used to model the survival probabilities of spores of various Bacillus species over time periods of millions of years at the historical ambient temperatures (25–40°C) encountered within the 250 million-year-old Salado formation, from which the putative ancient spore-forming bacterium Salibacillus marismortui strain 2-9-3 was recovered. The model indicated extremely low-to-moderate survival probabilities for spores of mesophiles, but surprisingly high survival probabilities for thermophilic spores.

2.6.3.3 Hospital Liquid Waste Treatment

Daiane Bopp Fuenteferia (2010) evaluated the contribution of untreated hospital wastewater to the dissemination of resistant P. aeruginosa strains in aquatic environments, through the analysis of their antibiotic susceptibility profile and genetic similarity. Wastewater samples were collected from two hospitals located in Rio Grande do Sul, RS, Brazil. Superficial water samples were collected from water bodies that received this wastewater discharge. The antibiotic susceptibility profiles of the strains were determined using the disk-diffusion technique and their genotyping was done by amplification of the Enterobacterial Repetitive Intergenic Consensus sequences (ERIC-PCR). The antibiotic resistance was higher among the hospital wastewater strains and the multiresistant phenotype was also observed only among these strains. The ERIC-PCR profiles did not reveal any genetic similarity among the P. aeruginosa strains from the wastewater and superficial water samples. On the contrary, they showed that genetically distinct populations were established in these different environments and probably that some other contamination source could be contributing to the presence of resistant strains in these water bodies.
2.6.4 Disposal

Saurabh Gupta and Ram Boojh (2006) studied the biomedical waste management practices at Balrampur Hospital, a premier healthcare establishment in Lucknow, in North India. The study shows that infectious and non-infectious wastes are dumped together within the hospital premises, resulting in a mixing of the two, which are then disposed of with municipal waste at the dumping sites in the city. Lucknow Municipal Corporation generally collect it every 2 or 3 days. The hospital does not have any treatment facility for infectious waste. The laboratory waste materials, which are disposed of directly into the municipal sewer without proper disinfection of pathogens, ultimately reach the Gomti River. All disposable plastic items are segregated by the rag pickers from the hospital as well as municipal bins and dumps. The open dumping of the waste makes it freely accessible to rag pickers who become exposed to serious health hazards due to injuries from sharps, needles and other types of material used when giving injections.

Byeong-Kyu Lee (2002) analyzed the recycling potential of plastic wastes generated by health care facilities. Waste streams and recycling data from five typical city hospitals and medical centers and three animal hospitals in Massachusetts were obtained. The recycling potential of plastic wastes produced by general city hospital departments, such as cafeterias, operating rooms, laboratories, emergency rooms, ambulance service and facilities, and animal hospitals were evaluated. Facilities, laboratories, operating rooms, and cafeterias were identified as major sources of plastic wastes generated by hospitals. It was determined that the recycling potential of plastics generated in hospital cafeterias was much greater than that in other departments. This was mainly due to a very slight chance of contamination or infection and simplification of purchasing plastic components. Methods to increase the recycling of medical plastic wastes were discussed. This study suggests that a
classification at waste generating sources, depending upon infection chance and/or plastic component, could be a method for the improved recycling of plastic wastes in hospitals.

Ghaly et al (2007) investigated the suitability of a passive technology, consisting of filters composed of a mixture of limestone and sandstone rocks, for the treatment of landfill leachates containing 6.6 mg L\(^{-1}\) iron and 1.8 mg L\(^{-1}\) manganese. The limestone and the limestone/sandstone filters successfully removed iron from the prepared solutions. The filters removed on average a minimum of 97.60\% of the iron from solution on a daily basis. The removal of manganese from solution was not as efficient as iron removal. The filters removed between 22.22\% and 100\% of the manganese from solution. Neither the filter type nor the solution type affected the iron and manganese removal efficiencies. Although iron precipitate was evident during the 7 day experimental period, armoring did not affect the removal efficiency of the elements. The pH of the water samples did not exceed 7.7. Therefore, the wetland ecosystem should be able to adjust to water having a slightly higher pH without suffering adverse effects.

Lim (2004) reported that the generation of municipal solid waste incinerator fly ash (MSWIF) has been increasing significantly over the recent past, and its disposal is problematic and costly due to high concentration of leachable heavy metals present in the material. This study explored a potential stabilization of MSWIF by blending with a natural sorbent material with low permeability, clay, and assessed the potential release of heavy metals from the stabilized mixtures under various simulated subsurface environments. The leaching test results suggested that the natural clay could turn the MSWIF into non-hazardous material. All the MSWIF-clay mixtures demonstrated leaching behavior different from that of the original MSWIF. Conversely, the oxidizing and alkaline conditions were not critical to the stabilized MSWIF-clay
mixtures. Apparently, clay in the mixtures could function as an adsorptive microbarrier to retain the heavy metals within the MSWIF-clay matrices.

Rajandrea Sethi and Antonio Di Molfetta (2007) reported that heat generation inside municipal solid waste (MSW) landfills is due to aerobic and anaerobic exothermic reactions occurring inside the waste. The result of heat generation and transport inside sanitary landfill leads to a temperature field that varies from mesophylic range (optimum at 30-40 °C) to thermophylic range (optimum at 50-60 °C). Due to high temperatures at the bottom of the landfill, liner systems can be severely damaged. The increment in convective and conductive heat transport could lead to an increase of the temperature in the surrounding geological layers and in the underlying aquifer. They investigate the origin of a thermal anomaly in the aquifer underneath a municipal landfill in the North of Italy. Heat transport model has been exploited using the analogy between heat and mass transport in porous media. The model showed that the thermal anomaly is due to convective and conductive heat transport from the landfill to the aquifer.

Hailong Wang et al (2008) concluded that Conventional incineration systems for biosolids management generally consume more energy than they produce and cannot be regarded as a beneficial use of biosolids. However, biosolids are likely to become a source of renewable energy and produce ‘carbon credits’ under the increasingly popular low-carbon economy policy. A large proportion of biosolids are currently landfilled. Biosolids contain nutrients and energy that can be used beneficially. Significant efforts have been made recently to develop new technologies to manage biosolids and make useful products from them. As a result, monoincineration and cocombustion will remain popular options for biosolids management. These options also provide a complete package for
biosolids management when the residual ash is used to manufacture construction materials.

Mufide Banar et al (2006) evaluate extensively the characterization and identification of major pollutant parameters by paying attention to the organic chemical pollution for unregulated dumping site leachate in Eski, Sehir/Turkey. However, analysis results were generally decreased in winter season when each parameter and each sampling point are examined separately. According to correlation between every parameter, especially solid content and dissolved oxygen concentration of leachate is affecting to other parameters. Also, sodium and potassium are changing proportionally with same parameters (suspended solids, fixed solids, dissolved oxygen) and high correlation between chloride and heavy metal concentration is showing.

2.6.5 Recovery from Hospital Wastes

Muralidhar and Panda (2000) stated that human placenta is a rich source of many biological products. It is an economical source as it is easily available as a hospital waste. The products obtained from human placenta include enzymes, genetic material, cellular proteins and antibodies. Some classes of enzymes which are not available after parturition or which cannot be obtained from the human body can be obtained from placenta. This article reviews various placental products including their extraction and purification.

2.7 PRETREATMENT OF INFECTIOUS BIOMEDICAL WASTE

2.7.1 Lime Pretreatment

Wei-Hua Chu (2007) studied with thirty-five strains capable of secreting extracellular alkaline proteases were isolated from the soil and waste water near the milk processing plant, slaughterhouse. Strain APP1 with the highest-yield alkaline proteases was identified as Bacillus sp. The cultural
conditions were optimized for maximum enzyme production. When the initial pH of the medium was 9.0, the culture maintained maximum proteolytic activity for 2,560 U ml\(^{-1}\) at 50°C for 48 h under the optimized conditions containing (g\(^{-1}\)): soyabean meal, 15; wheat Xour, 30; K\(_2\)HPO\(_4\), 4; Na\(_2\)HPO\(_4\), 1; MgSO\(_4\)\(\cdot\)7H\(_2\)O, 0.1; Na\(_2\)CO\(_3\), 6. The alkaline protease showed extreme stability toward SDS and oxidizing agents, which retained its activity above 73 and 110% on treatment for 72 h with 5% SDS and 5% H\(_2\)O\(_2\), respectively.

Nils-Olof Nilvebrant et al (2003) evaluated the treatment of lignocellulose hydrolysates with alkali, usually in the form of overliming to pH 10.0, has been frequently employed as a detoxification method to improve fermentability. The results suggest that alkali treatment of hydrolysates can be performed at temperatures below 30°C at any pH between 9.0 and 12.0 without problems with sugar degradation or formation of inhibiting aliphatic acids. Treatment with Ca(OH)\(_2\) instead of NaOH resulted in more substantial degradation of sugars. In conclusion, the conditions used for detoxification with alkali should be carefully controlled to optimize the positive effects and minimize the degradation of fermentable sugars.

Thaddeus Graczyk et al (2007) quantitatively tested solid waste landfill leachate and sewage sludge samples for viable Enterocytozoon bieneusi, Encephalitozoon intestinalis, Encephalitozoon hellem, and Encephalitozoon cuniculi spores by the multiplexed fluorescence in situ hybridization (FISH) assay. Quicklime stabilization was 100% effective, whereas microwave energy disintegration was 100% ineffective against the spores of E. bieneusi and E. intestinalis. Top-soil stabilization treatment gradually reduced the load of both pathogens, consistent with the serial dilution of sewage sludge with the soil substrate. This study demonstrated that sewage sludge and landfill leachate contained high numbers of viable, human-virulent microsporidian spores, and that sonication and quicklime stabilization
were the most effective treatments for the sanitization of sewage sludge and solid waste landfill leachates.

Javier Alejandro González-Leija (2008) analyzed the effect of several alkali treatments on the yield, gel strength, rheology, and chemical characteristics (quality) of the agar obtained from Gracilariopsis lemaneiformis from the Gulf of California using different alkali concentrations, temperatures and treatment times. Since agar yields were not significantly different among temperatures and times, the optimal conditions to obtain best quality agar were those providing the highest gel strength. Treatment time played an important role in increasing gel strength. Maximum gel strength (Nikan, 954 g cm$^{-2}$) was obtained with 5% NaOH at 100°C after 90 min of treatment, though these conditions resulted in an agar yield reduction of 25.5% relative to native agar. This treatment proved to efficiently yield G. lemaneiformis agar that will meet the commercial quality requirements regarding gel strength, 3,6 anhydrogalactose and sulfate content, as well as rheology and hysteresis.

Jih-Gaw Lin et al (1997) studied that the performance of an anaerobic digestion fed with waste activated sludge (WAS) pretreated with NaOH was examined. The laboratory work was run in four 1-1 semi-continuous anaerobic digestion reactors. Reactor A was fed with untreated WAS at 1% total solids (TS). The other three reactors, B, C and D, were respectively fed with WAS (1% TS) pretreated with 20meq l$^{-1}$ NaOH, WAS (1% TS) pretreated with 40meq l$^{-1}$ NaOH, and WAS (2% TS) pretreated with 20 meq l$^{-1}$ NaOH. The performances of reactors B, C and D, were superior to that of reactor A.

Bjorn Alriksson et al (2006) reported that alkaline detoxification strongly improves the fermentability of diluteacid hydrolysates in the production of bioethanol from lignocellulose with Saccharomyces cerevisiae.
New experiments were performed with NH₄OH and NaOH to define optimal conditions for detoxification and make a comparison with Ca(OH)₂ treatment feasible. The optimization treatments were performed as factorial experiments with 3-h duration and varying pH and temperature. Optimal conditions were found roughly in an area around pH 9.0/60°C for NH₄OH treatment and in a narrow area stretching from pH 9.0/80°C to pH 12.0/30°C for NaOH treatment. By optimizing treatment with NH₄OH, NaOH, and Ca(OH)₂, it was possible to find conditions that resulted in a fermentability that was equal or better than that of a reference fermentation of a synthetic sugar solution without inhibitors, regardless of the type of alkali used. The considerable difference in the amount of precipitate generated after treatment with different types of alkali appears critical for industrial implementation.

Voronova et al (2003) analyzed structural transformations induced in flax cellulose by alkaline treatment. (1) The presence of concomitant compounds (lignin, hemicelluloses, etc.) in untreated linen cellulose has no significant effect on the structural transformation occurring in cellulose under the action of NaOH, contrary to, e.g., regenerated wood cellulose (sulfate pulping). (2) The extrema in the dependences of the parameters characterizing structural changes in cellulose under the action of NaOH (swelling, transformation of cellulose I into cellulose II, hydrogen bonding strength, and degree of polymerization) are found within the NaOH concentration range 2–3 M. It is suggested that, over this range, structural rearrangement in the Na⁺ hydration shell facilitates penetration of the alkali into the crystalline regions of the cellulose structure.

Krupa et al (2005) compares the effects of various surface modifications, ion implantation, alkaline treatment and anodic oxidation, upon the corrosion resistance and bioactivity of titanium. The chemical composition of the surface layers produced was determined by XPS, SIMS
and EDS coupled with SEM. However, the most satisfactory bioactivity was shown by the samples subjected to oxidation + hydrothermal treatment, whereas the highest corrosion resistance was exhibited by the samples subjected to alkaline treatment followed by heating at 700°C.

### 2.7.2 Neem (Azadirachta indica) Pretreatment

Cardet et al (1998) tested the comparative efficiency of neem (Azadirachta indica) kernel oil, groundnut oil and a synthetic insecticide, K-OthrineO, in protecting stocks of leguminous tree seeds against seed beetles under Sahelian conditions. This study concluded that it is possible to use neem oil to efficiently protect tree seed stocks at low cost.

Yasmin et al (2003) used extract neem leave seed to control root knot nematode meloidogyne javanica of sweet guard. The root knot disease is economic importance as the loss is increased because root knot nematode predisposes in plants by other pathogens. Chemical control of root knot is costly and hazardous to agro-systems and environment. Neem seed kernel extracts have been effectively used to control field crop pests. The effect of neem seed, bark and leaf on the incidence of root-knot was studied.

Srinivasa Rao and his associates (2007) investigates the potential use of neem (Azadirachta indica) sawdust treated with hydrochloric acid for the removal of copper (II) and nickel (II) ions from wastewater. The effects of different system variables, viz, adsorbent dosage, initial metal ion concentration, pH and contact time were studied. The results showed that as the amount of the adsorbent was increased, the percentage of metal ion removal increased accordingly. The adsorption of metal ions followed a first order rate equation. Both Freundlich and Langmuir adsorption models are suitable for describing the sorption of Cu (II) and Ni (II) on the two forms of sawdust. Furthermore, the natural organic matter (neem sawdust) is
characterized by FTIR spectra and surface area analysis. At optimal conditions the maximum adsorption capacity is found to be 48.3 and 286 mg/g for Cu (II) and 31.5 and 74.1 mg g\(^{-1}\) for Ni (II) in natural and acid treated forms, respectively.

Babu and Gupta (2008) prepared adsorbent from neem leaves and used for Cr(VI) removal from aqueous solutions. Neem leaves are activated by giving heat treatment and with the use of concentrated hydrochloric acid (36.5 wt %). The activated neem leaves are further treated with 100 mmol l\(^{-1}\) of copper solution. Batch adsorption studies demonstrate that the adsorbent prepared from neem leaves has a significant capacity for adsorption of Cr(VI) from aqueous solution. The adsorption process follows second order kinetics and the corresponding rate constant is found to be 0.00137 g mg\(^{-1}\) min\(^{-1}\).

Fathy Abdel-Ghaffar et al (2008) studied the efficacy of water-free neem seed extract shampoo Wash Away Louse, provided by Alpha-Biocare GmbH, Düsseldorf (Germany), was investigated against Sarcoptes scabiei infesting dogs in Egypt. Ten naturally infested dogs were collected from different areas in the Nile delta. The occurrence of lesions, hair loss, and skin inflammation were regarded as signs of infestation and proved by detection of adult parasites and their developmental stages in scrapings of infested lesions. Adequate amount of the provided shampoo was applied topically and spread on the infested areas daily for 14 successive days. Scraping examinations were used to follow up the healing process. At day 7 of application, four dogs were completely free of mites as was proven by the disappearance of adults and/or any developmental stages of mites. The remaining six dogs showed a clear decrease in mite counts. By the end of the treatment (after 14 d), only a small number of mites were found in two dogs, while eight dogs were completely cured as was proven by mite counts and disappearance of clinical
signs. No remarkable signs of side effects or adverse reactions were observed throughout the study.

Makshoof Athar et al (2007) conducted laboratory batch experiments with Azadirachata indicum indicated that this population had an excellent ability to bind lead (II) from its aqueous solution. The experiments carried out examined pH, biomass quantity, time of contact, and temperature dependency. Under optimum conditions, the removal of lead (II) was found to be around 95%. Column experiments were performed to examine the binding of lead (II) to silica-immobilized biomass under flow conditions. They concluded that the decrease in the pH suggested an ion-exchange mechanism for metal binding, i.e., exchange of biomass functional-group (carboxyl groups) protons with the metal ions present in the solution.

Allameh et al (2002) studied the relationship between the activities of 3 cytosolic enzymes with aflatoxin biosynthesis in Aspergillus parasiticus cultured under different conditions has been investigated in order to find out the role of each enzyme in aflatoxin biosynthesis. Basically the activity of isocitrate dehydrogenase (IDH) was higher in non-toxigenic strains as compared to its counterpart toxigenic fungi (p < 0.05). In contrast, the activities of fatty acid synthase (FAS) as well as glutathione S-transferase (GST) were higher (P < 0.05) in toxigenic strains than that of the non-toxigenic fungi. Aflatoxin production was inhibited in fungi grown in presence of various concentrations of neem leaf extract. No significant changes in FAS and IDH activities were observed when aflatoxin synthesis was under restraints by neem (Azadirachta indica) leaf extract. During a certain period of time of culture growth, when aflatoxin production reached to its maximum level, the activity of FAS was slightly induced in the toxigenic strains fed with a low concentration (1.56% v/v) of the neem leaf extract. At the time (96 h) when aflatoxin concentration reached to its maximum levels,
the activity of GST in the toxigenic fungi was significantly higher (i.e 7–11 folds) than that of non-toxigenic strains. The difference was highest in mycelial samples collected after 120 h. However unlike FAS and IDH, GST was readily inhibited (~67%) in mycelia fed with 1.56% v/v of the neem extract. The inhibition reached to maximum of 80% in samples exposed to 6.25–12.5% of the extract.

Mishra and coworkers (2007) studied the role of dead biomasses viz., mango (Mangifera indica) and neem (Azadirachta indica) bark samples are assessed in the removal behavior of, one of important fission fragments, Cs(I) from aqueous solutions employing a radiotracer technique. The batch type studies were carried out to obtain various physico-chemical data. It is to be noted that the increase in sorptive concentration (from $1.0 \times 10^{-8}$ to $1.0 \times 10^{-2}$ mol.dm$^{-3}$), temperature (from 298 to 328 K) and pH (2.6 to 10.3) apparently favor the uptake of Cs(I) by these two bark samples. The concentration dependence data obeyed Freundlich adsorption isotherm and the uptake follows first order rate law. Thermodynamic data evaluation and desorption experiments reveal the adsorption to be irreversible and endothermic in nature proceeding through ion-exchange and surface complexation for both dead biomasses. Both bark samples showed a fairly good radiation stability in respect of adsorption uptake of Cs(I) when irradiated with a 300 mCi (Ra–Be) neutron source having an integral neutron flux of ~3.85.106 n.cm$^{-2}$.s$^{-1}$ and associated with a nominal $\gamma$-dose of ~1.72 Gy.h$^{-1}$.

Ravi Asthana et al (2006) studied Pharmaceutically important c-linolenic acid (GLA) which was produced (4.1 mg g$^{-1}$ dry wt) by laboratory grown cyanobacterium Fischerella sp. colonizing Neem (Azadirachta indica) tree bark. GLA isolated from the test cyanobacterium was active against Staphylococcus aureus ATCC 25923, Escherichia coli ATCC 25992, Salmonella typhi (local strain), Pseudomonas aeruginosa ATCC 27853 and
Enterobacter aerogenes MTCC 2822. The overproduction of GLA was also monitored by altering phosphate and nitrate levels in the nutrient medium. A doubling in phosphate concentration (58 lM) increased GLA level up to 12% over that of control cells while half of this phosphate level reduced GLA synthesis by 8%. In contrast, elevated nitrate concentrations (5 and 10 mM) stimulated biomass yield but not GLA, as the levels approximated to the nitrate-lacking control. The antibacterial potential of GLA from Fischerella sp. grown at varying P or N levels was at variance as evidenced by the diameter of inhibition zones against S. aureus. This variation in inhibition zones reflected differing levels of GLA as ascertained quantitatively by HPLC.

Uday Bandyopadhyay et al (2004) reported that neem (Azadirachta indica) bark aqueous extract has potent antisecretory and antiulcer effects in animal models and has no significant adverse effect (Bandyopadhyay et al 2002). They investigated that whether Neem bark extract had similar antisecretory and antiulcer effects in human subjects. A group of patients suffering from acidrelated problems and gastroduodenal ulcers were orally treated with the aqueous extract of Neem bark. Some important blood parameters for organ toxicity such as sugar, urea, creatinine, serum glutamate oxaloacetate transaminase, serum glutamate pyruvate transaminase, albumin, globulin, hemoglobin levels and erythrocyte sedimentation rate remained close to the control values. The bark extract when taken at the dose of 30–60 mg twice daily for 10 weeks almost completely healed the duodenal ulcers monitored by barium meal X-ray or by endoscopy. One case of esophageal ulcer (gastrosophageal reflux disease) and one case of gastric ulcer also healed completely when treated at the dose of 30 mg twice daily for 6 weeks. The levels of various blood parameters for organ toxicity after Neem treatment at the doses mentioned above remained more or less close to the normal values suggesting no significant adverse effects. Neem bark extract
thus has therapeutic potential for controlling gastric hypersecretion and gastroesophageal and gastroduodenal ulcers.

### 2.7.3 Solar Disinfection

Chitnis et al (2003) assessed solar heating as an alternative technology for Incineration. They immersed infectious medical waste with heavy load of bacteria \((10^8 \text{ to } 10^9/g)\) in water in a box-type solar cooker, which was left in the sun for 6hr and the amount of viable bacteria was reduced by 7 log. The results indicated that solar heating to be a cheap method to disinfect infectious medical waste in less economically developed countries.

XU Ruifen et al(2007) selected Hepatitis B surface antigen (HBsAg) as reference to evaluate the photo destructive effect of a self-prepared nano-TiO\(_2\) on viruses in aqueous suspension through sandwich ELISA assay (an in vitro enzyme immunoassay) under different conditions, and more general experiments on RNA (ribonucleic acid) and casein were carried out. Results indicate that when dispersed in aqueous media, with enough concentration and contact time, the tested nano-TiO\(_2\) is destructive to HBsAg, RNA and casein and TiO\(_2\) is destructive at least to most viruses in water. Since TiO\(_2\) has the combined functions of pollutant degradation and microbial sterilization, the advantage of almost completely mineralizing organics, and is safe and nontoxic to human body, it can be used in water treatment, medical appliances disinfection and some other fields for multi-purpose at the same time.

Soulas et al (1997) carried out field experiments in a forest nursery during the summer of 1994 to examine the effect of soil solarization on ectomycorrhizal soil infectivity (ESI) and soil receptiveness to inoculation with Laccaria bicolor. Soil samples from solarized, steamed, fumigated and
untreated plots were periodically collected and assayed for ESI. Untreated soil exhibited high ESI. Solarization was as effective as steaming or fumigation in reducing ESI in the uppermost layer. Solarization with a double layer of polyethylene film and fumigation were the only treatments which reduced ESI deeper in the soil. During July, the temperature of covered beds reached 50°C at a soil depth of 5 cm. Ectomycorrhizal fungi were among the soil-borne fungi most sensitive to solar heating. Soil solarization provides an effective disinfection method for controlled mycorrhization in forest nurseries.

Yong-Suk Chai et al (2000) reported that chlorine has been widely used to disinfect drinking water clue to simple, cheap, and well-developed technology; however, toxic chlorine by-products are formed such as carcinogenic trihalomethanes (THMs). Furthermore, some pathogens such as viruses, certain bacteria Campylobacter, Yersina, Mycobacteria, or Legionella, and protozoans Cryptosporidium or Giardia lamblia cysts have been known to be resistant to chlorine disinfection [Regli, 1992; Pontius, 1990]. Disinfection capability using both TiO\textsubscript{2} and UV radiation was more than 27 times as that by using only the UV light. Optimal TiO\textsubscript{2} concentration and UV light intensity were 0.1 g TiO\textsubscript{2} l\textsuperscript{-1} and 50W m\textsuperscript{-2} with which 100% reduction time was just 2-3 min in a batch-type slurry reactor.

Irving Spiewak et al (1998) explored the use of concentrated sunlight combined with dissolved photocatalysts to improve water quality. Initial experiments with bromacil using organic-dye photosensitizers indicated that the reaction kinetics was enhanced by concentrated light. Other pesticides (EPTC, Tribufos, Atrazine and Lindane) were also tested in normal and concentrated sunlight. Organic dyes were effective in degrading some of these compounds but did not appear to be promising for complete mineralization. Reaction rates were approximately proportional to sunlight intensity. The photoefficiency of reaction was in a range high enough to
indicate that visible light, as well as UV, was participating in the photo-reactions. Preliminary disinfection tests have indicated that either organic dyes or iron compounds are effective. It was concluded that solar irradiation with either organic dyes or the iron-peroxide system are a promising, possibly low cost, means of improving water quality. This system was also shown to mineralize phenol.

Amit Vohra et al (2005) report that TiO2 photocatalysis with ultraviolet (UV-A) light has proven to be a highly effective process for complete inactivation of airborne microbes. They investigated the enhancement in the rate of destruction of bacterial spores on metal (aluminum) and fabric (polyester) substrates with metal (silver)-doped titanium dioxide and compares it to conventional photocatalysis (TiO2 P25/+UV-A) and UV-A photolysis. Bacillus cereus bacterial spores were used as an index to demonstrate the enhanced disinfection efficiency. The results indicate complete inactivation of B. cereus spores with the enhanced photocatalyst. The enhanced spore destruction rate may be attributed to the highly oxidizing radicals generated by the doped TiO2.

Claude Alabouvette et al (2006) reported as biological control practices need an integrative approach, and more knowledge than chemical control. The most common approach to biological control consists of selecting antagonistic microorganisms, studying their modes of action and developing a biological control product and also they reported solarisation or solar heating is a method that uses the sun’s energy to increase soil temperature and so reach levels at which many plant pathogens will be killed or sufficiently weakened, in order to obtain significant control of diseases. Solarisation does not destroy all soil microorganisms, but modifies the microbial balance in favour of beneficial microorganisms. Indeed, many papers report situations where the efficacy of soil solarisation is not only due
to a decrease in the pathogenic populations but also to an increase in the density and activity of populations of microorganisms antagonistic to pathogens. Several review papers describe both the technology of solar heating and the mechanisms involved in the control of pests, pathogens and weeds by soil solarisation (DeVay et al 1991, DeVay 1995, Katan 1996). Soil solarisation has a large spectrum of activity; it controls fungi, nematodes, bacteria, weeds, arthropod pests and some unidentified agents, and often results in increased yields when applied to monoculture soils where specific pathogens have not been identified. In this case, solarisation probably controls weak pathogens or deleterious microorganisms responsible for reducing soil productivity, a phenomenon sometimes described as ‘soil sickness’ (Bouhot, 1997).

Margarita Ros et al (2008) reported as the Adenosine triphosphate (ATP) content, dehydrogenase, phosphatase, urease, and β-glucosidase activity decreased after manure amendment plus solarization (biosolarization), but they recovered after cropping, reaching levels higher than or similar to those before the biosolarization. However, these biochemical parameters decreased and did not recover with time in the methyl bromide (MeBr) treatment. Potential negative soil effects were assayed by measuring, ecotoxicity (Vibrio fisheri luminescence), germination index, electrical conductivity, and heavy metals content. Biosolarization did not negatively affect these parameters, while MeBr application irreversibly decreased the germination index and ecotoxicity. Higher-quality pepper production (extra and first class) were observed with biosolarization but not with MeBr, but no differences were found for pepper yield. Biosolarization gave a Meloidogyne incognita (M. incognita) incidence similar to that of MeBr application.

Chun Yoon et al (2007) performed a pilot study of microorganism repair after UV disinfection for agricultural reuse of secondary-level effluent
in paddy rice fields in Korea. Effluent from the bio-filter of a 16-unit apartment was used in a flow-through type UV-disinfection system. In low-dose UV disinfection, microorganisms increased within 12 h by approximately 5 and 1% due to photoreactivation and dark repair, respectively. This increase was not significant at a high UV dose (16 mW s cm\(^{-2}\)). The repaired microorganisms were further inactivated, rather than reactivated, by solar irradiation, and numbers decreased to non-detectible levels after 4 h of exposure to solar irradiation. Based on UV disinfection and repair studies, a UV dose of 30 mWs cm\(^{-2}\) is recommended as sufficient to produce reclaimed water virtually free of pathogens and may be adequate for disinfection of secondary effluent for agricultural irrigation in paddy rice culture.

Ming Chang et al (2007) reported that sewage sludge is a cost-effective media for the production of Bacillus thuringiensis (Bt) based biopesticides. To enhance the entomotoxicity of the fermentation broth, pretreatments of sewage sludge by alkali and ultrasonic were applied for their study. Effects of alkaline and ultrasonic pretreatments on the soluble COD (SCOD) and total COD (TCOD) were evaluated by altering the alkali addition dose and the ultrasonic specific energy. Suitable pretreatment conditions were optimized with 5 g l\(^{-1}\) sodium hydroxide (NaOH) for alkaline treatment and 1.2\(\times\)10\(^5\) kJ kg\(^{-1}\) of total solid for ultrasonic treatment. Fermentations of raw and pretreated sludge for biopesticides were carried out in a bench scale fermentor. Results revealed that both pretreatments were effective for Bt growth and metabolism. Higher viable cells (VC) and viable spores (VS) counts, δ-endotoxin yields and entomotoxicity were achieved in the pretreated sludge. The enhancement was attributed to more available nutrients and better oxygen transfer. Moreover, ultrasonic pretreated sludge was superior to alkaline pretreated sludge for δ-endotoxin production and entomotoxicity owing to its higher soluble C/N ratio and finer particles.
Pikaev (2001) collected the data from the Sixth International Conference on Advanced Oxidation Technologies for Water and Air Remediation was held on June 26–30, 2000 in London (Ontario, Canada) and reported as on the application of electrodeless gasfilled lamps with microwave or high-frequency excitation, which generate radiation with wavelengths from 170 to 350 nm, to the decomposition of organic pollutants were given. It was noted that this radiation can be successfully used for the mineralization of the above substances with no addition of H$_2$O$_2$ or O$_3$. General problems of the degradation of polychlorinated organic compounds (using chlorinated acetic acids as an example) in aqueous solutions under exposure to vacuum UV radiation (\( \lambda < 190 \) nm) were considered. Both oxidation and reduction processes were discussed and found that the action of sunlight improves the efficiency of degradation of phenol and malic acid in aqueous solutions on ozonation.

Haruhiko Yokoi et al (2003) developed a bactericidal agent operating under visible light irradiation with a silica gel-supported dihydroxo(tetraphenylporphyrinato)antimony(V) complex (SbTPP/SiO$_2$). The SbTPP/SiO$_2$ particles irradiated by fluorescent light in a test tube induced remarkable bactericidal activity for Escherichia coli cells. The bactericidal activity of the SbTPP/SiO$_2$ was affected by both the concentration of the SbTPP/SiO$_2$ and the light intensity. Under irradiation by visible light, the SbTPP/SiO$_2$ photocatalyst showed much superior bactericidal activity to the commercially available TiO$_2$. Moreover, under irradiation by sunlight, bactericidal activity of the SbTPP/SiO$_2$ was observed, and the bactericidal effect of the SbTPP/SiO$_2$ particles was effective for continuous treatment on a column photoreactor under fluorescent-light irradiation.

Josefina Vergara Sánchez et al (2008) carried out a test on the degradation of water soluble corn oil wastes by Fenton reaction and also
under mildly basic media in the presence of oxidants, such as hydrogen peroxide and persulfate, assisted with solar light. The degradation efficiency was obtained by analysis of chemical oxygen demand, carbon dioxide and gas chromatography. Over 90% of both chemical oxygen demand abatement and carbon dioxide recovery was accomplished by Fenton reaction. The presence of oxidants during the photodegradation resulted in high chemical oxygen demand abatement of the oil waste with the disappearance of the majority of the initial fatty acids present in the oil waste before treatment.

Chiu-Jung Liao and Shu-Lung Kuo (2008) reported that photocatalytic inactivation is mainly aimed at bacteria in surface water. Kaolinite is made to become the photocatalyst that has the inactivating capability with Ag\(^+\), Zn\(^{2+}\), and Ti\(^{4+}\) ions. When the kaolinite catalyst is irradiated by a sodium lamp, it produces photocatalytic action to destroy bacteria. The photocatalytic inactivating result shows that kaolinite-Ti catalyst has 100% inactivation efficiency in 150 min, while the inactivation efficiency of kaolinite-Zn catalyst is more than 85% in 200 min. Photocatalytic inactivation of bacteria occurs because when kaolinite catalysts are irradiated by a sodium lamp, catalysts are excited to carry on photocatalytic reaction; irradiation of catalysts with photons of energy equal to or greater than its band-gap results in the promotion of electrons from the valence band to the conduction band of the catalyst particles.

Anne Vikkula et al (2006) treated Carboxymethyl cellulose (CMC, DS 0.58) in solutions of sodium hydroxide (0.001 –1 M) at 95 °C. The treated (1 –12 h) CMC samples were purified by dialysis and analyzed by UV spectroscopy and by UV resonance Raman spectroscopy (UVRRS) with excitation at 244 nm. A UV absorption maximum at 265 nm and a UVRR signal at 1650 cm\(^{-1}\) were indicative of formation of \(\alpha, \beta\)-conjugated aldehyde end groups in CMC through 5-elimination. Another strong UVRR band at
1610 cm\(^{-1}\) gave evidence on conversion of some of the \(\alpha, \beta\)-conjugated aldehyde end groups to alkali stable aromatic structures.

Jalal et al (2006) tested forty six bacterial strains were isolated from nine different sources in four treatment plants namely Indah Water Konsortium (IWK) sewage treatment plant, International Islamic University Malaysia (IIUM) treatment plant-1,-2 and –3 to evaluate the bioconversion process in terms of efficient biodegradation and bioseparation. The bacterial strains isolated were found to be 52.2\% (24 isolates) and 47.8\% (22 isolates) in the IWK and IIUM treatment plants respectively. The results showed that the higher microbial population (9-10\(^{10}\) cfu mL\(^{-1}\)) was observed in the secondary clarifier of IWK treatment plant. Only the gram-staining identification was done in the strains isolated from IWK treatment plant not to be determined from IIUM. Among the isolates from IWK, 10 isolates of gram-positive bacillus (GPB) and gram-positive cocci (GPC), 10 isolates of gram-negative bacillus (GNB) and rest were both or undetermined. Gram-negative cocci (GNC) were not found in the isolates from IWK.

Arnold et al (2009) conducted the study to determine if a surface material with antimicrobial properties combined with an effective disinfectant could achieve total clearance of bacterial contamination. Five species of bacteria common to soil and human handling were present: Bacillus amyloliquefaciens, Bacillus cereus/thuringiensis, Staphylococcus epidermidis, Staphylococcus hominis ssp. novobiosepticus, and Staphylococcus intermedius were tested for endogenous microflora. Scanning electron microscopy confirmed the levels of Salmonella Enteritidis before and after disinfectant treatment. Aerobic plate counts on PCA confirmed the number of colony-forming units per milliliter of culture in the test and original cultures for disinfectant screening.
K. Venkateswaran reported that an increasing number of in situ life detection and sample return missions to other planetary bodies where life may be present are envisioned. As enabling technologies for these robotic missions emerge, awareness of the need to control the microbial contamination aboard spacecraft is growing. Knowledge of the microbial diversity of spacecraft assembly areas, as well as any exceptional characteristics that contaminant microbes might possess, are critical to the development of useful cleaning and sterilization technologies. Utilization of various modern molecular methods including microscopy techniques is obligatory to measure the cleanliness of spacecraft associated components.

Farrell Melnick et al (2005) stated that the use of optical microscopy (OM) and SEM as viewing and enumeration tools provides a direct and precise measurement of the quantity and type of contamination including microbes. Although there are no specific standards for surface contamination in the pharmacy, the usefulness of the SEM lies in its ability to provide clear, high resolution images that can often differentiate between ordinary particulates and microbes.

Ridgway et al (1981) surveyed the microtopological features of the mineralized layer at high magnification in the scanning electron microscope revealed several areas where microcolonization by coccoid-shaped or filamentous microorganisms had apparently occurred.

Frank L Bowling et al (2009) tested with four porcine samples scored then infected with a broth culture containing a variety of organisms and incubated at 37°C for 24 hours. The infected samples were then debrided with the hydro surgery tool. Samples were taken for microbiology, histology and scanning electron microscopy pre-infection, post infection and post debridement.
2.8 ANAEROBIC DIGESTION PROCESS

Srihari and Ashutosh Das (2010) presented the importance of renewable energy resources under the present energy crisis and also they reported as Biogas is an excellent alternative energy from anaerobic digestion process, natural byproduct of organic waste decomposition, at the same time which renders the solid waste management too.

Van der Merwe and Britz (1993) treated a high-strength effluent from a baker's yeast factory using a hybrid and an anaerobic filter digester under mesophilic conditions. A COD removal efficiency and methane yield of 67% and 0.207 m$^3$ kg$^{-1}$ for the anaerobic filter and 65% and 0.208 m$^3$ kg$^{-1}$ for the hybrid respectively, achieved at an OLR of 8.6 kg COD m$^{-3}$ day$^{-1}$. Decreasing digester efficiency was characterized by accumulation of isobutyric and propionic acids.

Bouallagui et al (2005) reviewed the potential of anaerobic digestion for material recovery and energy production from fruit and vegetable wastes (FVW). The organic fraction includes about 75% easy biodegradable matter (sugars and hemicellulose), 9% cellulose and 5% lignin. Anaerobic digestion of FVW was studied under different operating conditions using different types of bioreactors. It permits the conversion of 70–95% of organic matter to methane. A major limitation of anaerobic digestion of FVW is a rapid acidification of these wastes decreasing the pH in the reactor, and a larger volatile fatty acids production (VFA), which stress and inhibit the activity of methanogenic bacteria. Continuous two-phase systems appear as more highly efficient technologies for anaerobic digestion of FVW. Their greatest advantage lies in the buffering of the organic loading rate taking place in the first stage, allowing a more constant feeding rate of the methanogenic second stage. Using a two-stage system involving a thermophilic liquefaction reactor and a mesophilic anaerobic filter, over 95%
volatile solids were converted to methane at a volumetric loading rate of 5.65 g VS/l d. The average methane production yield was about 420 l/kg added VS.

Salminen and Rintala (2002) reviews the potential of anaerobic digestion for material recovery and energy production from poultry slaughtering by-products and wastes by quantifying organic solid by-products, wastes produced in poultry farming, poultry slaughterhouses and discuss their recovery and disposal options. They reported certain fundamental aspects of anaerobic digestion, future potential and current experience of the anaerobic digestion treatment of these materials.

Osman Nuri Agdag and Delia Teresa Sponza (2007) studied the feasibility of the anaerobic co-digestion of a mixed industrial sludge with municipal solid wastes (MSW) was investigated in three simulated anaerobic landfilling bioreactors during a 150-day period. All of the reactors were operated with leachate recirculation. The performance and toxicity test results showed that toxicity was observed in reactors containing industrial mixed sludge and better performance results in MSW reactor compared to mixed industrial sludge MSW.

Salsabil (2010) compared aerobic and anaerobic digestions with different sludge reduction processes such as ultrasonic, ozone, and thermal treatments. Each treatment was tested under the conditions to improve batch aerobic or anaerobic digestion are ultrasound (200,000 kJ kg TS\(^{-1}\)), thermal (40 °C, 60 °C, 90 °C for 90 min, 120 °C 15 min, 1 bar), and ozonation (0.1 gO\(_3\)g TS\(^{-1}\)). The different pretreatments induced organic matter solubilisation and intrinsic sludge reduction (total suspended solids) are ultrasound (47%), thermal 90 °C (16%), ozone (15%), thermal 60 °C (9%), thermal 40 °C (5%), autoclave (120 °C) (4.2%). TSS (and also VSS)
solubilisation were found to be highly correlated to the pretreatment ability to break the flocs rather than to specific energy input. The total values of TSS reduction ranged from 57% to 71% under aerobic conditions and from 66% to 86% under anaerobic conditions. Ultrasonic and ozone pretreatments prior to aerobic or anaerobic digestion led to the best reduction. Anaerobic digestion was globally more effective (compare to aerobic digestion) in enhancing sludge production reduction.

Shu-guang (2007) investigated two dry anaerobic digestions of organic solid wastes were conducted for 6 weeks in a lab-scale batch experiment for the start-up performances under mesophilic and thermophilic conditions. The enzymatic activities i.e. β-glucosidase N-α-benzoyl-L-argininamide (BAA)-hydrolysing protease urease and phosphatase activities were analysed. The BAA-hydrolysing protease activity during the first 2–3 weeks was low with low pH but was enhanced later with the pH increase. β-Glucosidase activity showed the lowest values in weeks 1–2 and recovered with the increase of BAA-hydrolysing protease activity. Acetic acid dominated most of the total VFAs in thermophilic digestion while propionate and butyrate dominated in mesophilic digestion. Thermophilic digestion was confirmed more feasible for achieving better performance against misbalance especially during the start-up period in a dry anaerobic digestion process.

John Novak et al (2010) studied a unique sludge digestion system consisting of anaerobic digestion followed by aerobic digestion and then a recycle step where thickened sludge from the aerobic digester was recirculated back to the anaerobic unit to determine the impact on volatile solids (VS) reduction and nitrogen removal. It was found that the combined anaerobic/aerobic/anaerobic (ANA/AER/ANA) system provided 70% VS reduction compared to 50% for conventional mesophilic anaerobic digestion with a 20 day SRT and 62% for combined anaerobic/aerobic (ANA/AER)
digestion with a 15 day anaerobic and a 5 day aerobic SRT. Total Kjeldahl nitrogen (TKN) removal for the ANA/AER/ANA system was 70% for sludge wasted from the aerobic unit and 43.7% when wasted from the anaerobic unit. TKN removal was 64.5% for the ANA/AER system.

Gulbin Erden and Filibeli (2010) investigated the effects of Fenton process on anaerobic sludge bioprocessing. A ratio of 0.067 g Fe(II) per gram H$_2$O$_2$, and 60 g H$_2$O$_2$/kg dried solids (DS) was applied to biological sludge samples preceding anaerobic sludge digestion. Single stage anaerobic digestion under thermophilic conditions is compared with two-stage anaerobic digestion (mesophilic digestion prior to thermophilic digestion). The comparison is in terms of solid reductions and specific methane productions. Fenton processed sludge gives higher solid reduction and higher methane production for each experiment. Another observation is that, Fenton process led to decrease the biosolids resistance to dewatering in terms of capillary suction time (CST), but had no effect on sludge dewatering on belt-press application.

Masse et al (2008) investigated the feasibility of using psychrophilic anaerobic digestion in sequencing batch reactors (PADSBRs) to co-digest grinded swine carcasses and swine manure slurry at 20 °C and 25 °C and they concluded that the addition of swine carcass to PADSBR feed did not affect the stability of the bioreactors at both CLRs. The performance of the PADSBRs co-digesting swine carcasses was not statistically different from the control in terms of biogas production and quality. There was no accumulation of volatile fatty acids in the bioreactors at the end of the treatment cycle. The mixed-liquor pH and alkalinity remained within acceptable ranges for the anaerobic microflora. Also, there was no operational problem caused by the formation of foam and scum in the system.
Yebo Li et al (2010) reviewed the principles and applications of the SS-AD process. Solid-state anaerobic digestion (SS-AD) generally occurs at solid concentrations higher than 15%. In contrast, liquid anaerobic digestion (AD) handles feedstocks with solid concentrations between 0.5% and 15%. Animal manure, sewage sludge, and food waste are generally treated by liquid AD, while organic fractions of municipal solid waste (OFMSW) and lignocellulosic biomass such as crop residues and energy crops can be processed through SS-AD. Some advantages of SS-AD include smaller reactor capacity requirements, less energy used for heating, and no processing energy needed for stirring. Due to its lower water content, the digestate of SS-AD is much easier to handle than the effluent of liquid AD. The variation in biogas production yields of different feedstocks is discussed as well as the need for pretreatment of lignocellulosic biomass to enhance biogas production. The effects of major operational parameters are summarized. While an increase in operating temperature can improve both the biogas yield and the production efficiency, other practices such as using AD digestate or leachate as an inoculant or decreasing the solid content, may increase the biogas yield but have negative impact on production efficiency.

Hanna Choi (2006) developed an electric pulse-power reactor consisting of one coaxial electrode and multiple ring electrodes to solubilize waste activated sludge (WAS) prior to anaerobic digestion. By pretreatment of WAS, the soluble chemical oxygen demand (SCOD)/total chemical oxygen demand (TCOD) ratio and exocellular polymers (ECP) content of WAS increased 4.5 times and 6.5 times, respectively. SEM images clearly showed that pulse-power pretreatment of WAS was found to result in destruction of sludge cells. Batch anaerobic digestion of pulse-power treated sludge showed 2.5 times higher gas production than that of untreated sludge. Solubilized sludge cells by pulse-power pretreatment would be readily utilized for anaerobic microorganisms to produce anaerobically-digested gas. Slow or
lagged gas production in the initial anaerobic digestion stage of pulse-power pretreated sludge implied that the methane-forming stage of anaerobic digestion would be the rate-limiting step for anaerobic digestion of pulse-power pretreated sludge.

Jeongsik Kim et al (2003) studied enhance the efficiency of anaerobic digestion with waste activated sludge (WAS) by batch experiments. We studied the effects of various pretreatment methods (thermal, chemical, ultrasonic and thermochemical pretreatments) on the biogas production and pollutants reduction owing to solubilization enhancement, particle size reduction, increased soluble protein, and increased soluble COD. The thermochemical pretreatment gave the best results, i.e., the production of methane increased by more than 34.3% and soluble COD (SCOD) removal also increased by more than 67.8% over the control. In this case, the biogas production, methane production and the SCOD removal efficiency were about 50371 biogas m⁻³ WAS, 3367 l methane m⁻³ WAS and 61.4%, respectively. Therefore, it is recognized that higher digestion efficiencies of the WAS were obtained through thermochemical pretreatment of the sludge.

Jesus Rodriguez-Martinez et al (2002) investigated the kinetics of anaerobic treatment of slaughterhouse wastewater in batch and upflow anaerobic sludge blanket (UASB) reactors. Different concentrations of organic matter in slaughterhouse wastewater did not change the first order kinetics of the reaction. In batch digesters, methane and nitrogen production stopped after 30–40, 20–30 h, respectively, and in UASB reactors it was terminated after 30–40 days. The constant of velocity was 3.93 and 0.23 h⁻¹ respectively, for methane and nitrogen production. The yield coefficient, Yp was 343 and 349 ml CH₄ per g of chemical oxygen demand at standard temperature and pressure conditions for batch reactors and UASB reactor, respectively.
2.9 PROCESS KINETICS

2.9.1 Reaction Rates and Reaction Rate Coefficients

Metcalf and Eddy (1993, 1995, 2003) stated that for process selection and design, the controlling stoichiometry and the rate of the reaction are of the principal concern. The two principal types of reactions that occur in biological treatment are classified as homogeneous and heterogeneous.

In homogenous reactions, the reactants are distributed uniformly throughout the fluid so that the potential for reaction at any point within the fluid is the same. Homogeneous reactions are usually carried out in the batch, complete-mix, and plug flow reactors. Homogeneous reactions may be either irreversible or reversible.

The expression for irreversible reactions of batch reactor is

\[ A \rightarrow B \]  \hspace{1cm} (2.1)

\[ A + A \rightarrow C \]  \hspace{1cm} (2.2)

\[ aA + bB \rightarrow C \]  \hspace{1cm} (2.3)

Heterogeneous reactions occur between one or more constituents that can be identified with specific sites, such as those on an ion-exchange resin and solid-phase catalyst. Heterogeneous reactions are usually carried out in packed and fluidized-bed reactors.

The rate of reaction is the term used to describe the change in the number of moles of a reactive substance per unit volume per unit time (for homogenous reactions) or per unit surface or mass per unit time (for Heterogeneous reactions).
For homogeneous reaction, the rate of reaction ‘r’ is

\[ r = \frac{1}{V} \frac{d(N)}{dt} \]  \hspace{1cm} (2.4)

If ‘N’ is replaced by VC, where V is the volume and C is the concentration,

\[ r = \frac{1}{V} \frac{d(VC)}{dt} = \frac{1}{V} \frac{VdC + CdV}{dt} \]  \hspace{1cm} (2.5)

If volume remains constant, (i.e Isothermal conditions), \( r = \pm \frac{dC}{dt} \).

\[ \frac{dC}{dt} V = QC_0 - QC + r_c V \]  \hspace{1cm} (2.6)

In batch reactor, flow is neither entering nor leaving the reactor i.e. flow enters, is treated, and then is discharged, and the cycle repeats). The liquid contents of the reactor are mixed completely.

\( Q = 0 \) for batch reactor, the equation becomes

\[ \frac{dC}{dt} = r_c - KC \]  \hspace{1cm} (2.7)

\[ \frac{C}{C_0} = e^{-KT} \]  \hspace{1cm} (2.8)

where \( r_c \) = Rate of conversion
\( K \) = First order reaction rate coefficient, \( T^{-1} \)
\( C \) = Concentration of organic matter remaining, \( M L^{-3} \)
\( C_0 \) = Initial concentration of organic matter, \( M L^{-3} \)
\( T \) = Detention time, \( T \)
Graphically by plotting – In \( (C/ C_0) \) versus ‘T’ is used to determine the reaction rate coefficient.

### 2.9.2 Growth Yield and Substrate Utilization rate

Metcalf and Eddy (1993, 1995, 2003); Perry McCarty (1964) reported that Bacterial growth curve represents, at time zero, substrate and nutrients are present in excess and only a very small population of biomass exists. As substrate is consumed, four distinct growth phases (Lag phase, Exponential phase, Stationary phase, and Death phase) develop sequentially. In biological treatment process, cell growth depends on the oxidation of organic or inorganic compounds. The ratio of the amount of biomass produced to the amount of substrate consumed is defined as biomass yield.

Biomass yield ‘\( Y \)’ = g biomass produced / g substrate utilized.

The maximum specific growth rate of the bacteria is related to the maximum specific substrate utilization rate, so

\[
k = \frac{\mu_m}{Y}
\]  

where \( k \) = maximum specific substrate utilization rate, g substrate/g microorganisms. d
\( \mu_m \) = maximum specific bacterial growth rate, g/g.d
\( Y \) = Yield coefficient, g/g

### 2.9.3 Effect of Substrate Concentration on the Microbial Growth Rate

Metcalf and Eddy (1993; 1995; 2003); Perry L. McCarty (1964) confirmed that the substrate utilization rate in biological systems can be modeled as
\begin{equation}
r_{su} = -\frac{kXS}{(K_s + S)}
\end{equation}

where \( r_{su} \) = rate of substrate concentration change due to utilization, g/m³.d

\( k \) = maximum specific substrate utilization rate, g substrate /g microorganisms. d

\( X \) = biomass concentration, g/m³

\( S \) = growth – limiting substrate concentration in solution, g/m³.

\( K_s \) = half velocity coefficient (substrate concentration at one-half the maximum specific substrate utilization rate), g/m³.

The substrate utilization rate in biological systems is also reported as

\begin{equation}
r_{su} = -\frac{\mu_mXS}{Y(K_s + S)}
\end{equation}

It is accepted that the anaerobic digestion of organic wastes is a complex multi-stage process.

2.10 CONCLUSION

A comprehensive literature survey was presented in this chapter and the following valuable informations are revealed from the literature review. i) The available literatures are mainly on generation of biomedical waste and related health risks due to hospital wastes. ii) Very few research articles are available on treatment techniques. iii) The published information regarding treatment and guidelines for analysis of biomedical waste are inadequate. All Incineration based technologies, Hydroclave, Microwave and Autoclave for the treatment of IBMW are too expensive for developing
countries and therefore, low cost treatment options are needed as an alternate for biomedical waste (BMW) management arises.

Hence using treatment options and analytical procedures of various other wastes, a detailed investigation was carried out for infectious biomedical waste (IBMW) to understand the effect of lime, neem (Azadirachta indica) leaves extract and also utilizing solar energy and solar energy with addition of lime solution in box-type solar disinfecter as a Pre-treatment to destroy the pathogenic organisms absolutely from the IBMW. The study also estimates the Infectious and general Biomedical wastes (BMW) quantity arising from different wards and units of one of the Hospitals in Coimbatore.

Anaerobic digestion was globally more effective (compare to aerobic digestion) in enhancing sludge production reduction. Therefore an attempt has been made on an engineered anaerobic digestion using pre-treated BMW and Mixed BMW (pre treated BMW and OFMSW) in long term batch mode as an alternate to burning technology.