Journal of Ayurveda and Integrative Medicine 10 (2019) 214–221

Contents lists available at ScienceDirect

Journal of Ayurveda and Integrative Medicine

journal homepage: http://elsevier.com/locate/jaim

Review Article

Biomedical waste management in Ayurveda hospitals – current practices and future prospectives

Renju Rajan, Delvin T. Robin*, Vandanarani M.

Department of Swasthavritta, School of Ayurveda, Amrita University, Amritapuri, India

ARTICLE INFO

Article history:
Received 11 April 2017
Received in revised form
3 June 2017
Accepted 11 July 2017
Available online 17 March 2018

Keywords:
Biomedical waste
Biomedical waste management
Health care waste
Traditional system
Ayurveda biomedical waste
Ecosystem

ABSTRACT

Biomedical waste management is an integral part of traditional and contemporary system of health care. The paper focuses on the identification and classification of biomedical wastes in Ayurvedic hospitals, current practices of its management in Ayurveda hospitals and its future prospective. Databases like PubMed (1975–2017 Feb), Scopus (1960–2017), AYUSH Portal, DOAJ, DHARA and Google scholar were searched. We used the medical subject headings 'biomedical waste' and 'health care waste' for identification and classification. The terms 'biomedical waste management', 'health care waste management' alone and combined with 'Ayurveda' or 'Ayurvedic' for current practices and recent advances in the treatment of these wastes were used. We made a humble attempt to categorize the biomedical wastes from Ayurvedic hospitals as the available data about its grouping is very scarce. Proper biomedical waste management is the mainstay of hospital cleanliness, hospital hygiene and maintenance activities. Current disposal techniques adopted for Ayurveda biomedical wastes are – sewage/drains, incineration and land fill. But these methods are having some merits as well as demerits. Our review has identified a number of interesting areas for future research such as the logical application of bioremediation techniques in biomedical waste management and the usage of effective micro-organisms and solar energy in waste disposal.

1. Introduction

Waste means any useless, unwanted or discarded substance or material, irrespective of whether or not such substance or material has any other or future use. This includes any substance or material that is spilled, leaked, pumped, poured, emitted, emptied or dumped onto the land or into the water or ambient air [1]. Waste generated by health care activities includes a broad range of materials, from used needles and syringes to soiled dressings, body parts, diagnostic samples, blood, chemicals, pharmaceuticals, medical devices and radioactive materials [2].

According to Biomedical Waste (Management and Handling) Rules, 2016 of India, 'biomedical waste' is defined as "*Any waste which is generated during the diagnosis, treatment or immunization of human beings or animals or in research activities pertaining thereto or in the production or testing of biologicals or in health camps* [3]".

Medical care is vital for our life and health, but the improper management of biomedical waste causes a direct health impact and damages the ecosystem including flora and fauna. Biomedical waste management is an integral part of traditional and contemporary system of health care. Waste management involves all the activities and actions required to manage waste from its inception to its final disposal [4]. Waste produced in the course of health care activities carries a higher potential for infection and injury than any other type of waste. It is essential that all medical waste materials are segregated at the point of generation, appropriately treated and disposed of safely [5]. A large proportion of healthcare personnel in Ayurvedic hospitals were completely unaware regarding the proper management of biomedical waste. Considering its impact on the environment and health, biomedical waste management requires immediate academic attention by increasing the awareness during training courses. We must also focus on cost effective and eco-friendly methods for its disposal.

2. Literature review methods

Review was done on literary material available on various sources. An extensive data mining was carried out from various

* Corresponding author.
E-mail address: delvintroby@gmail.com (D.T. Robin).
Peer review under responsibility of Transdisciplinary University, Bangalore.

http://dx.doi.org/10.1016/j.jaim.2017.07.011

texts, peer reviewed journals and some websites of the concerned subjects. Databases like PubMed (1975–2017 Feb), Scopus (1960–2017), AYUSH Portal, DOAJ, DHARA and Google Scholar were searched. We used the medical subject headings 'biomedical waste' and 'health care waste' for identification and classification. The terms 'biomedical waste management', 'health care waste management' alone and combined with 'Ayurveda' or 'Ayurvedic' for current practices and recent advances in the management of these wastes was searched. From PubMed, 936 studies were found on biomedical waste and 393 on biomedical waste management. 111 studies were reviewed on biomedical waste [Title/Abstract] and 76 articles on health care waste [Title/Abstract]. 0 results were obtained on healthcare waste management [Title/Abstract]. In Scopus, the documents available on the keywords 'biomedical waste' was 343, 'healthcare waste' was 366, 'biomedical waste management' was 331 and 273 on 'healthcare waste management'. Records available in DHARA about biomedical waste management was 0. No matching results were found in AYUSH portal on the keywords 'biomedical waste' and 'biomedical waste management'. Only 1 result was available on 'health care waste management'. From DOAJ, 37 results were available on the keyword 'biomedical waste' and 18 on 'health care waste', 0 using the keyword 'biomedical waste management' and 7 on 'health care waste management'. There were hardly any results found for 'Ayurveda' in/and 'biomedical waste management' in any of these databases. A pilot study was conducted within a few hospitals in Southern Kerala to identify the various biomedical wastes and their current disposal techniques and probable future techniques to aid its management. The primary data collected from various Ayurvedic hospitals and pharmacies were also included. Authentic text books were also referred for the familiarizing various waste management techniques.

3. Number of observations

Data collected from 3 Ayurveda colleges, 10 Government hospitals, 20 major private hospitals and 35 Ayurveda clinics were used to identify the type of wastes, the amount of waste generated and the disposal techniques followed.

4. Identification and classification of biomedical waste

From a consultative seminar on NABH Guidelines for Ayurveda hospitals organized at Care Keralam Ltd., it was found that the major waste material coming out of an Ayurveda hospital is the used *kizhi* (a material used for fomentation process) and medicated oil discarded after use. Large quantities of this oil are available and many unscrupulous elements misuse this spent oil. An eco-friendly way should be found out to make use of or to destroy this waste oil. Ayurveda creates less waste with blood or body parts, except in the case of *Rakthamoksham* (bloodletting), where blood-filled leech may be considered as a bio medical waste [6].

The information collected from various Ayurveda hospitals suggests that the specific wastes produced from the Ayurvedic hospitals and pharmacies are mainly organic in nature. Wastes from *Panchakarma* (purificatory therapy) procedures, *Raktamoksha* (bloodletting), items contaminated with blood, body fluids like dressings, plaster casts, cotton swabs etc. are also there. Besides, a little amount of wastes from the heavy metals like mercury and arsenic used for pharmaceutical purposes can be considered as biomedical wastes. Based on all these data, the biomedical wastes from Ayurvedic hospitals is arranged in Table 1.

5. Amount of waste generated

The amount of waste generated depends on various factors like type of health care establishment, specializations, proportions of reusable items used and proportion of patients treated per day and the type of procedures done.

Table 2 shows the average composition of waste obtained per day from 35 Ayurveda hospitals across Kerala.

6. Need of biomedical waste management

Proper biomedical waste management is the mainstay of hospital cleanliness, hospital hygiene and maintenance activities [8]. Appropriate hospital waste management system is an essential component of quality assurance in hospitals. But a large proportion of health care personnel were less aware about the proper management of biomedical waste, especially in Ayurvedic hospitals. Ultimate aim of waste management is the prevention of disease and protection of environment [9].

6.1. Health aspects

The need of biomedical wastes with regards to health aspects is mainly due to its capacity to produce injuries and infections. Injuries from sharps lead to infections to all categories of hospital personnel and waste handler [10]. Poor waste management and disinfection practices leads to nosocomial infections in patients. Suspended spores can also cause infection, for example, TB, tetanus, etc. The spread of *Aupasrgika rogas* [11] (communicable disease) mentioned in Ayurveda literature seems to be similar with that of nosocomial infections. *Yantras* and *sastras* (surgical instruments) used in Ayurvedic hospitals should be properly disposed off. They should be properly disinfected, in case they are being reused. Risk associated with hazardous chemicals and drugs will affect persons handling wastes at all levels. Another important point related to health aspect is 'disposable' being repacked and sold by unscrupulous elements [12].

6.2. Ethical aspects

It is the moral duty of health care workers to prevent hospitals from becoming centers of disease rather than center of cure [13]. Raising awareness on public health and environment hazards associated with inappropriate segregation, collection, storage, transport, handling, treatment and disposal of health care waste. Regular training program for all the sections of health care workers with special emphasis on waste handlers is essential [14]. Identifying safe, efficient, sustainable economic and culturally acceptable waste management practices and technologies and enabling the participants to identify the systems according to their particular needs is an important area to be focused.

6.3. Environmental reasons

Risk of air, water and soil pollution directly due to waste, or due to defective incineration emissions and ash.

a) Air pollution by means of biological, chemical and radioactive emissions [15]. Biological air pollution occurs from inside and outside the hospital premises. Nosocomial infections and occupational hazards by spores and bacteria occur within the hospital. Untreated and openly dumped biomedical wastes causes air pollution from outside. Chemical induced air pollution is by two major sources-open burning and incinerators, for example, plastic and hazardous materials release dioxins and furans (carcinogenic). Radioactive emissions also produce air pollution by small quantities of radioactive gases generated during research and radio

Table 1
Classification of biomedical wastes from Ayurvedic hospitals.

Type of waste	Examples
General non-hazardous waste	Food remnants, fruit peels, waste paper, packing materials etc. [7].
Hazardous wastes	Wastes from *Panchakarma* (purificatory therapy) procedures like *Vamana* (therapeutic vomiting), *Raktamoksha* (bloodletting), items contaminated with blood, body fluids like dressings, plaster casts, cotton swabs Used oils, powders, wastes after various fomentation procedures like *kizhi,dhara, avagaha* etc.
Medicine wastes	Wastes after the preparation of medicines, wastes of raw materials, discarded medicines,
Sharps	*Vasti yantras* (Instruments for administering medicated enema including metallic and disposable plastic ones) , *Salaka* (probe), instruments for *Raktamoksha* (bloodletting)

Table 2
Average composition of waste from Ayurveda hospitals in Kerala.

Material	Wet weight basis
Paper	4–5 kg/day
Plastic	<1 kg/day
Metals	1/bed
Glass	1 kg/day
Infectious waste (cotton, swabs etc.)	100 g/day
General waste (food waste, sweepings from hospital premises)	5–10 kg/day
Oil	3–4 l/day
Kizhi	500 g/bed
Dhanyamla	3 l/bed
Medicine/pharmacy waste	20 l/day
Blood after Raktamoksha	100–200 ml/bed

immune assay activities, and it is less relevant in case of Ayurvedic biomedical wastes.

b) Water pollution – Improper disposal and dumping in low lying areas and water bodies leads to severe water pollution. The presence of biologicals, chemicals or radioactive substances primarily results in pollution of water. Heavy metals and pathogens can leach out and contaminate the ground/surface water. All these alter the parameters such as pH and biological oxygen demand (BOD).

c) Land pollution – All types of biomedical wastes are finally disposed off on land. Pollution can be minimized by proper treatments. The heavy metals like mercury, cadmium etc. get absorbed by plants and can then enter the food chain. Thus biomedical wastes have a cumulative potential in pollution.

Studies conducted to evaluate indicators of environmental contamination, resulting from micro-organisms found in biomedical waste shows that contamination can occur through the air, water, and/or soil. The micro-organisms having the highest individual risks (host penetration) via air contamination are *Mycobacterium tuberculosis* and *Staphylococcus aureus*. Water contamination incurs the risk of ingestion of contaminated water, and infection by the Hepatitis A virus and the bacterium *Escherichia coli* predominate in this medium. Micro-organisms with high capacity for soil contamination include *Pseudomonas aeruginosa*, the Hepatitis B virus, *Enterococci*, and *S. aureus* [16].

Even though there were rules for waste management, recent reports from newspapers like Times of India makes the picture clear that it is not properly followed. For example – 'Biomedical, hazardous wastes recycled and sold in open market' – a report on 17 January 2017 – A raid conducted by Kolkata Municipal Corporation team revealed this. Another news regarding the improper waste disposal is 'Waste from Mettupalayam Government Hospital, its mortuary end up in Bhavani River' (16 Jan 2017). So the need of an eco-friendly and easy techniques in waste management is very much essential.

Thus, the improper management of biomedical waste can be considered as a '*Janapadodwamsa*' [17]. Acharya Charaka in his treatise – *Charaka Samhita*, mentions the etiological factors for *Janapadodwamsa* as inevitable and evitable. The inevitable causes include remote effects like the seasonal and environmental disturbances. Methane and carbon dioxide (CO_2) are greenhouse gases (GHG), whose presence in the atmosphere contribute to global warming and climate change [18] The evitable factors are those which can be prevented. Air pollution, water pollution and soil pollution have a sudden impact in *vayu* (air), u*dakam* (water) *desam* (land) or impairment of ecosystem and health. It can be controlled by adopting suitable waste management techniques.

6.4. Biomedical waste management in National Accreditation Board for Hospitals and Healthcare Providers (NABH) Accreditation Standards

National Accreditation Board for Hospitals and Healthcare Providers (NABH) is a constituent board of Quality Council of India, set up to establish and operate accreditation programme for healthcare organizations. The mentioning of biomedical waste management was found in the infection control section of Accreditation Standards for *Panchakarma* Clinics 2017. The programme includes an action plan to control outbreaks of infection, disinfection activities, biomedical waste (BMW) management, and training of staff and employee health. It also covers hand-hygiene guidelines, cleaning and disinfection practices, laundry and linen management processes, engineering controls to prevent infections, proper segregation, collection and transportation of biomedical waste from all patient-care areas of the *Panchakarma* Clinic is implemented and monitored. The *Panchakarma* Clinic should conduct appropriate 'in-service' training sessions for all staff at least once in a year [19].

7. Current disposal techniques followed and their demerits

The primary data collected from several Ayurvedic hospitals reveals that the disposal techniques adopted currently for Ayurvedic biomedical wastes are – sewage/drains, incineration and land fill.

7.1. Sewage/drains

It is the most common and inexpensive method of disposal. Sewage disposal is usually practiced for liquid wastes. Wastes after *Vamana, Virechana, Raktamoksha, Vasti* etc. are disposed using this process. Raw disposal of human body fluids and wastes leads to serious health impacts. Hence, concurrent disinfection [20] should be done before discarding it into drains.

One of the major problem addressed by Ayurvedic hospitals is the water mixed with oil, *mudga churna* (Besan powder) after the bathing of patients who underwent *abhyang*a (oil massage) or any other therapeutic procedures may lead to clogging due to sedimentation. This water when reaches the drains will adversely affects the useful bacterial flora.

The *kasayas* (decoctions) and liquids other than *taila* (oils) used for *Dhara, Avagaha* (a type of fomentation technique like sitz bath), *kshalana* are also disposed into drains. Most of these herbal preparations don't cause any issues unless and until they properly

drained into sewage system. Otherwise stagnant liquid wastes will emit foul odor and promote breeding of flies.

7.2. Incineration

It is a common technique adopted for solid and dry herbal-organic wastes; for example, used *kizhi* (material used for a type of fomentation), by-products of medicines and *churna* (powders), *Kasaya Kalka* (residue of decoction) etc. This process is usually selected to treat wastes that cannot be recycled, reused or disposed off in a land fill site [21]. It can be done by simple incineration/burning and using incinerators. Incineration requires minimum land. Another advantage of incinerators is that it can be operated in any weather. The incineration process destroys pathogens and reduces the waste volume and weight but leaves a solid material called biomedical waste ash [22] as residue which increases the levels of inorganic salts and organic compounds in the environment.

Demerits of incinerators are it is expensive to build, maintain and operate. The air-borne by-product of incineration is detrimental to the ozone layer. The air-borne particles have a noxious smell and vermin tend to congregate in the facility, potentially spreading disease throughout the area. High energy is required for the process and also requires skilled personnel and continuous maintenance [23].

7.3. Landfill

Huge amount of solid wastes are disposed using this method. It is the terminal method of disposal of ashes after incineration. Disposal of biomedical waste ash [16] in landfill may cause contamination of groundwater as metals are not destroyed during incineration.

However, this process has a number of drawbacks. Poisonous drugs like *Bhallataka* (*Semecarpus anacardium*) etc. are buried deep, otherwise accident exposure to non-purified *Bhallataka* fruits will leads to burns or adverse skin reactions [24]. References about its adverse effects of producing swelling and burns were found in *Rasatarangini*.

Landfills are the world's third largest anthropogenic emission source [25]. Open dumping cause's higher risks of disease transmission, acute pollution problems and open access to scavengers and animals [26]. Carbon dioxide, methane and other harmful gases generated by decaying organic wastes are released into the atmosphere. Methane, a greenhouse gas can itself be a danger to inhabitants of an area because it is flammable and potentially explosive [27]. Over dumping and not focusing on the biological treatment of the landfill will cause serious damage to the ecosystem.

7.4. Others

Reuse of *taila* (oils) used for *dhara* or *pizhichil* (type of fomentation technique) for the same person. This method is also not ideal because the medicated oil losses its potency and will be contaminated.

Classification of ayurveda biomedical wastes on the basis of disposal methods as per biomedical waste managemnt rules 2016.

Based on the disposal techniques adopted we can classify the wastes on the basis of colour coding.

Yellow – All those wastes that are to be burned.

Red – Recyclable wastes.

Blue – Glass disposed in cardboard boxes.

White – Sharps.

Table 3
Biomedical waste categories from the Ayurveda hospitals and their segregation, collection, treatment, processing and disposal options with respect to the Biomedical Waste (Management and Handling) Rules 2016 [28]. Based on the disposal techniques adopted we can classify the wastes on the basis of color coding. Yellow – all those wastes that are to be burned. Red – recyclable wastes. Blue – glass disposed in cardboard boxes. White – sharps.

Category	Type of waste	Type of bag or container used	Treatment and disposal options
Yellow	Items contaminated with blood, body fluids like dressings, plaster casts, cotton swabs and bags containing residual or discarded blood and blood components. *Wastes of Panchakarma (purificatory therapy) procedures like Vamana (Therapeutic Vomiting), Raktamoksha (bloodletting)*	Yellow colored non-chlorinated plastic bags or containers.	Incineration or plasma pyrolysis or deep burial In absence of above facilities, autoclaving or micro-waving, hydro calving treated waste to be sent for energy recovery.
	Expired or Discarded Medicines. Wastes after the preparation of medicines, wastes of raw materials, discarded medicines, used oils, powders, *wastes after various fomentation procedures like kizhi,dhara, avagaha etc.* *Cytotoxic – Heavy metals like mercury and arsenic etc. from Herbomineral preparations.*	Yellow colored non-chlorinated plastic bags or containers	Expired medicines shall be either sent back to manufacturer or disposed by incineration. Discarded medicine and wastes of drugs after procedures are either incinerated or disposed off into drainage.
	Chemical Liquid Waste	Separate collection system leading to effluent treatment system	The chemical liquid waste should be pre-treated before mixing with other waste water
	Discarded linen, mattresses, beddings contaminated with blood or body fluid.	Non-chlorinated yellow plastic bags or suitable packing material	Non-chlorinated chemical disinfection followed by incineration or plasma pyrolysis or for energy recovery.
	Microbiology, Biotechnology and other clinical laboratory waste:	Autoclave safe plastic bags or containers	Pre-treat to sterilize with non-chlorinated chemicals on-site as per National AIDS Control Organisation or World Health Organisation guidelines thereafter for Incineration.
Red	Contaminated Waste (Recyclable) (a) Wastes generated from disposable items such as tubing, bottles, intravenous tubes and sets, catheters, urine bags, syringes (without needles and fixed needle syringes) and gloves Disposable vasti netras or plastic glycerine syringes	Red colored non-chlorinated plastic bags or containers	Autoclaving or micro-waving/hydroclaving followed by shredding or mutilation or combination of sterilization and shredding. Treated waste to be sent to registered or authorized recyclers or for energy recovery or plastics to diesel or fuel oil or for road making, whichever is possible. Plastic waste should not be sent to landfill sites.

(*continued on next page*)

Table 3 (*continued*)

Category	Type of waste	Type of bag or container used	Treatment and disposal options
White (Translucent)	Waste sharps including Metals: Needles, syringes with fixed needles, needles from needle tip cutter or burner, scalpels, blades, or any other contaminated sharp object that may cause puncture and cuts. This includes used, discarded and contaminated metal sharps. Sharp instruments for *Raktamoksha* (bloodletting) *Vasti yantras* (metallic instruments for administering medicated enema), *Salaka* (probe),	Puncture proof, Leak proof, tamper proof containers	Autoclaving or Dry Heat Sterilization followed by shredding or mutilation or encapsulation in metal container or cement concrete; combination of shredding cum autoclaving; and sent for final disposal to iron foundries (having consent to operate from the State Pollution Control Boards or Pollution Control Committees) or sanitary landfill or designated concrete waste sharp pit. Vasti yantras and salaka are reused after proper sterilization.
Blue	Glassware: Broken or discarded and contaminated glass including medicine vials and ampoules except those contaminated with cytotoxic wastes.	Cardboard boxes with blue colored marking	Disinfection (by soaking the washed glass waste after cleaning with detergent and Sodium Hypochlorite treatment) or through autoclaving or microwaving or hydroclaving and then sent for recycling

Classifying waste from Ayurveda hospital as mentioned in Table 3 will make the disposal of it more easier and efficient. Considering the wastes from an Ayurvedic hospital, the wastes to be disposed in yellow bags will be more. Only a little amount of waste is in red and white bags. Blue bags have least significance in Ayurveda hospitals. The sharps in Ayurveda hospitals like *salaka* and *vasti yantra* are often reused after proper sterilization.

8. Best practices currently followed

The specific wastes from Ayurveda hospitals like *kizhi* and oil are disposed in various eco-friendly and productive methods. One of the interesting methods of management of used oil was found in an Ayurveda hospital at Thiruvanthapuram. The fresh oil waste after *dhara* and *pizhichil* is boiled along with *Kataka* seeds (*Strychnos potatorum*) till the foam subsides. It is then filtered and again boiled with *Kataka* seeds and the supernatant clear oil is collected and used as fuel for lighting lamps. The used oil is given for preparing grease and coated in the base of vehicles after painting. The wastes of various types kizhi are disposed as

a) *Njavara kizhi* (Type of fomentation with *njavara* rice) – in biogas plant.
b) *Naranga kizhi* (Type of fomentation used with lemon) – dried and used for fumigation as a mosquito repellent.
c) *Ela kizhi* (Fomentation using various medicated leaves) and *Churna pinda sweda* (Fomentation using medicated powders) - are either used for fumigation or burned.

In some Government hospitals, the drug residue after preparation of *kasayas* (decoction) is collected and dried and was supplied to farmers to prepare compost manure. Recently, a few major Ayurveda hospitals started using an eco-friendly, fuel free waste incinerator which converts waste to ash without using electricity or fuel.

9. Potential future trends to be adopted

Now-a-days, the pharmaceutical industry is trying to implement various 'Green Chemistry' practices by minimizing the use of reagents that are hazardous to the environment and designing alternative pathways [29].

The general rule of waste hierarchy, i.e. the 3 R's - Reduce, Reuse, and Recycle should be adopted for the scientific and appropriate waste management in future. Various eco-friendly procedures which can be done in the process of waste management are as follows.

9.1. Reduce

This includes the process and policy of reducing the amount of waste produced by a person or society [30]. This approach aids to conserve our natural resources. From a study conducted in a South Indian tertiary care hospital, it was found that effective segregation protocols significantly reduced biomedical waste generated [31].

9.2. Reuse

Based on the data collected from the pilot study from some Ayurveda hospitals, we got various options in reuse of wastes. Used oil can be effectively utilized in various other industries as lubricants for machinery, fuel for combusting wastes and as an aid to demould interlocking tiles, grease manufacturing etc. Some Ayurveda hospitals use the dried *kasaya kalka* for fumigation as a mosquito repellent. *Kasaya kalka* can also be used for compost preparation and ultimately into manure. *Gugglu* (*Commiphora mukul*) after preparation of medicines and *Shudhi* are used for fumigation in some hospitals. The major waste from Ayurveda pharmacy, the residual *Kashaya dravyas* (herbs for preparing decoction) can also be reused. Decoction prepared with reused *kasaya dravya* has the same phytochemical constituents and only difference is in its concentration; hence, it can be administrated in an increased dose. A few Ayurveda pharmacies opine that the residue from *arishta* (fermentative preparation) can be used in future as the *bija/kinwa* (solid lower most portion of fermented material) for further fermentation. The rest of the *bija/kinwa* can be disposed of by incineration. Most of the hospitals use the *Kalkas* (solid residue) of *sneha kalpanas* (medicated oils and ghee) along with *udwarthana churna* (powder massage). Various instruments for diagnosis, treatment and other activities should be properly established so that they can withstand sterilization. Properly sterilized glycerine syringes can be used to the same patient. *Vasti netra, salaka* etc. when properly sterilized can also be used again. *Jalukas* (leeches) are also reused after proper cleaning.

The waste water which is let into the drains can be reused after separating oil from water. This can be achieved with the help of gravity oil separators [32] to isolate oil from water. We got the concept of gravity oil separators from the reference from oil separation in petroleum spillage areas. The oil thus separated can be used for burning other solid wastes/in oil fired incinerators, interlocking tile manufactures, grease manufactures etc. The residual water is then send to effluent treatment plant and later used for agriculture, landscape, toilet flushing, dust control, construction

activities etc. Several studies show the potential of producing of electricity and disinfectant from waste water [33].

The limited space and the high cost for land disposal of biomedical waste ash produced from the solid waste incineration process led to the development of recycling technologies and the reuse of ash in different systems. In order to minimize leaching of its hazardous components into the environment, several studies confirmed the successful utilization of biomedical waste ash in agriculture and construction sector [34].

9.3. Recycle

The idea of converting waste into energy is gaining popularity now-a-days. Studies were conducted on the production of biodiesel from used cooking oils [35]. Similar technique can be developed in the waste oils from Ayurvedic hospitals. An initial investigation on production of biodiesel from Ayurvedic waste oil found that the properties of biodiesel produced from Ayurvedic waste oil conform to the American Society for Testing and Materials (ASTM) standards, except for the acid value [36]. Bio-methanation, has a strong potential for production of energy from organic wastes, which helps to reduce the consumption of fossil fuels and carbon dioxide emission [37]. Another method of effective recycling is the use of lignocellulosic residues of *Kashaya* (decoctions) and other herbal wastes as cattle feed and for biofuel production [38]. Plastics wastes can be recycled for road making [39]. Glasswares can also be recycled.

9.4. Recent advances in biomedical waste management in Kerala

Times of India, 24 October 2016, reported that to tackle the mounting biomedical waste crisis in Southern Kerala, especially in Kochi, the Kerala Enviro Infrastructure Ltd (KEIL) has proposed a treatment plant at Puthencruz in Ernakulam. There is only one biomedical waste treatment plant – IMAGE (IMA Goes Eco-friendly) in Kerala, situated at Palakkad that caters to around 6000 hospitals in Kerala.

9.5. Bioremediation methods in waste management

Bioremediation is another area which needs to be focused on [40]. It is a treatment that uses naturally occurring organisms to break down hazardous substances into less toxic or non-toxic substances. Significance of this method is that it uses no chemicals, as chemicals are very harmful to plant, animal and human life once they reach the water supply. Also, it can allow waste to be recycled. Some studies report that *Gomaya* (cow dung) as an excellent bioremediation method [41]. Various biological organisms present in cow dung helps to destroy and reduce the amount of pollutants in the environment. Other bioremediation practices which can be rationally used are –

a) Phytoremediation – use of plants to remove contaminants from soil or water. This process can remove metals from water. It is very effective in remediating soil and organic compounds. Several studies show that planting trees like neem, which has air purification action and phytoremediation action is an excellent idea to control pollution [42].
b) Environment Protection Authority (EPA) proposes 'land farming' as a form of bioremediation which, with the proper controls, can be a practical, effective, durable and cost effective method for treating certain types of contamination in soils [43].
c) Studies suggest that composting is one of the cost effective bioremediation technique. This method can be adopted to dispose herbal medicine wastes. Evidence is present in databases regarding the application of compost for effective bioremediation of organic contaminants and pollutants in soil [44].
d) Vermicomposting can also be adopted as an option for the disposal of organic wastes from Ayurveda hospitals. References on the use of vermicomposting for treating waste waters, remediating polluted soils, improving agricultural productivity are scientifically proven [45]. Thus, composting and vermicomposting can be used skilfully for organic farming of Ayurveda medicinal plants.
e) An experimental analysis of organic food waste for degradation by Ayurvedic herbal plants and medicines concluded that application of *Neem* (*Azadirachta indica*) and *Tulsi* (*Ocimum sanctum*) on food sample for degradation is very effective and economical. Also, the fertilizer generated after degradation of solid waste had shown improvement in the fertility of the soil [46].
f) Bio-filtration – effluents from the pharmaceutical industry often contain high concentrations of phenolic compounds. Biofiltration methods can be used for the removal of phenolic residues [47].
g) Bio-augmentation [48] – adding microbes and organisms to strengthen the same in waste to allow them to take over and decontaminate the area.
h) Rhizofiltration [49] – the use of plants to remove metals in water.
i) Application of oil-eating microbes [50] helps in the effective management of used oils, which are one of the important sources of waste in Ayurvedic hospitals.
j) A very cheap, easily available and effective method using fungus – Periconiella sp. isolated from cow dung was successfully tried, which degrades the biomedical waste materials very efficiently and quickly without leaving any trace of harmful effect on the population [51].

9.6. Solar energy in waste management

Solar heating seems to be a cheap method to disinfect infectious medical waste in less economically developed countries [52]. The use of solar energy for powering autoclave is an apt method to be adopted in waste management in a small hospital set-up [53]. There was a notable reduction in the parameters like Chemical Oxygen Demand (COD), total solids, volatile solids, electrical conductivity, alkalinity and microbial colony count at different stages of disinfection, which suggests that pathogens of biomedical waste can be effectively destroyed using solar disinfection with lime stabilization process [54].

10. Training and awareness programmes

Only a small number of Ayurveda hospitals are conducting training programs on waste management. Some of the Ayurveda hospitals were running training programs on waste management, fire and safety and housekeeping once in every year to bring out a uniformity and awareness among the staff. Just like IMAGE (Indian Medical Association Goes Eco-friendly), a biomedical waste treatment and disposal facility established at Palakkad, Ayurveda hospitals should develop a similar method in disposal of specific wastes from Ayurveda sector.

Although hygiene is an important area to be discussed and is not directly related to waste generation in the hospitals, it is relevant in the context of the nature of treatments proposed in Ayurvedic hospitals. The related accessories used for various Ayurveda treatment procedures, place of bathing, hydrotherapy equipments should maintain proper hygiene measures. A few Ayurveda

hospitals are using disposable biodegradable related accessories. The bathing area is cleaned using bleaching powder and hot water on daily basis as a part of disinfection and to prevent clogging. One of the Ayurveda hospitals in Thiruvananthapuram, is using sterile *Vasti* kit including disposable *Vasti* syringe, gloves, cotton etc. The plastic wastes are collected by the IMAGE group and the rest of the wastes are then incinerated.

10.1. Future research

Our review has identified a number of interesting areas for future research. The logical application of different bioremediation techniques in biomedical waste management has to be properly planned and implemented. Research should focus on the usage of effective micro-organisms [55] and solar energy in waste disposal. The waste to energy concept should be further developed to conserve the fossil fuels.

Conclusion

The impairment of ecosystem due to the impact of biomedical wastes on *vayu* (air), u*dakam* (water) *desam* (land) makes us to consider it as a '*Janapadodwamsam*'. So the proper identification, segregation and disposal of biomedical waste is an ethical & social responsibility of health care professionals. Strict implementation of biomedical waste management rules is the need of the hour. It should be made compulsory for healthcare facilities to get their healthcare personnel trained from accredited training centres & it should not become merely a one-time activity but should be a continuous process. The application of proper waste management techniques and its identification in the curriculum helps to improve their understanding of good practice in BMW management .We also need a cost effective and environment friendly technology. A more coordinated effort from the pollution control authorities and better training of health care workers and administrators is required.

Sources of funding

None.

Conflict of interest

None.

Acknowledgements

The authors would like to thank Dr. Jyothilal K, Professor and HOD, Department of *Swasthavritta* and other faculty members-Dr. Anusree Dilip and Dr. Cijith Sreedhar for their support and encouragement; Dr. Anandaraman Sharma, Professor, Department of Panchakarma for his valuable comments that greatly improved the manuscript. The authors would also like to thank various hospital authorities for sharing their views about different waste management measures they adopted.

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