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Review on hospital wastes and its possible treatments

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ABSTRACT

Medical waste management is of a great importance due to its potential impact to environment and consequently to human health. In the recent years, many efforts have been made by environmental regulatory agencies and waste generators to better managing the wastes from healthcare facilities. In the past, medical waste was often mixed with municipal solid waste and disposed in residential waste landfills or improper treatment facilities.

INTRODUCTION

In the course of health protection, there are many medical wastes include medical treatment materials and scientific research; it forms a separate category of medical or health care waste (Ropeik and Gray, 2002). The fraction of waste generated at medical institutions, known as special or regulated medical waste (Lee *et al*., 2004) or otherwise known as clinical waste (WHO, 1994), has not attracted the same level of attention as other types of wastes, particularly in developing countries, despite the fact that medical waste is labeled as hazardous because it poses serious and direct threat to human health (Coad, 1992; WHO, 1999).

In many developing countries, no proper and efficient rule has been compiled as yet to deal with medical wastes management and also there is no useful information available. In this review the author is focusing on hospital wastes management, the condition of waste segregation, the types of wastes treatments and solving the identified problems were suggested.

Hospital wastes nature

"Hospital wastes" refers to all wastes, biological or non biological from hospitals, that is discarded and not intended for further use and these include: pathological, infectious, hazardous chemicals, radioactive wastes, stock cultures, blood and blood products, animal carcasses, pharmaceutical wastes, pressurized containers, batteries, plastics, low level radioactive wastes, disposable needles, syringes, scalpels and other sharp items. These are in addition to food wastes, clinical bandages, gauze, cotton, cotton and other miscellaneous wastes. Other types of waste include toxic chemicals, cytotoxic drugs, flammable and radioactive wastes that can often be considered infectious (Caltivelli, 1990).

Health care waste consists of solid, liquid and gaseous waste contaminated with organic and inorganic substance including pathogenic radionuclide generated from in vitro analysis of body microorganisms. Hospital waste possesses serious tissues and fluid. WHO (1999) reported that, about 85% of health hazard to the health workers, public and air hospital waste is non-hazardous, 10% infective and 5% flora on the area not infective but hazardous. In India, it was reported that the value could generated within the hospital environment could be increased from 15% to 35% depending on the total groups amount. In Pakistan for example about 20% non-hazardous particles such as kitchen waste, paper and

of hospital waste could be found potentially infective or plastics, parts of human, foetus, blood and body fluid, hazardous (Agarwal 1998).

Sources of pharmaceutical products in the culture and stock of infective agents from laboratory environment are more than just consumers expelling waste, waste from surgery, etc, shape waste, waste unabsorbed medications through excretion into septic material that could cause damages to the handling systems and wastewater treatment plants. Sewage and pharmaceutical wastes, this includes pharmaceutical products (drugs and chemicals) that have been returned has been adversely being abused by anthropogenic from wards, contaminated or expired products, chemical influence. This includes liquid waste discharged from waste which comprises of discarded solid or liquid and domestic home, industries, agricultural and commercial gaseous chemical and radioactive waste, which includes sectors (Akter *et al.* 1999).

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Other sources include the animal farms washes, crop production and fish farms, where from the generator set enters the drainage, sampling point pharmaceutical products are used as growth promoters or is the point at which the washings from the laundry and as preventive maintenance. Hazardous medical waste washings from the dietary building enter chemicals and discarded cytotoxic drugs. Their presence in the environment drainage possesses serious environmental health risk due to their wastewater is emptied into the soil carcinogenic natural (Akter *et al.*1998; Shaner 1997).

As regards live pathogens found in hospital wastes, it was found that the most predominant is the genus *Bacillus* (80 - 90%) with *Staphylococci* and *Streptococci* varying between 5 and 10%, whereas the most common pathogens is *Staphylococcus aureus* (from 2 - 10 colonies per gram of waste). *Escherichia coli*, *Pseudomonas aeruginosa* and *Candida albicans* are also common along with varying numbers of other common nosocomial pathogens such as *Klebsiella Proteus* and *Enterobacter* species. The survival rate of the viruses has revealed that most material that is present in hospital wastes is able to carry viruses keeping them alive for several days (5 – 8 days). However the viral titre tends to decrease rapidly as time passes for example the hepatitis B virus has been detected but its potential to provoke infection has not been established.

The pathogens present in the wastes can leach out and contaminate ground water and surface water. Harmful Chemicals present in biomedical waste such as heavy metals can also cause water pollution; poor land filling technology may cause water pollution in the form of leachates. Excess nutrient leachate such as nitrates and phosphates from landfills. Water pollution can alter parameters such as pH, Biochemical Oxygen Demand (BOD) and Chemical Oxygen Demand (COD). There are instances where dioxins are reported from water bodies near incinerating plants. Dioxins enter the water body from the air (Annon, 2004). The effect of twenty four hospital wastes

samples taken from different hospitals waste dumpsites on its surrounding soil was examined. The counts of microorganisms in hospital dumpsite soil include the following; aerobic heterotrophic counts from 4.2 x 10^5 to 1.6 x 10^{10}, anaerobic heterotrophic counts from 1.0 x 10^5 to 1.6 x 10^9 while fungi counts from 0 to 6.9 x 10^6. The counts in soil adjacent to dumpsites include the following; aerobic heterotrophic counts from 1.0 x 10^5 to 4.0 x 10^9, anaerobic heterotrophic counts from 1.0 x 10^5 to 5.0 x 10^8, while fungi counts is between 0 to 1.0 x 10^6. Bacteria isolated at the soil dumpsite and soil adjacent to dumpsites include, respectively, *Bacillus* sp. (42.86 and 45%), *Micrococcus roseus* (14.29 and 10%), *Staphylococcus epidermidis* (9.52 and 10%), *Corynebacterium equi* (1.59 and 5%), *Bacillus subtilis* (4.76 and 5%), *B. licheniformis* (9.52 and 10%), and *Actinomyces istraelii* (3.17 and 5%). Fungi isolated included Rhizopus nigricans (27.59 and 18.52%), *Aspergillus flavus* (13.79 and 3.70%), *Penicillium rubrum* (6.86 and 3.70%), *Trichothecium roseum* (0 and 3.70%), *Penicillium viricadum* (6.90 and 0%) *Aspergillus niger* (34.48 and 44.44%), *Aspergillus nidulans* (0 and 11.11%), *Aspergillus visicolor* (3.45 and 3.45%), *Aspergillus parasiticus* (0 and 7.41%), and *Microsporum canis* (6.9 and 0%). The dumpsites soil recorded higher pH value than the adjacent soil. The investigation revealed that the hospital waste dumpsites may have adverse effects on its immediate environment (Oyeleke and Istifanus, 2009).

Wastewater is referred to any water, whose quality products (drugs and chemicals) that have been adversely being abused by anthropogenic from wards, contaminated or expired products, and chemical influence. This includes liquid waste discharged from waste which comprises of discarded solid or liquid and domestic home, industries, agricultural and commercial gaseous chemical and radioactive waste, which include sectors (Akter *et al*.1999).

Hospital wastes management's technologies

There are a number of methods that can be used to treat waste in order to inactivate potentially hazardous pathogens and chemicals pathogens.

In general, incinerators use very high temperatures (1800°F and above) to combust waste products. All biological compounds are completely destroyed at these temperatures, and so incineration is very effective at inactivating pathogenic agents. The primary disadvantages inherent in the use of incinerators are the cost due to the energy intensive nature of the process, and the potential for release of toxic compounds in to the atmosphere, which in the past included dioxins and furans (Thornton 1996).

Treatment of biomedical wastes

In general, health care facilities have been either to incinerate waste, encapsulate it, or to treat it such that it is safe for transport and placement in landfills. While incineration is effective, it is energy and thus cost intensive, and can lead to the production of toxic by-products (e.g., fly ash, metals) that are released into the atmosphere. In addition, there is a general “not in my backyard "attitude among the public towards incineration facilities. Similarly, encapsulation is expensive both in terms of equipment needed for containing waste, and the space needed for storage. In addition, encapsulation technologies do not necessarily inactivate the waste, such that the risk of biological or chemical contamination remains should the containment system be compromised.

Thus, the most favored solution to the handling is to process such wastes so that they can be safely placed in sanitary landfills. However, two fundamental problems must be addressed in any waste management process that ultimately results in material ending up in landfill facilities. First, to meet regulatory standards the material must be made biologically safe. That means that any pathogens or other infectious agents must be effectively inactivated. Pathogenic agents commonly include bacteria, viruses, fungi, and proteinacious infectious agents (termed prions).

Secondly, the waste must be made chemically safe. This means either degrading or otherwise in activating chemical components of the material, typically pharmaceuticals, hormones, and chemotherapy drugs. Removal of drugs in waste destined for landfills is of particular concern as it has been shown that these compounds make their way into the water table, and thus create a potential for comprising fresh water supplies destined for human or animal consumption (Jasim 2006).

Furthermore, there are essentially two ways in which to deal with biomedical and other hazardous wastes. One is through segregation, where hazardous wastes can be separated from non-hazardous materials, and then placed in designated containers designed to prevent release into the environment. The second is by waste treatment, where the wastes are treated in some way to render them non-hazardous. There are significant problems with segregation type waste management. These included finding acceptable locations for the containers, as well as designing containers that will not permit release of the waste for extended periods of time. The challenges faced by the nuclear power industry with respect to the removal and storage of spent nuclear fuel are a primary example of the difficulties that arise when segregation type waste management is used.

There is a similar public concern over biomedical waste, particularly in view of several well-publicized cases in the 1980's where biomedical waste was found to have washed up on public beaches. Because of the concern over AIDS and other infectious disease, the public perceives that the unregulated handling of biomedical waste posses a serious threat to health and safety (Burdick 1989). In 2004 the World Health Organization (WHO) released a policy paper on the subject of biomedical waste underscoring the risk of infection by exposure to biomedical waste, especially in areas where needles and syringe are scavenged from waste areas and dump sites. For example, the WHO estimated that in 2000, worldwide there were 21 million hepatitis B virus (HBV) infections, 2 million hepatitis C virus (HCV) infections, and 260,000 HIV infections due to injections with contaminated syringes as stated by World Health Organization. The WHO also states that the chance of infection from one needle-stick from a needle used on an infected source patient is 30% for HBV, 1.8% for HCV, and 0.3% for HIV. Since that the proportion of waste that has actually come in contact with an infected patient is a small fraction of total biomedical waste, the overall risk of random infection will of course be lower than the risks of infection reported by the WHO cited above. However, despite the low risk, and because of the current trend in society towards "zero risk", these occurrences and the public perception of risk they created, has led to the passage of biomedical waste regulations by a number of states in the U.S. and similar legislation in Canada. The handling and management

of biomedical and other hazardous wastes is under ever-increasing regulation and scrutiny, which has in turn led to a significant increase in the cost of handling biomedical waste (Marchese *et al*.1990). As a result, there is a need to develop waste management technologies that meet the standards imposed by government regulations, but which do so at an economically sustainable cost. In addition, any waste management system should be as "environmentally friendly" as possible, given emerging trends and policies with respect to energy use and the potential for environmental contamination, especially ground water.

One problem that has arisen in the area of biomedical waste management is the improper characterization of some waste as regulated waste in order to ensure compliance with regulations. Some savings can be made through training of health care workers in order to reduce the amount of material that is improperly placed in the biomedical waste stream. In another example, Toronto's Hospital for Sick Children reported a 35% reduction of hazardous waste resulted in a 50% savings in overall waste management costs. Therefore, even small improvements in biomedical waste management can yield significant economic benefits.

However, there will always be an unavoidable amount of waste that is legitimately biomedical waste and which must be treated in order to meet local, regional, or national standards with respect to handling of potentially hazardous materials. As a result, there remains a strong demand for viable solutions to the management of potentially infectious biomedical waste.

Non-Incineration Methods

In these processes, various methods of heating without combustion are used to inactivate biological compounds.These methods include steam sterilization (autoclaving), microwave, dry heat, and microwave processes. Other methods include the use of gamma-irradiation to inactivate biological pathogens that may be present in the waste. As with incineration, these processes can either be relatively energy intensive (e.g., autoclaving, microwaves, heating) or potentially involve handling of dangerous energy sources (gamma irradiation devices). In addition, these processes are time consuming and as a result more costly to perform. In addition, the use of steam, heat, or radio wave energy poses an additional occupational risk to workers involved in handling and treating the waste materials.

In addition to non-incineration methods that use various forms of energy to heat waste, chemical treatment is also used as a method for treating biomedical wastes. For example, compounds such as chlorine and various chlorine derivatives, or ethylene oxide, can be used as effective ways in which to disinfect materials. However, chemical treatment methods generally require significant contact time in order to inactivate pathogens. In addition, the use of chemicals can create their own hazardous material problem in that the disinfectant may be dangerous to handle and/or difficult to dispose of safely.

Ozone

Ozone is a form of oxygen, consisting of three oxygen molecules (O3). Unlike diatomic oxygen (O2; the breathable oxygen present in the atmosphere), ozone is very unstable, and decays to O2 within about 30 minutes under normal atmospheric conditions. Ozone is a powerful oxidizing agent. It is able to oxidize a number of molecules including metals (with the exception of gold, platinum, and iridium), nitrogen oxides, carbon, ammonia, and sulfides to

name a few. Ozone is of particular value as a disinfectant, as it is able to promote the oxidation of carbon-carbon double bonds (C=C). This type of bond is found in many biological molecules, and in other types of organic compounds, most notably pharmaceuticals. As a result, ozone is effective to kill essentially all pathogens including bacteria, fungi, viruses, as well as prions. Ozone is also effective to promote the degradation of a large number of drug compounds. The generation and handling of ozone is relatively simple using a variety of available technologies that make use of oxygen in the ambient atmosphere. As a result, ozone is conveniently generated on site, and does not require specialized containers for transport, as are required with other chemicals. Further, ozone degrades naturally into oxygen in a relatively short period of time (10-30 min), and thus does not leave any toxic residue behind.

Use of Ozone as a Disinfectant

The use of ozone has been widely investigated for use in water treatment as well as for the treatment of biomedical waste. The Clark County (Nevada) Water Reclamation District recently reported the results of their own studies suggesting that ozonation is an effective method for disinfecting drinking water. Systems using ozone to disinfect biomedical waste have been developed. The TSO3 Company offers an ozone sterilizer for use in disinfecting medical instruments. While the unit is compact, it is not designed to use in treating mixed biomedical waste.

In particular, the TSO3 system does not have the ability to shred materials prior to ozone treatment, and thus is only effective for topical sterilization. Ozonator™ System for Biomedical Waste Management More recently, Ozonator Industries has developed an ozone treatment system specifically designed for high-throughput treatment of biomedical wastes. The Ozonator™ system combines a shredding step to reduce the waste to smaller particles (less than 30 mm), and then treats the shredded material with ozone. The design of the Ozonator™ system effectively provides a continuous batch process, with each batch taking about 10 minutes to process. Current models of the system allow for a maximum 200 kg (440 lbs) load per cycle. Shredding provides an additional advantage in reducing the volume of the waste up to 90% and increases the overall the cost-effectiveness of the system in reducing landfill costs.

Ozone is generated on-site using source water and either ambient atmospheric oxygen, or medical oxygen supply commonly available in health care facilities. The power consumption of present units is 37kW (peak). At commercial power costs of $0.10 per kWh, the cost of energy for the system is about $90 per day.18 The entire process, from loading, through shredding, ozone treatment, and unloading, is fully automated, reducing the exposure of workers to materials. The system also has a variety of safety features to ensure shutdown should any part of the process fail to operate within defined parameters. The system is also easy to train on, and workers can be fully trained in its operation in about an hour. Once materials are loaded into the system, ozone begins to flood the chamber. When ozone levels reach 1000 ppm shredding begins. During the treatment phase, ozone levels are maintained at a level of at least 3500-4500 ppm.

Testing efficacy

To test the effectiveness of the Ozonator™ system, three different assays have been used. In the first set of experiments, a total of 20 STS Spore

strips, each strip containing 6 x 10^5 *Bacillus atrophaeus*, and 1 x 10^5 *Geobacillus stearothermophilus* spores respectively, were treated with ozone for one hour.21 After ozone exposure, strips were sent to an independent laboratory to be tested for spore viability. Spores were germinated at 35°C and 55°C in liquid culture and on agar plates. The results showed at least a 104-fold reduction in spore viability and 39/40 strips were negative for growth (noviable spores) after treatment in the Ozonator™ system.

Since ozone has a density greater than air, it is expected that ozone levels in the treated material are greater than that in the airspace, and as a result, actual ozone concentration in the treated material is likely greater than the measured value. In addition, ozone has a half-life of about 30 minutes under ambient atmospheric conditions. Since after material is moved to the post-treatment chamber, no additional ozone is actively added, the ozone present after treatment begins to naturally decay. Therefore, the residual ozone in the post-treatment chamber is likely lower than the levels attained during the material treatment phase of the process. As a result, the levels of ozone as measured likely represent less than actual ozone levels during treatment, and therefore can likely be considered minimum levels attained.

Bacterial spore viability after ozone treatment. 3M Attest™1294 indicators contain a standardized population of viable *Bacillus subtilus* ATCC 9372 spores. The results of these tests showed at least a 10^6-fold reduction in spore viability after treatment with the Ozonator™ using standard treatment protocols. Finally, within each batch the Ozonator™ system has the ability to include an FDA-cleared, ozone-specific colorimetric indicator to confirm that ozone levels have reached a pre-determined minimum level.

The output from the Ozonator™ system is sterile waste that is landfill-ready. Testing of material processed using the Ozonator™ shows that at least 99.9999% of microorganisms are killed by the ozone treatment process (a 1 million-fold reduction in pathogen levels). After processing, waste is discharged into a disposal tank, which is then suitable for removal to a landfill site.

The Ozonator™ has been recently approved by the North Carolina Department of Environment and Natural Resources for use in treating regulated medical waste, including microbiological and pathological wastes.

RECOMMENDATION

The basic recommendations are meant simply as guidelines to stimulate better and more specific planning and action programs at the municipal government level and then at the level of individual health care facilities. There are eleven recommendation as stated with Technical Working Group of the Basel Convention by the Basel Action Network (BAN) (1999) to deal with hospital wastes which are

(1) Clearly define the problem,
(2) Focus on segregation first,
(3) Institute a sharps management system,
(4) Keep focused on reduction,
(5) Ensure worker safety through education, training and proper personal protective equipment,
(6) Provide secure collection and transportation,
(7) Require plans and policies,
(8) Invest in training and equipment for reprocessing of supplies,
(9) Invest in environmentally sound & cost effective medical waste treatment and disposal technologies,

(10) Develop an infrastructure for the safe disposal and
recycling for hazardous materials, and
(11) Develop an infrastructure for safe disposal for municipal solid waste

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