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A Critical Review on Biomedical Waste and Effect of Mismanagement

Himabindu P. A[1]
[1]M.Tech. Scholar,
Department of Environmental Engineering,
Sri Jayachamarajendra College of Engineering,
Mysore- 570006, Karnataka, India

Udayashankara T. H[2]
[2]Professor,
Department of Environmental Engineering,
Sri Jayachamarajendra College of Engineering,
Mysore- 570006, Karnataka, India

Madhukar M[3]
[3]Research Scholar,
Department of Environmental Engineering,
Sri Jayachamarajendra College of Engineering,
Mysore- 570006, Karnataka, India

***Abstract*— Biomedical waste is identified under many terminologies like hospital waste, healthcare waste etc., which are generated due to long or short term care of persons. Various health care establishments are the minor and major source of these types of wastes. Biomedical waste may be primarily classified as Hazardous and Non Hazardous wastes. Further, the biomedical waste is categorized by WHO and also under The Biomedical Waste (Management & Handling) Rules, 1998, India. According to previous studies the quantum of waste generated in a health care establishment depends on the Income of the country, type of Hospital, Region etc. Biomedical wastes are highly infectious and can be a potential source for transmission of diseases if not properly managed. Hence, a proper management procedure has to be adopted to safely dispose the wastes to safe guard the public health and Environment and a stringent regulation have to be imposed on the health care establishments before and after it is approved for execution. Further, the hospital staffs are at high risk of being infected by these biomedical wastes, therefore, the occupational health and safety can be recommended to be a component of biomedical management plans with qualified personnel in Hospitals.**

Keywords— ***Biomedical; Hospital; Healthcare; Waste; Sources; Effects***

I. INTRODUCTION

Hospitals and healthcare centers are a complex institution which is frequented by people from every walk of life in the society without any difference between age, gender, race and religion [1]. It is ironic that these health care delivery system, which are established to provide treatment and safeguard the health of public has become a source of infection and means of spreading diseases in the process of health care [2]. These health care facilities generate wastes which are universally known as biomedical waste. Biomedical waste is also characterized as health care waste, clinical waste, hospital waste, Medical Waste etc. which can be used appropriately wherever necessary. Typically, Bio Medical Waste (BMW) refers to any solid or liquid/fluid waste material with or without its containers or bottlers or vials and any other intermediate wastes which are generated during term (long or medium or short) of care which may involve observation, diagnosing, therapeutic and rehabilitative process for a person [3]. During these processes, production & testing of biological are carried out which intern generates hazardous contaminated/infectious waste.

According to WHO (World Health Organization), Health Care Waste is defined as the total waste stream from a health care establishment, research facilities, laboratories, and emergency relief donations. The standard definition given in The Biomedical Waste (Management and Handling) rules, (1998) India, states that "Any waste which is generated during diagnosis, treatment or immunization of humans or animals, or in research activities pertaining thereto or in the production of testing of biological". According to these Rules, it is the duty of every "occupier" i.e. the person who has control over the institution and or its premises, has to take all necessary steps to ensure that waste generated is handled without any adverse effect to human health and environment.

Various health care establishments such as hospitals, clinics, outpatient surgery centers, pharmacies and nursing homes are the major sources of these BMWs [4]. Previously, authors have attempted in reviewing on biomedical waste management, however an extensive review on the sources, classifications, and quantum of generation and effects of biomedical waste is not found. Hence, in this review an attempt in made to provide detailed information on the characteristics and sources, classification and category and effects of improper management of BMW on health and environment is presented.

II. CHARACTERISTICS & SOURCES

The main characteristics of major concern includes [5]

a) Infectious or potentially infectious;
b) Sharps;
c) Cytotoxic;
d) Publicly sensitive due to the nature of the waste.

BMW includes 80-99% combustibles with moisture content of 0-90% depending up on the materials (plastic or anatomical waste) and heating value of around 3000 – 6000 kcal/kg [6,7]. Biomedical waste has many forms and is generated in various facilities as mentioned in Chart 1.Depending on the quantum of waste generated facilities can be further classified as presented in Table 1

III. CLASSIFICATION AND CATEGORY

Almost, 75-85% of hospital waste is nonhazardous waste which is comparable to municipal waste or household refuse consisting of both wet and dry wastes and they do not entail any particular hazard [8]. The remaining part of waste which comes out from the patient caring units, pharmaceuticals, labs etc., accounts to 15-25% (Figure 2) [9]. Biomedical waste or Health care waste generated in an establishment are categorized according to Biomedical Waste (Management and Handling) Rules and WHO is as given in Table 2.

Sharps includes i) Needles (whether or not attached to a syringe or covered by a plastic guard); ii) IV tubing with needle attached; iii) Glass Pasteur pipettes; iv) Disposable glass pipettes; v) Glass slides and cover slips; vi) Infusion sets, Scalpels, razor blades, and lancets; and vii) Broken glass and splintered plastic, when contaminated with blood or other potentially infectious material. Non-contaminated broken lab glass and plastic such as beakers and bottles are NOT considered sharps for disposal purposes.

Further, Sharps can be categorized as a) Sharps, which are either contaminated or not contaminated with biological material; b) Radioactive sharps, which are sharps contaminated with radioactive material; and c) Chemical sharps (e.g. broken mercury thermometers, or syringes contaminated with chemotherapy drugs). Laboratory glassware is not considered sharps waste for disposal purposes, but may be sharp enough to puncture normal garbage bags and endanger waste handlers. Lab glass includes items such as broken glass beakers or bottles, plastic pipettes and pipette tips.

Infectious wastes are that type of waste, which has the potential in causing or spreading infections to humans/animals [12]. According to WHO, "Infectious waste is suspected to contain pathogens (bacteria, viruses, parasites, or fungi, refer Table 3) in sufficient concentration or quantity to cause disease in susceptible hosts". Table 4 provides the information on the sources and example of Infectious Waste. The category of infectious waste that is sourced from laboratory examination can be labeled as pathological waste, which can only be treated using specific methods.

Pathological waste may contain pathogens, or could be perceived as containing pathogens. Other infectious waste generates from isolation wards, materials, or equipment that has been in contact with infected patients, human discharges, body parts, fetuses etc. Infected sharps are the subcategory of infectious wastes hence it explained separately. Chitnis (2005) reviewed on biomedical wastes generated in Laboratory Medicine in which information on wastes inventory in different section of pathological department is as given below

1. Sample Collection: Plastic or Glass Vacutainers, needles, syringes, cotton swabs, Lancet
2. Blood Bank: Plastic or Glass Vacutainers, Lancet, hypodermic collection needles, plastic tubing, blood bags or bottles, slides, gauze pieces
3. Biochemistry: Plastic or Glass Vacutainers, test tubes, glass bottles, plastic tips, autoanalyzer cups, plastic bottles, chemicals, blood
4. Hematology: Plastic or Glass Vacutainers, slides, Hb tubes, capillaries, lancet, ESR tubes, chemicals, immersion oil, blood, stains
5. Bacteriology: Plastic or Glass Vacutainers, test tubes, glass bottles, saline bottles, plastic bottles, testing containers, slides, infectious samples, bacteriological medium with growth, culture plates, blood, immersion oil, stains
6. Endocrinology: Plastic or Glass Vacutainers, glass bottles, auto analyser cups, plastic tips, serum storage plastic cups, bottles, blood, radioactive tubes, expired radioactive solution, ELISA plates, reagents
7. Serology: Plastic or Glass Vacutainers, blood, serum stored, tips, ELISA plates, reagents
8. Clinical Pathology: Urine and stool containers, reagents, slides, filter paper, paper strips, sticks wooden, chemical reagents
9. Histopathology: Human tissues, organs, formalin, gauze, cotton, chemicals, stains

Pharmaceutical wastes are formed due to the accumulation of expired medicinal stocks and it's packaging, unused or left out medicines etc. which are generated with or without intension. It also includes spilt and contaminated pharmaceutical products, drugs, vaccines, and sera that are no longer necessary. The category can be extended to the discarded substances that are used in the handling of pharmaceuticals, for example bottles, containers, cartons, gloves, masks, connecting tubing, and drug vials etc.

In genetics, Geno- toxicity describes the property of chemical agents that damages the genetic information within a cell causing mutations, which may lead to cancer. Waste substances with Geno-toxic properties may include waste containing cytostatic drugs (often used in cancer therapy),Geno-toxic chemicals, vomit, urine, or feces from patients treated with cytostatic drugs, chemicals, and radioactive material [14]. Geno- toxic materials which are most commonly used in Health care procedures are classified by working group of IARC (International Agency for Research on Cancer) [15].

Cytotoxic (or antineoplastic) drugs, have the ability to kill or retard the growth of selected living cells and these are used in chemotherapy of cancer and also as immunosuppressive agents in organ transplantation and in treating various diseases with an immunological basis. These drugs are commonly used

in specialized departments such as oncology and radiotherapy units, whose main role is cancer treatment. Hazardous cytotoxic waste can be categorized as Alkylating agent, Antimetabolites and Mitotic Inhibitors (IARC, 2000).

As mentioned in Table 2 Pathological waste entails of organs, tissues, human fetuses, body parts and animal carcasses, blood, and body fluids. Within this category, recognizable human or animal body parts are also called anatomical waste and this particular category should be placed as a subcategory of infectious waste, even though it may also include body parts which are in healthy condition.

The Chemicals in form of solid, liquid or gaseous when discarded forms chemical waste (ex. Housekeeping, Cleaning, disinfection procedures followed in diagnostic and experimental work). These may wastes may be hazardous or nonhazardous in nature depending on the chemical property (ex. Formaldehyde, photographic chemicals, solvents, organic and inorganic chemicals). Heavy metal content also represents chemical waste of hazardous category which commonly arises from clinical equipment containing mercury (thermometers, blood-pressure gauges, etc.). Similarly, Cadmium waste can be expected from discarded batteries and Radiation proofing doors or panels forms a source of lead in X-ray and diagnostic centers. Medicines containing trace amounts of heavy metals are considered as pharmaceutical waste. Many types of gas (Anesthetic, ethylene oxide, oxygen, compresses air etc.) are used in treatment procedures which are often stored in pressurized cylinders, cartridges, and aerosol cans which may contain residues.

Radioactive wastes are produced as a result of radionuclides medicinal treatments, cancer therapies and medical equipment that uses radioactive isotopes. Pathological waste that is contaminated with radioactive material is considered as radioactive waste rather than infectious waste. Radioactive waste generates from unused liquids from radiotherapy or laboratory research, contaminated glassware, packages, or absorbent paper, urine and excreta from patients treated or tested with unsealed radionuclides and sealed sources. Some of the radionuclides used in health care are β emitters (^{3}H, ^{14}C, ^{32}P), ɣ emitters (^{51}Cr, ^{75}Se, $^{123, 125, 131}I$), α emitters (^{222}Rd, ^{226}Ra) [3].

Classification of radioactive wastes given by WHO, is as follows

- Sealed sources (Airtight and Water tight);
- Spent radionuclide generators;
- Low-level solid waste (Absorbent paper, swabs, glassware, syringes, vials);
- Residues - shipments of radioactive material and unwanted radionuclides envisioned for diagnostic or treatment;
- Liquid immiscible with water used in radioimmunoassay;
- Spillage and decontamination of radioactive spills;
- Excreta from patients treated or tested with unsealed radionuclides;
- Low-level liquid waste (washing apparatus);
- Gases and exhausts from stores and fume cupboards.

III. QUANTITY OF WASTE GENERATED

The quantity of waste produced in a hospital depends on the level of national income and the type of facility concerned. In a high-income country a University Hospital can produce up to 4-9 kg of waste/bed/day and at General and District hospital it ranges from 1-4kg of waste/bed/day [7, 16]. Similarly, in middle income and low income country 0.5-6kg and 0.5-3kg/head of Population respectively [11]. It can be observed that the quantum of waste generation not only depends on the type of hospitals and also depends on income of the country. It may also differ from management of hospital i.e. for example in India Hospital management can be Government, Semi Government or Private. A case study conducted in one of the districts of south India showed that Government and Private Hospitals generates around 5-7kg and 2-4kg of waste/bed/day respectively [17,18] and another study conducted in one of the district in West India revealed that private hospitals generates around 1-3kg/Bed/day and Government Hospitals also generate the equally [1]. From this is can be observed that rate of generation not on depends on type of hospital it may also depend on the region.

IV. EFFECTS OF MISMANAGEMENT

The biomedical wastes when not managed properly it can pose serious risks to society and the environment through Air emissions or Contamination of Water or Physical Contacts. Improper disposal method like open dumping and unrestrained burning, increases the risk of spreading infections and of exposure to toxic emissions.

Mismanagement of hospital waste entails a combination of improper handling of waste during generation, collection, storage, transport and treatment [19]. Improper handling involves some unsafe procedure followed during handling of wastei.es without wearing personal protective equipment (PPE), poor storage (e.g. high temperature, High Residence time), transporting manually for longer distances, unpacked or uncovered containers instead of closed plastic or puncture proof bags, etc. Other examples include duration of exposure, lack of knowledge on equipment decontamination procedures, etc., all of which affect hospital workers in different ways [20].

Following Groups of Individuals are exposed [21]

- Inside Health Care Center: Staff (Doctors, Nurse, Auxiliaries), Stretcher- bearers, Patients, Scientific and Technical Personnel, Logistic (cleaners, Laundry, waste managers, carriers, maintenance, pharmacists, lab technicians, visitors)
- Outside: In site and off Site transport personnel, waste processing personnel, general public, Rag Pickers.

Dumping of wastes in uncontrolled manner without adopting proper treatment technique can pollute the air, soil and water, and may also can attract rodents and flies. Most medical waste is incinerated, a practice that is short-lived because of

environmental considerations. Open cast burning or incineration of the wastes releases GHSs, Dioxins and other toxic emissions which can cause respiratory disorders, cancers and increases the global temperature [22]. The air emissions affect the local environment and may also affect communities hundreds or thousands of miles away due to the drifting of pollutants through wind. The toxic ash residues sent to landfills form incinerators for disposal have the potential to leach into groundwater. If the mercury polluted materials are incinerated airborne mercury which is a known neurotoxin, is produced which enters a global distribution cycle in the environment, contaminating the organisms. The radioactive gaseous generated may blend with the indoor air and can affect the workers [20].

Improper management of wastewater and sewage sludge can result in contamination of water and soil with pathogens and toxic chemicals. Discharging the chemical and pharmaceutical wastes impairs the performance of the biological treatment which can end up in polluting the water source of the ecosystem. The antibiotics used in treating the patients are discharged as urine to the sewers which can also impact on the performance of wastewater treatment plant.

Infectious agents such as feces, vomit, saliva, secretions, blood etc., can cause serious health risks on individuals by effecting organs or systems like gastrointestinal, Respiratory, Eye, Skin and also cause Anthrax, Meningitis, AIDS, Hemorrhagic fever (Ebola), Hepatitis (A, B & C), Influenza (H1N1) etc. [23]. These types of infections can spread mainly through contact with the body fluids [24]. The extent of microorganism survival in contaminated wastes is an important factor in spreading of diseases or infections to the waste handling personnel or to public [25, 26]. The survival of microorganisms may depend on the environmental factors such as temperature, humidity, solar radiation, substrate, type of disinfectant etc. The passive carriers (rodents or flies) carries these pathogenic organisms which may assist in spreading of diseases. Measures on controlling their proliferation should also be considered under biomedical waste management [27, 28].

Hussain and Mushtaq, (2014) concludes that Lack of awareness among patients higher the possibility of getting infectious diseases in the hospital. This may be due to their level of literacy and housing condition and handling of wastes. Most of those chemicals and pharmaceuticals used in Hospitals entail a health risk due to their properties (toxic, carcinogenic, mutagenic, repro toxic, irritant, corrosive, sensitizing, explosive, flammable, etc.). An individual can get exposed through various routes (inhalation of gas, vapor or droplets, contact with the skin or mucous membranes, or ingestion) to these chemicals or pharmaceuticals [15]. Motacki and Burke (2011) Person handling chemicals or pharmaceuticals must be well aware with Material Safety and Data Sheet (MSDS) to avoid accidents and incidents. Labelling of the hazardous materials may also help in identifying or create awareness among publics visiting the vicinity [34].

V. CONCLUSION

From the present review it can be clearly stated biomedical wastes generated form heath care facilities are highly infectious and can be a source for transmission of diseases. Wastes generated in hospital irrespective of their sources have to be processed accordingly. Further, it is the duty of hospital management to take all necessary steps to ensure that waste generated is handled and disposed cautiously to safe guard human health and environment. The quantity of waste generated in a hospital may depend on the Income of the country, type of Hospital, Region etc. Segregation and labelling of wastes at source may help identifying the proper handling and treatment procedure. Hence, a proper management procedure has to be adopted to safely dispose the wastes to safe guard the public health and Environment and a stringent regulation have to be imposed on the health care establishments before and after it is approved for execution. All the staffs handling the materials in the health care facilities must be aware of the material safety and data sheets in order to handle the chemicals and pharmaceuticals due to spillage. Additionally, the hospital staffs are at high risk of being infected by these biomedical wastes, therefore, the occupational health and safety can be recommended to be a component of biomedical management plans with qualified personnel in Hospitals.

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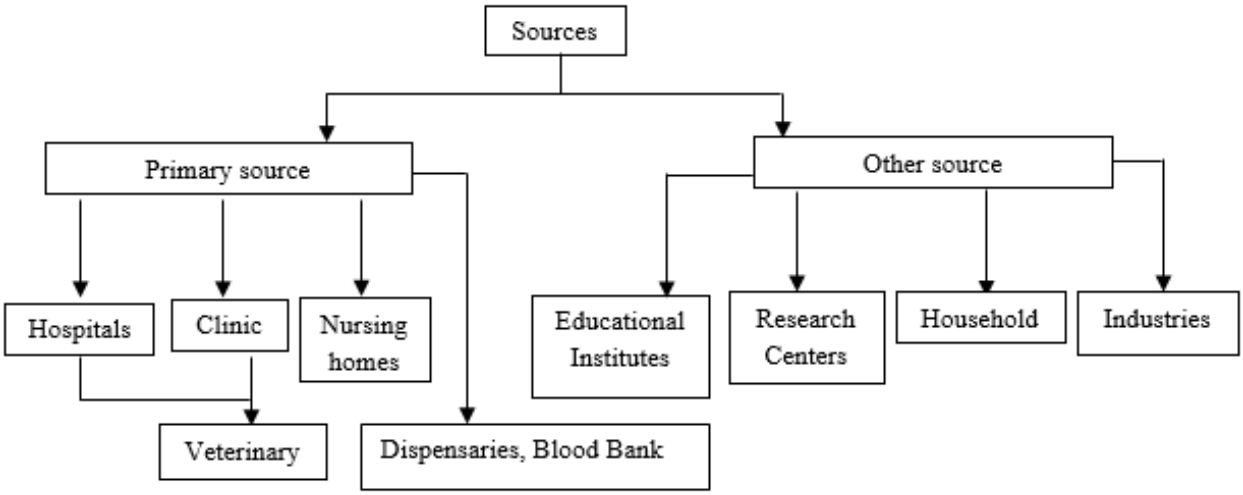

Figure 1 Sources of Biomedical Waste Classification of Biomedical Waste [32]

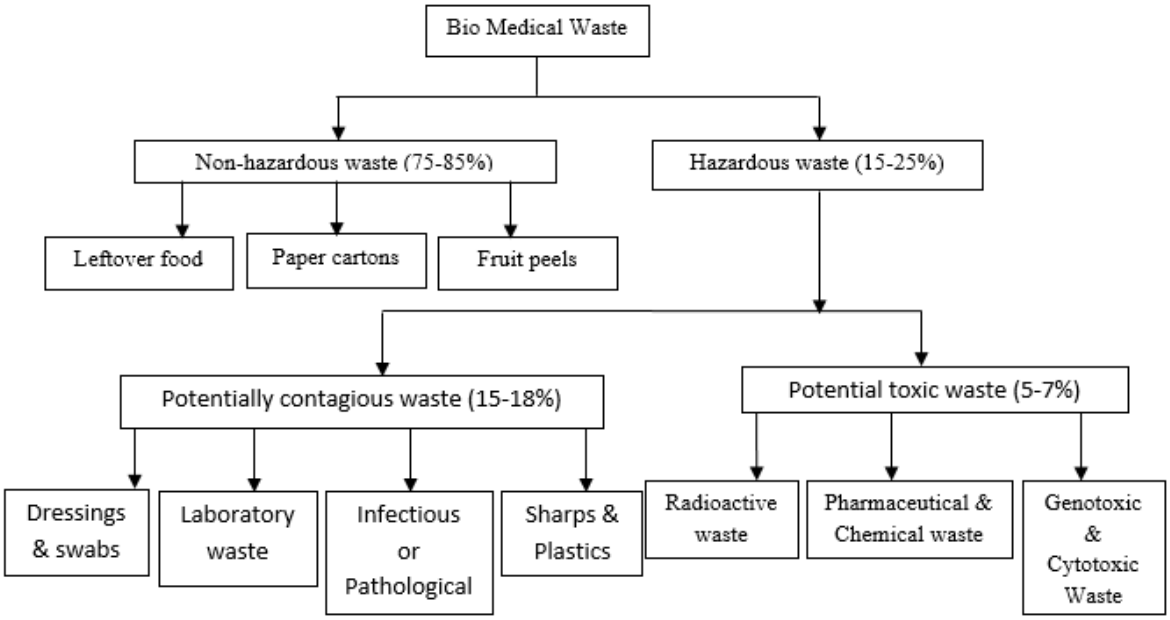

Figure 2 Classification of Biomedical Waste **[33]**

TABLE 1. CLASSIFICATION OF BMW SOURCE **[30]**

Major

- Govt. hospitals, Private hospitals, Nursing homes, Dispensaries,
- Primary health centers, Emergency Services,
- University Medical colleges and research centers, paramedic services
- Veterinary colleges and animal research centers
- Obsteric and Maternity Clinics
- Dialysis Center, Transfusion center,
- Blood banks/mortuaries/autopsy centers
- Biotechnology institutions
- Production units.

Minor

- Physicians office, dentists' clinics, chiropactors
- Animal houses/slaughter houses
- Blood donation camps
- Vaccination centers
- Acupuncturists, psychiatric clinics, cosmetic piercing, tattoo parlor
- Funeral services, Home treatment
- Institutions for disabled persons
- Ambulance/Mobile Health cares

TABLE 2. CATEGORIES OF BMW [10,11]

Waste category	Description or Contents
Human anatomical waste	Tissues, organs, Recognizable body parts (Healthy or Unhealthy), Limb, Finger, Skin, Muscle, Toes, Ear, Eyes and other appendages, Foetus, bones etc.(does not include tooth, hair and nails)
Animal waste	Tissues, organs, body parts, carcasses, bleeding parts, fluid, blood and experimental animals used in research, waste generated by animal houses
Microbiology and bio-technology waste	Laboratory culture, stocks, specimens of micro-organisms live or attenuated vaccines, human and animal cell culture used in research, wastes from production of biologicals and devices used in transfer of culture
Sharps	Needles, syringes, blades, glass capable of causing puncture or cuts
Discarded medicines	Wastes consisting of contaminated, outdated and discarded medicines, left out medicines, spillage
Soiled waste	Waste items contaminated with blood and body fluids including cotton, dressings, linen beddings
Solid waste	Waste obtained from disposable items other than sharp waste such as tubing catheters, intravenous sets etc.
Liquid waste	Waste generated from laboratory, washing and cleaning activities, disinfection and housekeeping activities
Incineration ash	Ash from incineration of any bio-medical waste
Chemical waste	Chemicals used in production of biological, chemicals used in disinfection, laboratory reagents, film developer, expired pharmaceuticals, solvents
Genotoxic or Cytotoxic Waste	Waste with genotoxic or cytostatic properties, substance commonly used in therapy eg. Antineoplastics or chemotherapy agents.
Heavy Metals	Batteries, broken thermometer, pressure gauges
Pressurized containers	Gas Cylinders, Cartridges, Aerosol Cans,
Radioactive waste	Unused liquids from radio therapy, lab research, contaminated glassware, packages, adsorbents, human discharges, sealed and unsealed radionuclides

TABLE 3. MICROORGANISMS AND DISEASES [31]

Bacterial	Tetanus, gangrene and other wound infection, anthrax, cholera, other diarrhoeal diseases, enteric fever, shigellosis, plague etc.
Virus	Hepatitis, poliomyelitis, HIV-infections, TB, STD rabies etc.
Parasites	Amoebiasis, giardiasis, ascariasis, ankylomastomiasis, taeniasis, echinococcosis, malaria, leishmaniasis, filariasis etc.
Fungal	candidiasis, cryptococcoses, coccidiodomycosis etc.

TABLE 4. SOURCES OF INFECTIOUS WASTE

Source	Example
Laboratory	Cultures and Stocks, Infected animals, Instruments or materials in contact with body fluids.
Surgery and autopsies	Tissues (blood or body parts, foetuses) and materials or equipment contacted with blood or body fluids, breathing tubes, laryngeal mask
Isolation of Wards	Excreta, urine drainage bags, catheters, dressings, clothes,
Haemodialysis	Tubing and filters, disposable towels, gowns, aprons, gloves and laboratory coats