

## Chapter 6

# Biomedical Waste

Biomedical waste comprises of all liquid and solid wastes generated from medical establishments and activities involving biological materials. Besides health care, the relevant activities include clinical research, research involving animals, animal farms, dead animals, and others. The generation of biomedical waste is not restricted to specific activity or organisations. It can originate from homes during dialysis and using insulin injections, animal health activities in rural areas, butchering of sick animals in butcher houses, medical shops, use of sanitary napkins and ear buds, use of diapers, and air ports when passengers through away restricted medicines without prescription.

Many countries do not have separate regulation and mechanism to manage biomedical waste. Among those which have adopted separate legislation have different definition with respect to biomedical waste.

For example, as per the Biomedical Waste (Management and Handling) Rules (1998) of India, “Biomedical waste” means

any waste, which is generated during the diagnosis, treatment or immunisation of human beings or animals or in research activities pertaining thereto or in the production or testing of biologicals, and including categories mentioned in Schedule I

The schedule I of the above rule comprises of waste category, human anatomical waste, animal waste, microbiology and biotechnology wastes, waste sharps, discarded medicines and cytotoxic drugs, soiled waste, solid waste (wastes generated from disposable items other than the waste sharps), liquid waste, incineration ash, chemical waste.

The legal document Order No. 242/96 dated 13 August 1996 Portugal clinical waste includes all the waste generated by health-care establishments, research facilities, and laboratories are grouped into four classes (Pa’ssaró 2003):

*Group I—not subject to special treatment,*

*Group II—not subject to special requirements in its treatment,*

**Fig. 6.1** Biomedical waste stored unscientifically for recycling



*Group III—comprises of contaminated wastes, or potentially contaminated waste, and*

*Group IV—wastes that must be incinerated*

Clinical waste is defined in regulation 1(2) of The Controlled Waste Regulations 1992 (SI1992/588) of United Kingdom as follows:

1. any waste which consists wholly or partly of human or animal tissue, blood, other body fluids, excretion, drugs or other pharmaceutical products, swabs or dressings, or syringes, needles or other sharp instruments, being waste which unless rendered safe may prove hazardous to any person coming into contact with it, and
2. any other waste arising from medical, nursing, dental, veterinary, pharmaceutical or similar practice, investigation treatment, care, teaching or research, or the collection of blood for transfusion, being waste which may cause infection to any person coming into contact with it.

The Medical Waste Tracking Act (1988) of the United State of America (USA) makes administrator of the act in each state to promulgate regulation listing the type of medical waste. This has resulted in the inclusion of an elaborate list of medical wastes by individual authorities responsible under the act in each state.

Biomedical waste management is influenced by social, cultural and economic circumstances. About 10–15 % of waste from hospital are considered ‘‘infectious’’ (USC 1988). Figure 6.1 shows biomedical waste stored unscientifically for recycling. The risky wastes comprising of infectious/toxic/radioactive substances can contaminate the non-risky wastes resulting in huge quantity of risky wastes demanding costly treatment and disposal options.

Enforcement of rules pertaining to biomedical waste in developing countries are difficult for the following reason: (1) quacks in professions, (2) profession being practiced by numerous doctors from home and garage without formal trade

license, (3) practice is intentionally not registered in any government organization to avoid income tax, (4) attitude of health care professionals to discard as it is and where it is, (5) pressure to increase profits, (6) poor law enforcement by local bodies which can take action for causing nuisance, (7) the behaviour of waste throwing is deep registered in unconscious mind, and (8) lack of importance given for education in waste management.

The health care sector in the developing countries is a mixed bag with ownership lying in the hands of doctors, quacks, non-medical professionals, government, doctors operated for profit, and charity. The profession does not attract as many laws as other industries. People do not negotiate for the service received by health care establishments a reason which is sufficient for many entrepreneurs to establish hospitals whose only motive is profit. People in the neighbourhoods do not complain about doctors as they have to maintain relation with doctors as they are needed in emergency.

The main characteristics of biomedical waste are: (1) disinfection nearest to source, (2) mutilation often disinfection at the earliest opportunity, (3) does not affect individual or environment, and (4) a solution does not become problem.

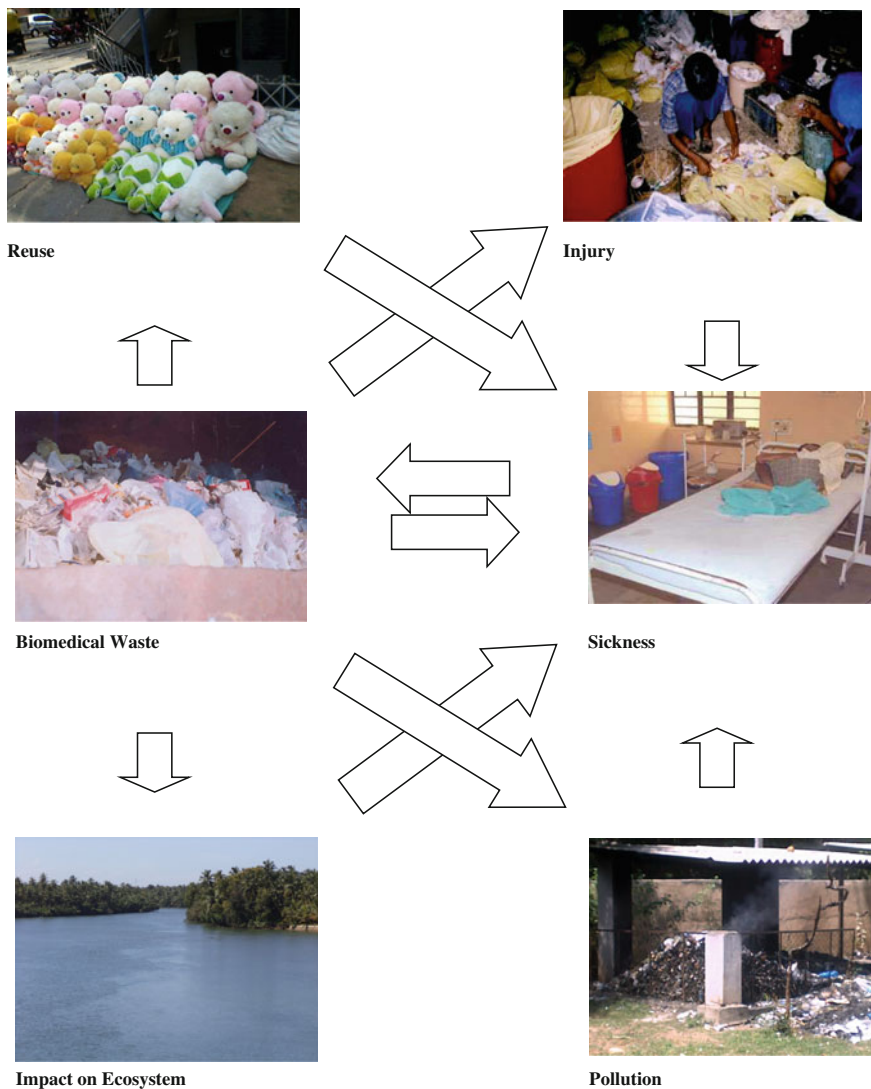
## 6.1 Significance

Healthcare establishments have particular responsibilities with respect to the wastes they generate (Pruss et al. 1999). However, the impact of biomedical waste has not been given significant attention often (Saurabh et al. 2009). Negligence in biomedical waste management contributes to environmental pollution, sickness of humans/animals, and depletes natural as well as financial resources (Henry and Heinke 1996; Oweis et al. 2005).

The evolution of biomedical waste as a separate category of waste dates back to the late 1970s, when medical wastes were found on the beaches in the east coast in the USA. This followed enactment of the US Medical Waste Tracking Act (MWTa) in 1988.

Biomedical waste, if not managed properly, will pose significant environmental and health impact. The grave health hazards posed by the poor handling of biomedical waste to the hospital staff, rag-pickers, municipal workers and the community have been well, documented. In many developing countries, an overall management of the biomedical waste is still an exception and not a rule. Lalji et al. (2008) recommend monitoring and legal action as significant steps in the management of biomedical wastes.

In spite of the intrinsic impacts, treatment and disposal of biomedical waste remain a negligent activity resulting in pathogens entering in food due to mixing of infectious animal waste with meat. It is also a common practice in many developing countries to supply meat derived from animals with infectious diseases which in turn may contaminate food with which it comes in contact.



**Fig. 6.2** Consequences of indiscriminate biomedical waste disposal

Figure 6.2 shows some consequences of indiscriminate biomedical waste generation. The hazardous nature of the biomedical waste is due to the following: (1) infection, (2) genotoxicity (deleterious action on genetic material of cell affecting its integrity), (3) toxicity, (4) exposure to radioactivity, (5) injury.

In many countries a number of contaminated waste materials like cotton, syringes, sharps re-enter the market either in the same or an altered form. Infected cotton may be used for making ear buds and toys. Syringes from waste are often repacked and sold as new packs.

**Table 6.1** Examples of pathogenic virus and associated disease

Virus	Disease
Adenovirus	Colds
Arenavirus–Junin	Hemorrhagic fever
Arenavirus–Lassa	Lassa fever
Arenavirus–Machupo	Hemorrhagic fever
Coronavirus	Colds
Coxsackievirus	Colds
Ebola virus	Ebola hemorrhagic fever
Echovirus	Colds
Filovirus–Marburg	Hemorrhagic fever
Guanarito virus	Venezuelan hemorrhagic fever
Hantaanvirus	Hemorrhagic fever with renal syndrome (HRFS)
Hepatitis C	Parenterally transmitted non-A, non-B, liver infection
Hepatitis E	Enterically transmitted non-A, non-B hepatitis
HHV-8	Associated with Kaposi sarcoma in AIDS patients
HTLV-II	Hairy cell leukemia
Human herpesvirus-6 (HHV-6)	Roseola subitum
Human immunodeficiency virus (HIV)	Acquired immunodeficiency syndrome (AIDS)
Human T-lymphotropic	T-cell lymphoma-leukemia virus I (HTLV-I)
Monkeypox	Monkeypox
Morbillivirus	Measles (rubeola)
Orthomyxovirus–Influenza	Flu
Parainfluenza	Flu
Paramyxovirus	Mumps
Parvovirus B19	Fifth disease, anemia
Parvovirus B19	Aplastic crisis in chronic hemolytic anemia
Poxvirus–Vaccinia	Cowpox
Poliovirus	Poliomyelitis
Poxvirus–Variola	Smallpox (extinct)
Reovirus	Colds
Respiratory syncytial virus	Pneumonia
Rhinovirus	Colds
Rotavirus	infantile diarrhea
Sabia virus	Brazilian hemorrhagic fever
Sin nombre virus	Adult respiratory distress syndrome
Togavirus	Rubella (German measles)
Varicella-zoster	Chickenpox

Source Medical Air solutions (2011; Sylvane 2011; Anthony and Elizabeth 1981)

Tables 6.1, 6.2, 6.3 and 6.4 give examples of pathogens that are present in some typical biomedical wastes. Presence of the pathogens in substantial quantities would spread disease through air, water, food, vectors, rodents, touching, etc. Needle injury will result in sero-conversion (development of specific antibodies to microbes in the blood serum due to infection or immunization) with respect to Hepatitis C (HCV) and Human immunodeficiency virus (HIV).

**Table 6.2** Examples of pathogenic bacteria and associated disease

Bacteria	Disease
<i>Actinomyces israelii</i>	Actinomycosis
<i>Bacillus anthracis</i>	Anthrax
<i>Bartonella henselae</i>	Cat-scratch disease, bacillary angiomatosis
<i>Bordetella pertussis</i>	Whooping cough
<i>Borrelia burgdorferi</i>	Lyme disease
<i>Campylobacter jejuni</i>	Enteric pathogens distributed globally
<i>Chlamydia pneumoniae</i>	Pneumonia, bronchitis
<i>Chlamydia psittaci</i>	Psittacosis
<i>Clostridium tetani</i>	Nonrespiratory airborne
<i>Corynebacteria diphtheria</i>	Diphtheria
<i>Coxiella burnetii</i>	Q Fever
<i>Ehrlichia chaffeensis</i>	Human ehrlichiosis
<i>Enterobacter cloacae</i>	Nonrespiratory airborne
<i>Enterococcus</i>	Nonrespiratory airborne
<i>Francisella tularensis</i>	Tularemia
<i>Haemophilus influenzae</i>	Meningitis
<i>Helicobacter pylori</i>	Peptic ulcer disease
<i>Legionella parisiensis</i>	Pneumonia
<i>Legionella pneumophila</i>	Pontiac fever
<i>Legionella pneumophila</i>	Legionnaires' disease
<i>Micromonospora faeni</i>	Farmer's lung
<i>Micropolyspora faeni</i>	Farmer's lung
<i>Mycobacterium avium</i>	Cavitary pulmonary
<i>Mycobacterium intracellulare</i>	Cavitary pulmonary
<i>Mycobacterium kansasii</i>	Cavitary pulmonary
<i>Mycobacterium tuberculosis</i>	Tuberculosis
<i>Mycoplasma pneumoniae</i>	Pneumonia
<i>Neisseria meningitidis</i>	Meningitis
<i>Nocardia asteroides</i>	Nocardiosis
<i>Nocardia brasiliensis</i>	Pulmonary mycetoma
<i>Nocardia caviae</i>	Nocardiosis
<i>Pseudomonas cepacia</i>	Nonrespiratory airborne
<i>Saccharomonospora viridis</i>	Farmer's Lung
<i>Salmonella Typhi</i>	Typoid Fever
<i>Shigella Dysenteriae</i>	Bacterial Dysentery
<i>Streptococcus pyogenes</i>	Scarlet fever, pharyngitis
<i>Thermoactinomyces sacchari</i>	Bagassosis
<i>Thermoactinomyces vulgaris</i>	Farmer's Lung, hypersensitivity Pneumonitis
<i>Thermomonospora viridis</i>	Farmer's Lung, hypersensitivity Pneumonitis
<i>Vibrio cholerae</i>	Cholera
<i>Yersinia pestis</i>	Pneumonic plague

Source Medical Air solutions (2011; Sylvane 2011; Anthony and Elizabeth 1981)

Substitute products with less or non-hazardous materials or using technologies that generate less toxic/volume of waste (like precapsulated amalgam, non-hazardous biodegradable detergents, digital radiography, mercury free restorations,

**Table 6.3** Examples of pathogenic protozoa and associated diseases

Protozoa	Disease
Balantidium coli	Dysentery, intestinal ulcers
Giardia lamblia	Diarrhea
Entamoeba histolytica	Amoebic dysentery, infections of other organs
Isospora belli	Intestinal parasites, gastrointestinal infection
Isospora hominis	Intestinal parasites, gastrointestinal infection
Pneumocystis carinii	Pneumocystosis

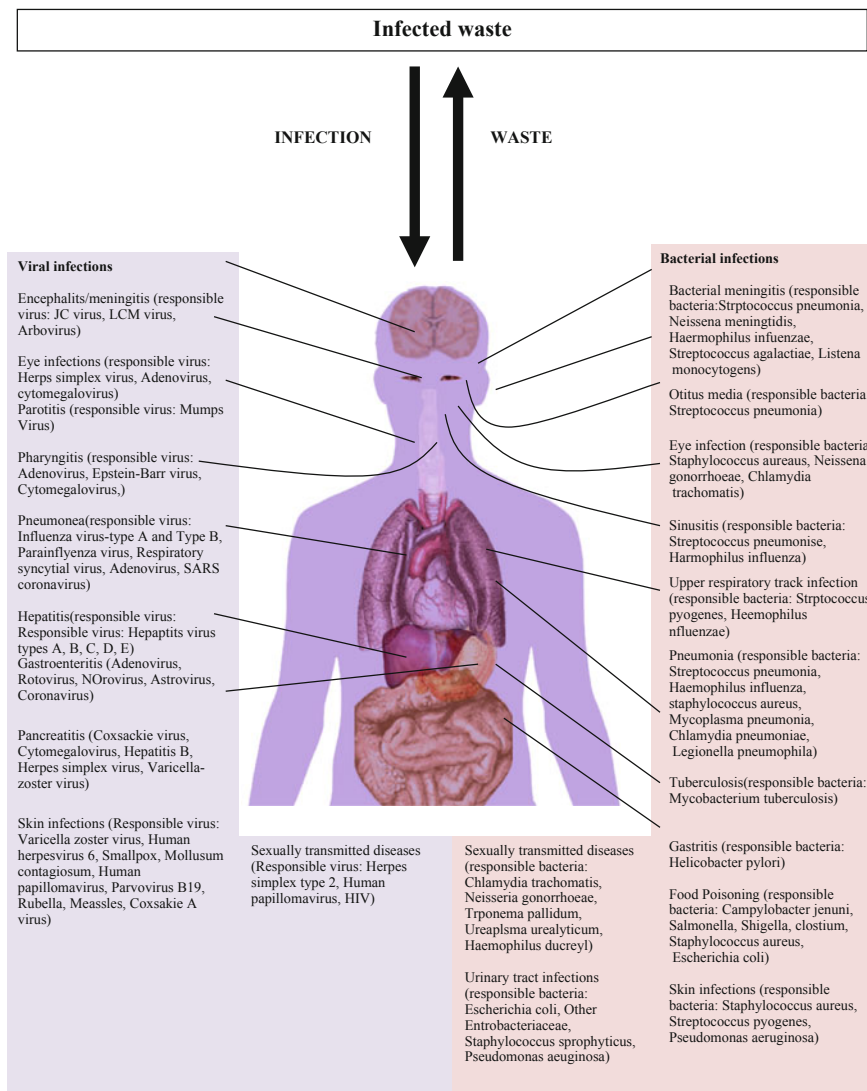
Source Medical Air solutions (2011; Sylvane (2011; Anthony and Elizabeth 1981)

**Table 6.4** Summary of treatment and disposal options for biomedical waste

Sl. No.	Waste category type	Treatment and disposal option
1.	Animal waste	Incineration/deep burial
2.	Chemical waste	Treatment by chemical for liquids. Secured landfill for solids
3.	Genotoxic	Destruction/Incineration and disposal in secured landfills
4.	Incineration ash	Disposal in municipal landfill
5.	Microbiology and biotechnology wastes	Local autoclaving/micro-waving/incineration
6.	Pathological waste	Incineration/deep burial
7.	Pharmaceutical waste	Destruction/Incineration and disposal in secured landfills
8.	Pressurized containers	Return to suppliers/Controlled destruction
9.	Radio active waste	Concentrate and contain or dilute and disperse
10.	Sharps	Disinfection and mutilation/shredding
11.	Soiled waste	Destruction/incineration and disposal in secured landfills
12.	Waste with heavy metal	Heavy metal recovery

steam sterilization, X-ray system cleaners without chromium, etc.) would definitely help degradation of environment. Materials such as zinc, mercury, silver from amalgam and X-ray fixer and lead from film backing can be reclaimed/recycled using appropriate method.

Figure 6.3 shows a schematic diagram depicting a infection cycle with respect to biomedical waste. Many studies have proven that virus can survive in water for 9–10 months at 8 °C (Anthony and Elizabeth 1981). In fact pathogen life span varies widely. For example, Feline influenza (cat influenza) caused by *Herpes Virus* can stay in the environment for a day whereas *Calici virus* can stay alive for 8–10 days in the environment. *Parvovirus* which is responsible for *Feline infectious enteritis* can live on for 12 months in the environment. *Feline leukaemia virus* and *Feline immunodeficiency virus* die within hours once they are outside the host. *Feline infectious peritonitis* can live up to seven days in cat litter (WFC 2011).



**Fig. 6.3** Schematic diagram depicting infection cycle [Source Based on Medical Air solutions 2011; Sylvane 2011; Anthony and Elizabeth 1981]

According to the World Health Organization (WHO) estimation for the year 2001, infectious diseases resulted in 26 % of all deaths worldwide (Findhauser 2003). Nearly 40 % of these deaths were due to respiratory infections and diarrhoeal diseases. Existing drugs and vaccines, as well as providing access to good food and water, could have prevented much of these deaths.



The number of emerging pathogens has increased over the last 40 years. Six viral pathogens, were discovered in the 1970s, and in the 1980s, this number rose to seven, which included HIV. In the 1990s, the number rose to 20 which included hepatitis E, F and G, as well as the West Nile encephalitis virus (Desselberger 2003). Newly discovered pathogens in this decade include the new strain of the avian influenza virus and the SARS virus.

### ***6.1.1 Household Biomedical Waste***

Household biomedical waste (HBW) is a subgroup of biomedical waste commonly found in MSW and in wastewater streams. These special wastes originate in households and pose problems in their safe handling. They pose human health and environmental hazards. Examples of HBW include expired drugs, bandages, syringes, sanitary napkins, disposable diapers, expired cosmetics, blood stained cloths, used bottles of syrups/tablets/ear-drops/eye-drops, used ointment tubes, empty pain killer spray cans, contaminated meat, ear buds, dead animals, etc.

Many of these waste materials are categorized as biomedical because as they will have any or all of the following property: (1) infection, (2) contaminated with body fluids, (3) expired or active drugs.

The quantities of HBW vary from countries to countries and houses to houses. The quantities have been estimated to vary between 0 and 3 % of MSW by weight. The variability depends on development of a country and income of individual. HBW emit dioxines and furans when burn at dump sites. Storm water can pick infection from HBW.

### ***6.1.2 Biomedical Waste from Rural Area***

It is often understood that the urban area is the origin of biomedical waste. Irrespective of whether a country is under developed or developed, the rural areas in the country do contribute to the biomedical waste in substantial quantities. Even though the impact may not be visible immediately, it would harm the health and environment over a period of time. The common biomedical waste in rural area includes placenta during animal birth, carcass of dead sick animals, intentionally killed rodents, expired drugs, waste generated in veterinary hospitals and incineration centres. Further the waste from aopsials in rural area and household biomedical waste discussed earlier can not be over ruled which include diapers, sanitary napkins, condoms, bandages. The impact of such practice will occur over period of time. But ignorance among the rural people often leads to improper disposal contaminating food items produced. Quantities are often not estimated and reported. The fly-tipping of biomedical waste from urban area and illegal burying would also cause for an accumulating of biomedical waste in the rural area.

## 6.2 Nosocomial Infection and Health Burden Due to Biomedical Waste

Nosocomial infections are infections that spread in the healthcare service unit in hospitals. This type of infection is also known as a healthcare-associated infection or hospital-acquired infection.

Infectious waste contains pathogens in significant concentration to cause sickness in susceptible hosts. Infectious waste includes stocks and cultures of infectious material from surgery/autopsies on patients with infectious sickness, laboratory work, waste that was in contact with infected animals/patients/substance.

Studies conducted in 55 hospitals of 14 countries in four regions (Europe, Eastern Mediterranean, South-East Asia and Western Pacific) showed an average of 8.7 % of patients in hospital had nosocomial infections. Over 1.4 million people throughout the world suffer from nosocomial infection (Health Canada 1997a). The highest frequencies of nosocomial infections occur in the Eastern Mediterranean (11.8 %) and South-East Asia Regions (10.0 %), with a occurrence of 7.7 % in the European and 9.0 % in Western Pacific Regions (Health Canada 1997b).

Major risks associated with poor waste management are: (1) nosocomial infections to patients/hospital staff/visitors due to poor waste management, (2) injuries from sharps to hospital personnel and waste handlers, (3) risk associated with hazardous chemicals to persons handling wastes, (4) risk of infection outside hospitals to general public and waste handlers, and (5) degradation of quality of water, air and soil.

Cross-transmission of infection from healthcare workers to patients has been explained in a variety of clinical settings (Malavaud et al. 2001; Munoz et al. 1999; Slinger and Dennis 2002; Weinstock et al. 2000).

Examples of disease spread by hospital waste include respiratory infections, gastroenteric infections, genital infections, ocular infection, skin infections, acquired immunodeficiency syndrome (AIDS), meningitis, haemorrhagic fevers, anthrax, septicaemia, viral hepatitis A, bacteraemia, candidaemia, viral hepatitis B and C.

## 6.3 Characteristics and Quantities

The quantity of biomedical waste differs from country to country and among individual health care establishments. While establishment offering only consultancy and prescription do not generate medical waste, the highly sophisticated hospital with serious infection control policy will generate huge quantity of wastes. While some hospitals use linen on examination tables others use *medical exam table paper*. Since paper used to spread on medical examination table is discarded after each use the quantity would proportionately higher.

Typical quantity of medical waste as published by the Institute for Ecopreneurship is 1.5 to 2.0 kg/bed/d for France, Belgium and England, 1.1 kg/bed/d for the USA, 0.01 to 0.2 kg/bed/d for Middle East, Asia and Africa, 0.25 to 1.13 kg/bed/d for latin America.

Trends reported by Pruss et.al. (1999) and Johannessen (1997) ranged from 3 kg/bed/d for Latin American countries, 3–6 kg/bed/d for Western Europe, 2.5–4 kg/bed/d for high-income Eastern Asian nations, 7–10 kg/bed/d for North America, 1.4–2 kg/bed/d for Eastern Europe nations, 1.8–2.2 kg/bed/d middle-income Eastern Asian nations, and 1.3–3 kg/bed/d for eastern Mediterranean nations.

Data compiled by Pruss et.al (1999) and Halbwachs (1994) indicated that high-income nation generate 1.1–12.0 kg/person/year, middle-income nations generate 0.8–6.0 kg/person/year and low-income nations generate 0.5–3.0 kg/person/year.

The average generation rates in Jordan ranged from 0.29 to 1.36 kg/bed/day, while in terms of patient numbers it is from 0.36 to 0.87 kg/patient/day (Hani et al. 2007). While the studies conducted by Fayez et al. (2008) in Jordan revealed generation rate ranges from 0.26 to 2.6 kg/bed.

Studies from Jasem and Hani (2007) revealed that the rate of waste generation in Kuwait is from 3.87 to 7.44 kg/bed/day. This waste consisted of 71.44 % of domestic waste, 0.76 % of sharps and 27.8 % of infectious/hazardous waste.

Pruss et al. (1999) recommend the following estimates for *preliminary* waste management: planning: (1) 15 % pathological and infectious waste, (2) 80 % general health-care waste, (3) 3 % chemical/pharmaceutical waste, (4) 1 % sharps waste, (5) less than 1 % other waste, like radioactive waste or broken thermometers.

Biomedical waste can be categorized into following categories:

*Ash of incinerated biomedical waste:* Incineration ash comprises of ash generated during incineration of biomedical waste.

*Animal waste:* Animal waste comprises of animal tissues, body parts carcasses, organs, bleeding parts, fluid, blood/experimental animals used in research, waste generated by animal houses, and veterinary institutions.

*Chemical waste:* Waste containing chemical substance, which includes film developer, laboratory chemicals, solvents, expired and no longer needed disinfectants, scrap amalgam, elemental mercury, undeveloped X-ray film, used X-ray fixer, condemned lead aprons lead foil and cleaning agents.

*Genotoxic:* Waste containing material with genotoxic properties, including antineoplastic and cytotoxic drugs, genotoxic chemicals. Genotoxic waste may have teratogenic, mutagenic, or carcinogenic properties. It leads to severe health problems inside hospitals and after disposal. Genotoxic waste includes cytostatic drugs, body fluid from patients treated with cytostatic drugs, and radioactive material. Cytotoxic (or antineoplastic) drugs are type of Genotoxic waste have the ability to kill/stop the growth of certain living cells. They are used in therapy of neoplastic (an abnormal new growth of tissue in animals or plants) conditions.

*Microbiology and biotechnology wastes:* Wastes from laboratory stocks/cultures or specimens of micro-organisms, human and animal cell culture and

infectious agents from research/industrial laboratories, wastes from production of toxins, biologicals, devices and dishes used for transfer of cultures.

*Pathological waste:* Pathological waste comprises of human fetuses; tissues, animal carcasses, organs, blood, body parts, anatomical waste, blood and saliva-soaked materials, Extracted teeth without amalgam restorations and body fluids. In this category human or animal body parts are called anatomical waste. Some of the pathogens can be dangerous, as they could possess high pathogenicity and resistant to treatment (Askarian et al. 2004).

*Pharmaceutical waste:* This category comprises of discarded medicines like partially used ointments, syrups, tablets, expired drugs, and used massage oils.

*Pressurized containers:* Waste containing containers with pressurized liquids, powdered materials, or gas, like gas containers and aerosol cans.

*Radioactive waste:* Waste from radiotherapy or research laboratory which includes contaminated packages, glassware or absorbent paper, urine/excreta from patients treated/tested with radionuclides.

*Sharps:* Sharps are substance that could cause cuts/puncture wounds. It includes needles, scalpel, knives, blades, razors, scalpels, X-Acto knives, scissors, infusion sets, bone chips, saws, nails and broken glass. These are considered to be high risk waste as the injury caused by them while handling infectious waste and patient can result in deadly disease to medical or paramedical staff.

*Soiled waste:* Soiled wastes are substance contaminated with body fluids including cotton, soiled plaster casts, lines beddings, dressings.

*Waste with heavy metals:* Waste consisting of waste contaminated with heavy metals/derivatives such as waste thermometers, batteries and manometers.

*Food waste infected by patient:* Food waste which has come in contact with infected person.

Tips for avoiding generation of excess medical waste include: (1) reduce the generation of waste at the point of source, (2) sterilization and reuse of instrument, and (3) digitization of all clinical records.

## 6.4 Treatment and Disposal

Typical biomedical waste management steps are shown in Fig. 6.4 which are (1) segregation into various components, (2) waste handling and storage, (3) transportation, (3) treatment and disposal.

Rural areas and areas where service of common biomedical waste treatment and disposal facility (CBMWTDF) are not available Health Care Establishments (HCE) shall dispose through captive facility to avoid spreading of infection and toxicity.

A location for storage of biomedical waste should be earmarked inside the establishment generating such waste. Biomedical waste, in bags/containers, should be stored in a separate room, place or building of a size suitable to the quantities of waste generated. Unless a cold storage room is available, healthcare waste should



**Fig. 6.4** Elements of biomedical waste management

not exceed 48 h during the winter and 24 h during the summer in warm climate regions, 72 h in cool season and 48 h in hot season in regions with temperate climate. *Radioactive waste* shall be stored in containers behind lead shielding and should be labelled depicting type of radionuclide, the date, and details of storage conditions required. *Cytotoxic waste* shall be stored away from other biomedical waste in secure location.

Segregation is carried out in biomedical waste management mainly following reasons: (1) to avoid contamination of non-infectious waste by infection, (2) to avoid entry of toxic waste like lead, mercury and radioactive substance, and (3) Entry of chlorinated waste which ultimately leads to generation of dioxins and furans.

Mixing of infected waste with non-infected waste leads to increase in volume of infected waste resulting in increase in volume of infected waste. Figure 6.5 shows waste segregation at source. Figure 6.6 shows a chute conveyor in a modern hospital to transfer waste from individual wards in different floors to a centralized

**Fig. 6.5** A good practice of onsite segregation. The recycle waste like plastic, sharps and non infected waste shall be segregated to avoid generation of dioxins and furans due to combustion of all the waste and avoid increase in infected waste due to contact between infected and non-infected waste



storage area from where different categories of waste will be collected and transported to a common treatment facility. Failure to segregate infected waste at source may lead to rise in treatment and disposal cost as all the waste needs critical treatment and disposal methods to avoid spread of infection. The entry of mercury, lead and radioactive substances will have direct implication in terms of release of these heavy metals and radioactive substance into air, water, food and soil damaging flora and fauna and physic-chemical components of environment.

Apart from lead and mercury health care units use hazardous chemicals like Cidex, Collodion, Coumadin, Epinephrine, Mitomycin C which are irritant and toxic (Shaner-McRae et al. 2007).

Dioxins and furans are groups of toxic substances that share similar chemical structures. These chemicals are persistent and bioaccumulated. Several dioxins are highly carcinogenic and connected with immune, reproductive, endometriosis, endocrine disturbance and behavioral problems in children (Ryan et al. 2002; Rier and Foster 2002; Schettler 2003). Combustion of biomedical waste which has chlorine in its waste is a major source of dioxines and furans.

All the waste should not be incinerated and the following categories need to be avoided for safety and environmental considerations: (1) large amounts of reactive chemical waste, (2) pressurized gas containers, (3) halogenated plastics, (4) sealed ampoules, (5) waste with heavy metals like mercury, cadmium and lead, (6) silver compounds, and (7) photographic/radiographic wastes.

Even though the dental care activities generate small quantity of waste, some waste is highly toxic in nature (Sreenivasa et al., 2010). Cristina et al. (2009) highlight the need for enhancing dental healthcare service waste management.

Table 6.4 shows a summary of the treatment and disposal options for biomedical waste. Table 6.5 shows the major sources of various categories of waste with in a hospital. The major sources of dental care waste are: (1) department of oral medicine and radiology: major waste generated are syringe, lead foil, biopsy specimens and pharmaceuticals, (2) department conservative density and endodontics: major wastes generated in this department are cotton which are soaked in saliva and blood-collected in a container, (3) silver amalgam: amalgam contains



**Fig. 6.6** Chute conveyor in modern hospital to transfer waste from individual wards in different floors to centralized storage area from where different category of waste will be collected and transported to common treatment facility

mercury which is toxic and generate immense amount of mercury vapours and waste while handling them, (4) department of peroidontics: major wastes in this department are tissues and scalpels and blades, (5) department of oral and maxillofacial surgery: this department generates extracted teeth, extracted teeth with amalgam, (6) department of prosthodontics: this department generates *plaster of paris*, stone casts, waxes and acrylic resins, (7) department of pedodontics: this department generates extracted teeth (8) department of orthodontics: this department generates orthodontic bands and arch wires-overnight immersion in 2 % glutaraldehyde.

An absence or poor implementation of legislation especially in the developing nations gives rise to concerns about the environmental as well as public health impacts due to poor storage, collection, handling, recycling and disposal of bio-medical wastes.

Increase in syringe needle has been dramatic in the past three decades prior to which needles were being reused after heat sterilisation. Occupational transmission of blood borne pathogens has been extremely well documented (Shapiro 1995; Mitsui et al. 1992; Polish et al. 1993; Lanphear et al. 1994; Marcus 1998). Sharps from both human health care as well as veterinary institutes pose health risk to people handling them.

Some service providers in the USA can haul the sharps placed in the pre-paid postage box to the treatment facility of sharps through the US Postal Service. After receipt of sharps confirmation of destruction is made available electronically. Even though such practice is yet to catch up in developing countries it can happen in the near future.

Encapsulation (Fig. 6.7) is one of the methods for the disposal of sharps. In encapsulation sharps are collected in leak proof and puncture-proof containers and

**Table 6.5** Checklist depicting major sources of various categories of waste

	Animal Waste	Ash of incinerated biomedical waste	Chemical Waste	Genotoxic	Microbiology and Biotechnology Wastes	Pharmaceutical waste	Pathological Waste	Pressurized containers	Radioactive Waste	Sharps	Soiled Waste	Waste With Heavy Metals
Burn unit			✓			✓	✓	✓		✓	✓	✓
Cardiology			✓			✓	✓	✓		✓	✓	✓
Casualty/Emergency/Trauma			✓			✓	✓	✓		✓	✓	✓
Dentistry			✓			✓	✓			✓	✓	✓
Dermatology			✓			✓	✓			✓	✓	✓
Ear Nose Throat (ENT)			✓			✓	✓	✓		✓	✓	✓
Gastroenterology			✓			✓	✓			✓	✓	✓
Incinerator		✓				✓						
Maternity and Gynecology			✓			✓	✓			✓	✓	✓
Neonatology			✓			✓	✓			✓	✓	✓
Nephrology			✓			✓	✓			✓	✓	✓
Oncology			✓	✓		✓	✓			✓	✓	✓
Ophthalmology			✓			✓	✓			✓	✓	✓
Orthopedic			✓			✓	✓			✓	✓	✓
Pathology					✓					✓	✓	✓
Pediatric			✓			✓	✓			✓	✓	✓
Postmortem						✓				✓	✓	✓
Pharmacy			✓					✓			✓	✓
Psychiatric						✓				✓	✓	✓
Pulmonology						✓		✓			✓	✓
Radiology									✓			
Surgery			✓			✓	✓	✓		✓	✓	✓
Urology			✓			✓	✓			✓	✓	✓
X-ray Department			✓									

when the container is three-quarter full, binding materials like bituminous sand, plastic foam, cement mortar, or clay is poured until the container is completely filled. Medium is then allowed to dry and the containers are sealed and disposed to landfill sites.

Figure 6.8 shows the needle mutilator being used to avoid re-entry of needles into market, but such practice is discouraged in some places considering work place safety.

The risk of infection with HIV after one needle stick exposure is approximately 0.3 % and ranges from 3.3 to 10 % for hepatitis C (Christine et al. 1997).

Figure 6.9 shows sharp pits used for storing needles and other sharps. The pits are provided with small opening from where sharps are dumped into water proof pit with proper lining.

Attempts by health care workers to disassemble sharps waste shall be kept to a minimum. The single uses, self-sealable and locking sharp containers made of plastic are widely used in developed country to protect hospital staff. But the developing countries still continue to discard the sharps in unscientific ways. Law in France has placed the responsibility on the organisations supplying self injection medicines for the disposal of used needles.

Unsafe injections and the subsequent transmission of blood borne pathogens take place regularly in the developing nations. As per the studies conducted by Simonsen et al. (1999) each person in developing nations receives an average of





**Fig. 6.7** Needle encapsulation

**Fig. 6.8** Needle mutilation under progress



**Fig. 6.9** Sharp pits



1.5 injections/person/annum majority of which are not necessary and at least half of the injections in 14 of 19 countries are not safe.

Incineration is not a disposal option for pressurized containers due to the risk of explosion. Undamaged containers like ethylene oxide cartridges or cylinders, nitrous oxide cartridges, cylinders attached to the anaesthesia equipment, pressurized cylinders of oxygen, carbon dioxide, nitrogen, compressed air, hydrogen, cyclopropane, acetylene, petroleum gases, etc., should be returned to the supplier. Damaged pressurized containers which are not suitable for refilling can be crushed after emptied completely, and can be disposed of in landfill.

Sharps can be disposed in a rectangular or circular pit lined with brick/masonry/concrete. The pit should be roofed with heavy concrete slab penetrated by a narrow opening. The pit can be sealed once it is full.

Even though such practice is not observed in many countries, biomedical waste demands special vehicle with proper labelling to identify from a distance and during accidents. The inside of vehicles should be provided with proper racks to store different categories of waste. The floor shall be metallic and smooth to carry out washing and disinfection activity.

#### Box 6.1 Path of expired medicine in supply chain

Medicine from manufacturer is delivered to distributors by carrying and forwarding agencies (C&F agencies). The distributors then pass the medicines to wholesale dealers who in turn pass them on to retail chemists. When the medicines expire they are passed on to backwards. The retail chemist will give it to a whole sale dealer who in turn gives it to a distributor and same shall be passed on to C& F agencies. The C& F agencies shall pass the expired drugs to manufacturer for destruction.

If inter-province movement of the expired drugs within a country is restricted by governing laws, the discarded medicine is destroyed within the province where it is generated and certificate of destruction is submitted to manufacturer and enforcing authorities.

In case of hospitals managed by state governments in India, an inventory of medicine is maintained and excess medicine nearing expiry date is passed on to the other hospitals which has shortage of such medicine.

Pharmaceuticals have increasingly been known as chemical pollutants of the environment (Daughton 2003). For proper handling of hazardous pharmaceutical waste, health care establishments need to create additional waste streams (Smith 2007). Pharmaceutical wastes are usually discarded into the trash or dumped into a sink or toilet and enter the sewer waste stream (Smith 2002) even though bulk of it is disposed by manufacturer/distributors (**Box 6.1**). Most sewage and water treatment facilities do not consider pharmaceutical contaminants; hence these wastes are left untreated and enter surface, ground, and drinking water (Kummerer 2001).

**Fig. 6.10** Expired medicines being segregated from packaging prior to incineration



Figure 6.10 shows common disposal facility wherein pharmaceuticals are separated from their packaging materials. The metal/glass/plastic packing is usually separated to avoid load on disposal facilities. Pharmaceuticals need to be scientifically disposed of by high temperature (i.e. above 1,200 °C) incineration. Pharmaceuticals need particular attention during disasters as large quantities of pharmaceuticals are donated as humanitarian assistance demanding safe disposal if this assistance is unused.

### Segregation

Segregation is the most important procedure in biomedical waste handling. In addition to segregation at source discussed earlier health care establishments also have to provide good transfer point before hauling to treatment/disposal facility. Figure 6.11 shows individual rooms with colour coding so that the different category will not be mixed with each other.

Incineration is one of the economical ways of destructing pathogens. Figure 6.12 shows batch type double chambered incinerator. The rotary incinerators are available in the range of 0.5–3 tons/hour and hence are appropriate if the quantity to be treated is high. But it is appropriate to make feasibility study before finalizing the incinerator.

Batch type biomedical incinerator shall have two chambers and shall have at least 99.00 % combustion efficiency (C.E).

The combustion efficiency is calculated using equation:

$$\text{Combustion efficiency} = (\% \text{CO}_2)(100)/(\% \text{CO}_2 + \% \text{CO})$$

When biomedical wastes are loaded with halogenated chemicals, dioxins/furans and other toxic air pollutants may be generated. The gases generated in primary chamber are heated to high temperatures to destroy gaseous organic compounds.

The temperature at primary chamber shall be  $800 \pm 50$  °C from where gases enter secondary chamber maintained at  $1,050 \pm 50$  °C where gas residence time should be at least one second, with at least 3 % oxygen in the stack emission.

**Fig. 6.11** Individual rooms with colour coding as per local legislation or protocol will increase chances of cross contamination and reduce cost of treatment and disposal incineration



**Fig. 6.12** Biomedical waste incinerator



Further efficient segregation of plastics at source to eliminate PVC will also help in tackling generation of dioxins and furans.

Rotary kiln operates at 1,200–1,600 °C allowing decomposition of persistent chemicals such as PCBs. The rotary kilns have a slope of 3–5 % and rotate 2–5 turns per minute. The waste is inserted at the top and ashes are emptied at the bottom of the kiln. Gases from primary chamber are heated to elevated temperatures to destroy gaseous organic compounds and usually have a residence time of two seconds. Biomedical waste incineration is one of the main sources of dioxin and furan (Lerner 1997; Walker and Cooper 1992; Vesilind et al. 2002).

Incineration is an option to dispose of pharmaceutical waste but low-temperature incineration (<800 °C) provides only limited treatment. Hence a dual chambered incinerator discussed above is used. Pharmaceuticals are treated in incinerators which operate at high temperatures (>1,200 °C). In many nations cement kilns are also used for disposal of treatment of pharmaceutical waste.

**Fig. 6.13** Autoclave

### **Autoclaving**

The autoclave should be dedicated for treating biomedical waste. Figure 6.13 shows biomedical waste autoclave. The biomedical waste should be subjected to (1) a temperature of more than 121 °C and pressure of 15 pounds per square inch (psi) for a residence time of more than 60 min, or (2) a temperature of more than 135 °C and a pressure of 31 psi for a residence time of more than 45 min, or (3) a temperature of not less than 149 °C and a pressure of 52 psi for a residence time of more than half an hour.

While operating a vacuum autoclave, biomedical waste should be subjected to a minimum of one pre-vacuum pulse to eliminate the air from autoclave.

Biomedical waste shall be considered properly treated only when the time, temperature and pressure indicators indicate required temperature, pressure and time were reached during the autoclave process. If for any reasons, temperature, pressure or time indicator indicates that the required values was not reached, the entire biomedical waste must be autoclaved again till the proper temperature, pressure or time are achieved.

The autoclave should be completely and constantly kill biological indicator at the maximum design capacity. Common biological indicator for autoclave is bacillus stearothermophilus spores. Vials or spore strips of indicators with at least  $1 \times 10^4$  spores per millilitre are used for testing. Autoclave used for treating biomedical waste shall have a residence time of more 30 min, regardless of temperature and pressure, a temperature more 121 °C or a pressure more 15 psi.

A chemical indicator tape/strip that changes colour when a temperature is reached can be used to confirm that a specific temperature is achieved. It is prudent to use more than one strip over the waste package at various locations to make sure that the entire package is adequately autoclaved.

### **Shredding**

Shredding is carried out to avoid re-entry of contaminated plastic and glass items to market. Figure 6.14 shows shredding process under progress. The shredded plastic and glass can then be reprocessed for manufacture of new items.

**Fig. 6.14** Biomedical waste being fed into the shredder



### **Hybrid treatments**

These are the treatment units in where two or more treatment processes are carried out simultaneously. Typical examples include hydroclave wherein shredding and autoclaving is carried out simultaneously. Another example includes microwaving and autoclaving being carried out in single equipment.

Rotating-blade shredders are most widely used in shredding biomedical waste. They consist of blades attached to wheels rotating in opposite directions.

### **Microwaving**

Microwave treatment should not be used for cytotoxic, hazardous or radioactive wastes, contaminated animal carcasses, body parts and large metal items. Presence of metal leads to sparking and possibly health hazards. The microwaving demands comparatively higher investment and proper segregation of waste.

### **Deep Burial**

Deep burial pits are recommended and used in rural and isolated areas where it is not prudent to invest huge amount of money. Figure 6.15 shows a typical deep burial facility. A deep burial pit/trench is dug approximately two metres deep. The biomedical waste shall be half filled and covered with lime followed by soil. This method needs adequate precaution so that animals do not have access to burial sites. Proper covers of sheet metal or wire meshes may be used. When wastes are inserted to the pit, a layer of approximately 10 cm of soil should be spread to cover the wastes. The deep burial site should be relatively impermeable. No shallow well shall be close to the deep burial pit. The pits should be away from habitation, and sited in such a way that no surface water or groundwater contamination occurs. The deep burial location shall not be prone to erosion or flooding.

H5N1 strain of avian flu originated from China in 1996 spread rapidly across Asia, Europe, and Africa. The presence of was confirmed in birds/humans in more than 55 countries (Ganesh et al. 2008). The main means of transmission to humans was through contact with infected live poultry and surfaces contaminated with

**Fig. 6.15** Biomedical waste deep burial facility



secretions/excretions of infected birds. Avian flu outbreak during 2003 and 2004 resulted in the death/destruction of 44 million Birds and 29 million birds, in Vietnam and Thailand respectively. As of mid-2006, about 200 million domestic birds had either died or culled (FAO 2012).

About 24 tonnes of poultry feed, about 28 thousand eggs, and more than 3 lakh birds were destroyed after 2007 avian flu outbreak in Manipur district of India along with contaminated material from 166 farms in the infected zone (Ganesh et al. 2008).

Birds during out break were usually killed by decapitation (Cutting head) or by feeding poisons. Some farms used sedatives mixed with water prior to culling operation. The culled bird were packed in bas and disposed within farm premises. During the past outbreaks of avian flu announcement were made in some countries asking owners of backyard poultry birds not to release the birds in the morning so that veterans could collect birds in the next morning making cash payment.

As per, the infected birds can be disposed off by open fire or deep burial. Even though it is well known fact that uncontrolled combustion would lead to air emissions, creating such infrastructure during epidemics is not possible within few days/hours. The wood requirement will be around 500 kg per 100 kg of dead birds. Deep burial with a dimension of  $2 \times 2 \times 2$  m would accommodate 1,800 dead birds. It is necessary to ensure the groundwater levels to avoid groundwater contamination.

Apart from infected birds, infected material in poultry like meat, eggs, egg trays, used litter, manure, feather, feed, feed ingredients, and manure, cloths used by farm personnel, drugs and vaccines should also be destroyed by deep burial or open burning. While it is recommended that crops grown in the farm should be uprooted and buried/burnt, it is not practiced by farmers as they cannot afford financial shock.

DAHDR (Department of Animal Husbandry, Dairying and Fisheries), Ministry of Agriculture, Government of India, 2006: Action Plan of Animal Husbandry for Preparedness, Control and Containment of Avian Influenza.

**Fig. 6.16** Biomedical waste being chemically treated



### **Chemical Treatment**

Chemical treatment can be both on- and off site. While it is recommended to use disinfectant a point of generation with respect to sharps, other wastes can be disinfected as shown in Fig. 6.16. Chemical treatment is the choice where power is not available to operate autoclave or any other equipment which demands power. Chemicals are added to the waste to kill or inactivate the pathogens in biomedical waste. The choice of chemical depends on the availability of chemical and safety of the operator. It is essential that large biomedical waste and waste with cavity be shredded for better efficiency. Table 6.6 shows commonly used chemical disinfectants in which can be used for disinfection of biomedical waste. 1 % (of active chlorine) sodium hypochlorite is most commonly used disinfectant due to safety reason but care should be taken to treat the waste while active chlorine is still present as chemical is not stable.

### **Needle Encapsulation**

Needles are often source of infection spreading and hence need extra care for avoiding re-entry into user stream.

## **6.5 Radioactive Waste**

Management of radioactive waste from health care establishments should follow appropriate national legislation. The waste may be suitable for release after some days to a few years. If a release is not permitted as per law, waste should be returned to the supplier/producer of the original material.

Waste that can neither be returned nor released to the supplier/producer, waste should be destined to a disposal facility or a facility for long term storage for future disposal after treatment or conditioning of waste.

Containers of radioactive waste should be marked as 'RADIOACTIVE WASTE' with the radiation symbol. The container should be labeled with



**Table 6.6** Commonly used chemical disinfectants which can be used for disinfection of solid wastes

Chemical	Application	Physical and chemical properties	Health hazards
Chlorine dioxide	Active against most bacteria, viruses, and spores	Reddish-yellow gas at ambient temperature reacts with water/steam to generate corrosive fumes of hydrochloric acid; explosion limit: >10 % in air	Irritant to skin, eyes, and respiratory tract; toxic
Sodium hypochlorite	Active against most viruses, bacteria, and spores; not effective for disinfection of liquids with high organic content like blood or stools	Available as aqueous solution with 2–12 % of active chlorine; solutions of low concentration are more stable; decomposes at ambient temperature into sodium chloride, sodium chlorate and oxygen; reacts with acids to generate hazardous chlorine gas; light will accelerate decomposition	Irritant to eyes, skin, and respiratory tract; toxic
Glutaraldehyde	Active against both bacteria and parasite eggs	Available in 25–50 % aqueous solutions; shall be used with acetate buffer as 2 % aqueous solution	Concentrated solutions are irritant to skin and eyes
Ethylene oxide	Inactivating effect against all micro-organisms	Flammable and explosive above 10 °C at concentrations of 3 % and above in mixtures with air; soluble in water and many organic solvents; very reactive at ambient temperature	Extremely irritant to skin and eyes; classified as a human carcinogen
Formaldehyde	Inactivating effect against all micro-organisms; can be used for dry, solid waste, in combination with steam at 80 °C. Contact time: 45 min	Gas at ambient temperature; polymerizes at temperatures below 80 °C; flammable and explosive at concentrations of 7–73 % in mixtures with air; reactive at ambient temperature. Formalin is a 37 % solution of formaldehyde	Irritant to skin, eyes, and respiratory tract; toxic. Formaldehyde is classified as a probable human carcinogen

information required by statute such as origin of the waste, period of storage required, quantity, responsible person, etc.

Storage facilities for radioactive waste shall have the following characteristics:

- Shall have adequate capacity to store waste generated prior to treatment, or transportation,
- Shall have non-flammable walls and floors,
- Shall have simple construction,
- Floor shall be impermeable and constructed in a way that it can be easily decontaminated,
- Shall be fire-resistant and have lockable doors,
- Shall have adequate ventilation,
- Shall have arrangement for air sampling and radiation alarms,
- Shall have fire control/detection equipment as required by per statute,
- Shall have compartments to store different kinds of waste,
- Shall have demarcation as required by regulatory authority,
- Shall have a record keeping mechanism about all the information required as per statute,
- Shall provide protection to waste from weather, and
- Shall have movable radiation shielding to protect workers from radiation.

#### **Treatment and conditioning**

Treatment is carried out to enhance the characteristics of waste before storage/disposal. The basic objectives of the treatment are:

Volume reduction (for liquid waste: evaporation under controlled conditions, for solid waste: low-force compaction, shredding, and controlled incineration).

Removal of radionuclides (for liquid waste: ion exchange, for solid waste: decontamination).

Change of composition (for solid waste: not applicable, for liquid waste: precipitation/filtration).

Treatment processes can result in the generation of secondary radioactive wastes (spent resins, contaminated filters, sludge, ash) and they should be managed appropriately.

Conditioning is used for converting radioactive waste to a form which is more suitable for handling. The operations include (1) placing the waste in suitable containers, (2) immobilization of radioactive waste in concrete, (3) and providing additional packaging.

#### **Precautions for handling radioactive waste**

1. Disposal of sharps containing radioactive residues shall be carried out after storing the same until radiation reaches permissible limits,
2. Radioactive solid waste should not be treated by autoclave or microwave,
3. Solid radioactive waste like bottles, glassware, and containers shall be deformed/mutilated before disposal to avoid reuse,
4. Radioactive waste shall be stored for decay in labelled containers, under lead shielding, until radiation reaches permissible limits,

5. Spilled radioactive waste shall be retained in suitable containers until the radiation reaches permissible limits, and
6. Patient's excreta after diagnostic procedures shall be checked frequently for radioactive contamination.

## 6.6 Mercury in Biomedical Waste

Health care facilities contain an array of mercury-containing products, e.g., medical instruments, clinical laboratory chemicals (fixatives, stains, reagents, preservatives, dental amalgam, electrical equipment, mercury cells (batteries), fluorescent lamps and cleaning solutions.

Mercury based instruments used in health care facilities include:

1. Thermometers (used for measurement of body temperatures),
2. Sphygmomanometers (used for measurement of blood pressure),
3. Esophageal dilators (bougie tubes),
4. Feeding tubes,
5. Miller Abbott tubes and Cantor tubes (used to clear intestinal obstructions),
6. Gastrointestinal tubes,
7. Intraocular pressure devices,
8. Strain gauge,
9. Urinometer,
10. X-Ray Machines, and
11. Barometers in respiratory therapy.

Breakage of the above instruments can result in a potentially hazardous spillage affecting humans and environment.

Strategies for management of mercury containing waste in health care facility include:

1. Separation of reusable and non-reusable mercury containing products,
2. Recycling mercury-containing goods,
3. Proper handling/disposal of mercury and mercury contaminated waste, and
4. Using alternatives for products that contain mercury.

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