Radioactive and Hospital Waste Management: A Review

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Abstract - It has been a long since problem of waste treatment and their disposal. Waste management does create a major problem if it is not properly performed. Various problems including different side effects occur to the people where untreated or partially treated waste is disposed, thus care should be taken while waste management and disposal. It becomes more difficult a job to perform radionuclide therapy treatment waste management and their disposal, thus a novel technique has been invented with certain modifications from a past segregated technique known as BioChroma. Waste from the hospitals are also harmful and should be managed properly in order to ensure no side effects from the waste toxins that are disposed off in various water bodies, land dumping zones, etc. Especially care should be taken of cytotoxic and antineoplastic class of drugs that has the capability to ensure cure of patients as well as the capability to take lives if not treated properly before disposal.

Keywords: waste management, BioChroma, cytotoxic drugs, antineoplastic drugs, radionuclide therapy.

I. INTRODUCTION

Today's world is facing a genuine problem of remediation of toxic waste materials generated from the one so needful sector of biology that is impossible to avoid, i.e., Medicine. In the medicine sector or the sectors concerning public health matters there has been a boom in the past decade in the use of novel drugs and novel techniques, but little concern is shown regarding the environmental effects of these toxins and the side effects of the various techniques used for to cure patients. Rather cure is becoming a curse for the people where the toxic materials are dumped from these health care institutions. A major curse in India has always been radioactive waste treatment and their disposal.

Radioactive wastes management refers to the degradation of toxic radioactive substances that can harm the environment by it degradation products. Radionuclide therapy is one of the best techniques known to man for treatment of various deadly diseases such as cancer (1). This therapy includes use of various radioisotopes of which I131 plays a major role in treatment of thyroid glands. Patients undergoing treatment with the radionuclide incorporate in them substantial amounts of radioactivity in their generated wastes. The waste generated can contain upto 90% of the administered radioactivity according to the level of radionuclide therapy the patient has undergone during the therapy(2). The radioactive half-life is 8.02070 days of I131, thus there is a considerable chance of accumulation of the radioactive wastes in the sewer tanks and thus when disposed to the environment can cause serious damage to the natural flora and fauna if not treated first. Thus it is very much advisable to collect the waste generated from the patients who has undergone radionuclide therapy in a separate container for its treatment and its safe disposal (3-8).
As of now there are two management systems that is practically used for the treatment of radioactive waste management from the patients undergoing radionuclide therapy.

1) Delay and Decay.

2) Biochroma.

1) Delay and Decay.

Delay and decay is the most conventional method used by various organizations, institutions, research facilities and hospitals to safely manage the radioactive waste materials. It is basically used for the abation of the radionuclide I^{131} . Its process is a very complex one and needs a high cost funding agency to fund for the remediation process [(9-13)]. I^{131} ablation therapy depends on the dosage of the radionuclide incorporated. It may be seen in several cases that loss of taste, pain in the neck, sialoadenitis and gastritis occurs as a result of radionuclide remnants due to the incorporation. [(14)]

2) Biochroma:

BioChroma is a new and patented biological treatment system with a final adsorption phase. This technology is based on a thorough optimization of wastewater treatment concepts, which are based on the physical principle of chromatography and were developed and built in the late 1970s. But due to its high cost and high man power involvement this technique was not used since. The adsorption stage uses an activated carbon that used to be changed frequently thus was a major problem in cost effectiveness. BioChroma was developed as an alternative to these complicated and expensive systems, whereby the fundamental elements of the chromatography-based technology were used and optimized.

The BioChroma system (Figure 1) collects the wastewater generated at the radiological therapy ward in buffer tanks fed by special pumps, which are fitted with a device that shredders the solid matter and thus homogenizes the effluent. Equipped with an aeration system, these holding tanks act as a precursor to the biological treatment stage, as well as they help to avoid anaerobic processes and their associated problems of unpleasant odors.

Before reaching the biological treatment plant, the wastewater is preclarified at a sedimentation stage, where larger particles, which might hinder the performance of the activated sludge in the biological reactor, are separated.

The next process step is an optimized biological treatment plant that is installed upstream of the final adsorption and filtration stage. This biological reactor is comparable to a small plant for processing municipal wastewater. It is equipped with a secondary clarification stage and a filter to separate any suspended solids. Thus, final organic contamination is reduced to a minimum and the downstream adsorption filter system can be protected against undesired clogs.

The mentioned final adsorption filter line consists of activated carbon filters and selective ion exchangers for eliminating the dissolved radioactive components in the wastewater before it is collected in the final storage tanks, where it is subject to constant monitoring, before being ultimately discharged into the sewage system. (15)

II. ADVANTAGES OF BIOCHROMA PROCESS:

The advantages offered by the BioChroma technology compared with processing systems based on the delay and decay principle are in the following list:

- Overall space requirements can be reduced by 50% thanks to its high degree of technological innovation and lower requirement of reaction volumes.
- The combination of the various process steps allows a more flexible continuous operation.
    - The system provides sufficient capacity to absorb sudden peaks, thus offering considerably enhanced comfort to final users (e.g., unlimited shower water operation).
    - The nuclear medicine department can be temporally extended (by up to 30 %) on short notice.
- Unpleasant odors do not present any problems whatsoever throughout the entire system, due to the absence of anaerobic zones.
- A fully automated operation allows savings in personnel costs.
- Elimination of the risk of possible leakages or cross-contamination of the various radioactive effluents (a main issue to be dealt with in delay and decay plants).
- Fewer safety measures have to be taken, since large holding tanks and their associated collecting basins (which are normally installed in systems that adopt the delay and decay principle) are not needed anymore.

- BioChroma systems are easy to install, irrespective of any on-site obstacles (e.g., cellars with a difficult access).

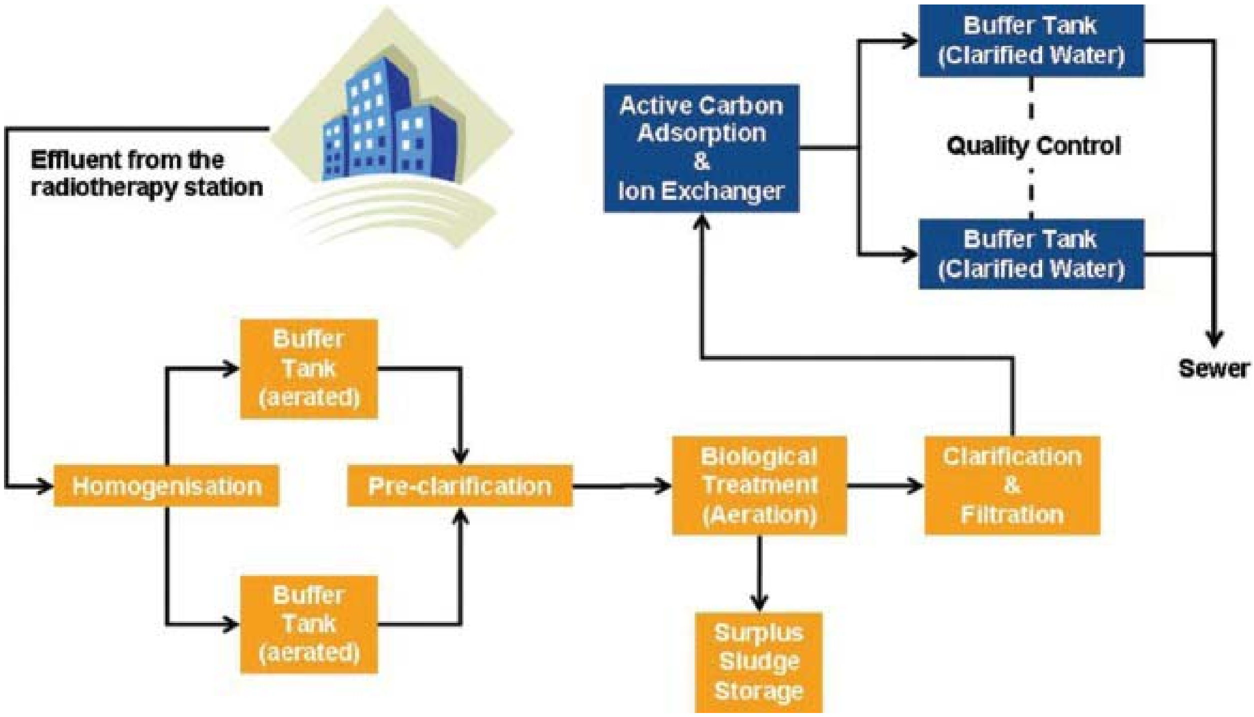

Figure 1

III. BIO-MEDICAL WASTE:

Bio-medical waste means any solid, fluid or liquid waste including the containers or any intermediate product. It is generated during the diagnosis, treatment or immunization process of the patients [16]. Biomedical waste management is required due to health, environmental, legal and aesthetic reasons in addition to ethical reasons. There are many harmful agents in the Bio-medical wastes. They pollute water and food and cause alimentary infections like cholera, typhoid, dysentery, infective hepatitis, polio, ascariasis and hook worm diseases. It can be categorized

based on the risk of causing injury and/or infection during handling and disposal[17]. The physico-chemical and biological nature of these components, their toxicity and potential hazard are different in nature. The biomedical waste originating from different kinds of such establishments has been categorised into 10 different categories.

Components of biomedical waste:-

1. Human anatomical waste
2. Animal waste
3. Microbiology and biotechnology waste
4. Discarded medicines and cytotoxic drugs
5. Waste sharps such as hypodermic needles, syringes, broken glass etc.
6. Solid waste such as bandages, plaster casts
7. Solid waste
8. Liquid waste generated from any of the infected areas
9. Chemical waste
10. Incineration ash

Health hazards associated with poor management of Bio-medical waste

(i) Injury from sharps to staff and waste handlers associated with the health care establishment.

(ii) Hospital Acquired Infection/HAI (Nosocomial) of patients due to spread of infection.

(iii) Risk of infection outside the hospital for waste handlers/scavengers and eventually general public.

(iv) Occupational risk associated with hazardous chemicals, drugs etc.

(iv) Unauthorised repackaging and sale of disposable items and unused / date expired drugs

According to the WHO, the global life expectancy is increasing year after year. However, deaths due to infectious disease are increasing. It was seen from a study conducted by the WHO in 1996 that more than 50,000 people die everyday from infectious diseases. One of the major factor for the increase in infectious diseases is improper waste management. The list of infections and diseases documented to have spread through bio-medical waste are- tuberculosis, pneumonia, diarrhoeal diseases, tetanus, whooping cough etc., are other common diseases spread due to improper waste management (18-20).
The proper management of biomedical waste has become a worldwide humanitarian topic today (21).

IV. Hospital waste:

Service to mankind has been the only aim of the hospitals. From the beginning, the hospitals are known for the treatment of sick persons but we are unaware about the adverse effects of the garbage and filth generated by them on human body and environment. Nowadays it is a well established fact that there are many adverse and harmful effects to the environment including human beings which are caused by the "Hospital waste" generated during the patient care. It is now a matter of concern about the problems of waste disposal in the hospitals (22). Hospital waste is a potential health hazard to the health care workers, public and flora and fauna of the area. Hospital acquired infection, transfusion transmitted diseases, rising incidence of Hepatitis B, and HIV, increasing land and water pollution lead to increasing possibility of catching many diseases. Air pollution due to emission of hazardous gases by incinerator such as Furan, Dioxin, Hydrochloric acid etc. have compelled the authorities to think seriously about hospital waste and the diseases transmitted through improper disposal of hospital waste. This problem has now become a serious threat for the public health and ultimately, the Central Government had to intervene for enforcing proper handling and disposal of hospital waste and an act was passed in July 1996 and a bio-medical waste (handling and management) rule was introduced in 1998.

A modern hospital is a complex, multidisciplinary system which consumes thousands of items for delivery of medical care and it is a part of physical environment. All these products consumed in the hospital leave some unusable leftovers i.e. hospital waste. The last century witnessed the rapid mushrooming of hospital in the public and private sector, dictated by the needs of expanding population. The advent and acceptance of "disposable" has made the generation of hospital waste a significant factor in current scenario. Thus hospital waste management is a necessary thing to carry out so that the environment does face its toxic effects. Hospital waste refers to all waste generated, discarded and not intended for further use in the hospital (22).

Classification of hospital waste

(1) **General waste:** Largely composed of domestic or house hold type waste. It is non-hazardous to human beings, e.g. kitchen waste, packaging material, paper, wrappers, plastics.
(2) **Pathological waste:** Consists of tissue, organ, body part, human foetuses, blood and body fluid. It is hazardous waste.
(3) **Infectious waste:** The wastes which contain pathogens in sufficient concentration or quantity that could cause diseases. It is hazardous e.g. culture and stocks of infectious agents from laboratories, waste from surgery, waste originating from infectious patients.
(4) **Sharps:** Waste materials which could cause the person handling it, a cut or puncture of skin e.g. needles, broken glass, saws, nail, blades, scalpels.
(5) **Pharmaceutical waste:** This includes pharmaceutical products, drugs, and chemicals that have been returned from wards, have been spilled, are outdated, or contaminated.
(6) **Chemical waste:** This comprises discarded solid, liquid and gaseous chemicals e.g. cleaning, housekeeping, and disinfecting product.

(7) **Radioactive waste:** It includes solid, liquid, and gaseous waste that is contaminated with radionucleides generated from in-vitro analysis of body tissues and fluid, in-vivo body organ imaging and tumour localization and therapeutic procedures [23].

Pharmaceutical waste thus can be categorised into two sub-divisions:
1) Cytotoxic drugs.
2) Antineoplastic drugs.

V. CYTOTOXIC DRUGS AND THEIR EFFECTS:

Cytotoxic drugs are primarily used as anti-cancer agents [24-25]. Cytotoxic drug is the by-product of cytotoxic drug therapy administered to patients. All cytotoxic waste must be collected in ***purple*** containers, which clearly display the telophase symbol in white together with the wordage "Cytotoxic Waste" printed on the container [26].

Cytotoxic drugs are highly toxic to cells, mainly through their action on cell reproduction. Many have proved to be carcinogenic, mutagenic or teratogenic [27-29].

Cytotoxic waste includes any residual cytotoxic drug following a patient's treatment, and the materials or equipment associated with the preparation, transport or administration of the drug therapy. Cytotoxic drugs are primarily eliminated from the patient by renal and hepatic excretion.

Exposure to cytotoxic waste may occur through removing or inserting catheters, handling vomitus, blood, excreta or fluid drained from body cavities.

To minimise the risk of exposure to cytotoxic waste, control measures may include:

>> Elimination, substitution or isolation of identified high risk activities

>> Engineering or automated methods to minimise the amount of handling

>> safe systems of work for identified waste management activities – segregation, packaging, storage, transport, administration and disposal.

>> Identification of cytotoxic waste through designated labelling, and use of purple bags and containers

>> Managing cytotoxic waste generated by outpatients and domiciliary services under the direction of the referring health care facility

>> Training of supervisors, workers and all those who may be exposed to contaminated waste

>> Maintaining records and tracking cytotoxic waste in accordance with the requirements of the EP Act and Waste Policy

>> A transport and disposal flowchart covering internal and external activities from waste generation to treatment and destruction

>> Appropriate personal protective equipment for identified waste management activities [27].

Current perspective in India:

But in India, though all the components of waste management are present, yet their implementation is being interfered with owing to several reasons. Lack of manpower training, improper periodic survey of machinery functions, poor availability of waste collecting bins or plastic bags and more dependence on manual disposal of wastes rather than automated methods pose a significant problem in the process of Biomedical waste disposal. Though the 'waste tracking' system has recently been introduced in the state of Gujarat in order to minimise faulty disposal of wastes, but the system awaits yet to be implemented in the other states of the country.

The main speedbreaker in the path of waste disposal in India remains in the administrative levels and not at the level of implementation of techniques. So the solution lies in the recruitment of a supervising committee composed of highly competent individuals from different professional fields viz. doctors, pharmacologists, biomedical waste disposal authority, naturalists and biomedical waste neutralizing agencies. These individuals from the different fields of specialization will be able to detect the existing loopholes in the present day waste disposal system of this country. The biomedical wastes are often left untreated due to non-functioning of instruments like incinerators, etc. Such unwanted delays can be avoided by the use of simpler techniques such as inertization and chemical disinfection. Though the use of double chambered pyrolytic incinerators is the best approach, yet in countries like India where the instruments are not properly installed or repaired, simpler methods may be acceptable. Chemical disinfection with sulfuric acid or potassium permanganate can be done as an alternative means to incineration. But these can never replace the superiority of incineration technique. Therefore, the best logical way seems to be packing and transportation of the cytotoxic drugs to the original supplier so that they can be properly processed and disposed off as per international guidelines.

The second most important loophole lies in the irresponsibility of the personnel employed for proper disposal of the wastes. This can be overcome by introduction of good quality trackers to ensure that the wastes are being properly transported to the sites as specified. And also time to time monitoring of the trackers is needed to see if they are properly working.

Finally, the best means to overcome the health hazards from improper disposal of biomedical wastes lies in the realization of the duty of the administrative staff towards their people. No technique can be more sound than the responsibility of the people themselves to outrun the unwanted hazards of improper waste disposal. (28)

VI. Antineoplastic Drugs and their effects:

Antineoplastics are the drugs that prevent or inhibit the maturation and proliferation of neoplasms. .

Antineoplastic agents travel the body and destroy cancer cells. Many of the side effects associated with antineoplastic agents occur because treatment destroys the body's normal cells in addition to cancerous cells.

General Toxicities of Antineoplastic drugs are:

- Bone marrow depression
- Lymphocytopenia
- GIT Stomatitis
- Diarrhoea
- Nausea and Vomiting
- Alopecia
- Hyperuricaemia
- Hair loss

Antineoplastic drugs are not only used prominently in different types of cancers but also in conjunction with surgery, radiotherapy and immunotherapy in the combined modality approach for many solid tumors, especially metastatic.

Classification of Antineoplastic Agents:

1. Alkylating Agents
    - Nitrogen mustards: Melphalan, Cyclophosphamide, Ifosfamide
    - Nitrosoureas
    - Alkylsulfonates
    - Ethyleneimines
    - Triazene
    - Methyl Hydrazines
    - Platinum Coordination complexes: Cisplatin, Carboplatin, Oxaliplatin
2. Antimetabolites
    - Folate Antagonists: Methotrexate
    - Purine antagonists
    - Pyrimidine antagonists: 5-Fluorouracil, Cytarabibe
3. Natural Products
    - Plant Products
        - Vinca Alkaloids: Vincristine, Vinblastine
        - Taxanes: Paclitaxel, Docetaxel
        - Epipodophyllotoxins: Etoposide
        - Camptothecins: Irinotecan
    - Microorganism Products
        - Antibiotics: Doxorubicin, Bleomycin

- Enzymes: L-Asparaginase

4. Miscellaneous
    - Hydroxyurea
    - Imatinib Mesylate
    - Rituximab
    - Epirubicin
    - Bortezomib
    - Zoledronic Acid
    - Geftinib
    - Leucovorin
    - Pamidronate
    - Gemcitabine

5. Hormones and Antagonists
    - Corticosteroids: Prednisone, Dexamethasone
    - Estrogens: Ethinyloestradiol
    - Antiestrogens: Tamoxifen
    - Progesteron derivative: Megestrol Acetate
    - Androgen: Testosterone propionate
    - Antiandrogen: Flutamide , Bicalutamide
    - Aromatase inhibitor: Letrozole , Anastrazole
    - 5-alpha reductase inhibitor: Finasteride
    - GnRH Analogue: Leuprolide, Buserelin
    - Growth Hormone, glucagon and insulin inhibitor: Octreotide [30-39]

VII. CHARACTERISTICS OF ANTINEOPLASTIC DRUGS:

Antineoplastic drugs that are volatile must not be used in a biological safety cabinet unless the cabinet is vented to the outdoors [30-35].

The toxicity of antineoplastic drugs has been well known since they were introduced in the 1940s. Because most antineoplastic drugs are nonselective in their mechanism of action, they affect noncancerous as well as cancerous cells, resulting in well-documented side effects. During the 1970s, evidence came to light indicating health care workers may be at risk of harmful effects from antineoplastic drugs as a result of occupational exposure [36].

Antineoplastic drugs are part of a larger group called “hazardous drugs” [37].

Any drug or substance that has the potential to cause harm to a person’s health upon exposure can be said to be hazardous. A hazardous drug should have one or more of the following characteristics in humans such as genotoxicity, carcinogenicity, reproductive toxicity, teratogenicity or other developmental toxicity. Therapeutic agents including antineoplastic, cytotoxic agents can be classified as hazardous drugs.

These drugs could be potentially hazardous to human health [38].

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