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A Review Article on the Bio Medical Waste Management Issues with critical appraisal in Indian Context.

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I. Introduction

The waste that is generated during diagnosis/treatment from health care facilities be it hospitals,nursing homes,clinics,dispensaries,outpatient service providers,diagnostic centres,research laboratories,immunisation camps,blood banks is termed as **Bio Medical Waste(BMW**) which can be solid or liquid". 85% of BMW is General waste but the quantity of BMW that needs special attention is 15% of which 10% is infectious and approximately 5% is hazardous waste which may be non infectious(WHO,2002) **85% of non hazardous waste is of two types Type I Hospital kitchen waste** eg food items
Type II Recyclable waste eg glass bottles and cardboard boxes, packings etc
Out of the **15% hazardous waste, 5% consist of toxic chemicals, cytotoxic drugs and radio active waste. 10% consist of infectious waste which is of two types**
Type I Sharp waste which includes needles, scalpels and blades.
Type II Non sharp waste which can be patient contaminated waste and or laboratory waste. Patient contaminated waste can be plastics and non plastics ; plastics include IV sets, catheters and disposal syringes. Non plastics include dressings, cotton plugs and gauges. Laboratory waste include specimens, medical lab waste (body fluids, blood, pus and sputum) and animal carcasses and anatomical waste.
85% of BMW which is similar to ordinary municipal waste consists of food items (40%)
,plastic(19%),paper and cardboard(14%),metal(8%),glass(6%), textile(5%) and other material (8%). Organic constituents of this fraction of BMW such as paper & plastics can be reused after recycling and remaining organic components of BMW which cannot be reused or recycled can be used for the production of biofuels and other valuable chemicals.The remaining 15% BMW which needs special attention is broadly categorised as incinerable waste(collected in yellow bags), non recyclable cytotoxic plastic waste (collected in red bag), sharps (collected in white picture proof bags). BMW has gained attention in recent years because of many reasons, the important among them being: increase in its quantity, its hazardous nature and its complex behaviour on reaching the environment. The importance of BMW was all the more realised after the COVID 19 pandemic. Thus we in our article are presenting the literature surveys pertaining to BMW issues, the lacuna persisting in this context with special emphasis in the Indian scenario.

II. Methodology:

For our study research articles from year 2000 to present were searched on Scopus, Pubmed and Google Scholar. Full research articles based on BMW were considered.To scroll articles on the search engines we used the terminologies- hazardous waste, medical waste, clinical waste, pathological and infectious solid and liquid waste, health care waste, hospital waste, hospital waste waters and hospital waste incinerated ash.

III. Literature Review

Our literature review shall focus on three major aspects pertaining to BMW issues.These being biomedical waste management(BMW M), Liquid biomedical waste/ Hospital wastewater(HWWs) and Solid biomedical waste.

The first literature exploration deals with BMW M issues nationally and internationally.This is vital because if has been strictly advised by the WHO,1999 that the waste generated from health care facility(HCF) should be treated as a special waste (Rushbrook et.,2000), The United States Environmental Protection Agency(USEPA) way back in 1991 had defined this waste as a hazardous waste.The most notable challenge with BMW is that its quantity and quality not only differs among the countries but also within the same country depending on the type of HCF, proportion of reusable to disposable items used in the treatment procedures and waste management practices followed by the waste handlers of that particular HCF. Also the quantity of BMW generated depends on the income level of a country and it has been proclaimed by researchers that developed countries generate more BMW in terms of kg bed^{-1} day^{-1} as compared to developing countries. In the present scenario BMW is recognised as 2nd most hazardous and potentially infectious waste (Defra, 2005; Karademir,2004). As per the US EPA medical waste is the 3rd largest emitter of dioxins. Realising the hazardous

potential of waste generated from HCFs in polluting the environment and consequently adversely affecting human beings, animals and plants strict legislations were framed globally by both developing and developed countries for its handling and disposal (Sadeghi,2002). In developed countries legislations are strict ,sound management practices are followed and best available techniques are used for the disposal of BMW (Tudor et al., 2005). On the other hand in developing countries legislations are famed but are not strictly practised, management of waste is handled by poorly educated workers and untrained staff with improper guidance(Silvia et al.,2005;Diaz et al., 2005). Thus the governments across the globe through BMW M rules plan to mitigate the impact of Bio medical waste (BMW) in the community but these provisions are yet to be fully implemented and the overall scenario of BMW handling and its disposal is still masked by the shadow of unawareness (Baishakhi et al., 2017). Apart from the failure to comply with the principles of waste segregation at the source, lack of required devices to make the infectious waste harmless is another major problem associated with BMW (Marzieh Hadipour 2013).BMW is a special category of waste (Baveja et al., 2000 ; Tsakona M et al.,2007) and because health care institutions use a variety of chemicals so BMW could be dangerous to the ecological balance and public health (Ajay et al., 2006). To minimise the eco toxicological risk of BMW it is essential that waste segregation and infectious waste treatment before its disposal is managed by the hospital (Dasimah et al., 2012). These aspects of BMW management are the responsibility of the hospital authorities and need personal awareness, scientific practices and above all good administration. In 2016, Oli and others have assessed that the involvement of private health care workers in BMW handling practices is poor as compared to public hospitals.Chauhan and others 2016 have found the limited contribution of private health care organisations in setting up waste recycling units. A comprehensive bio waste management research analysis done by Thakur and Ramesh ,2015 state that-

- Out of the total publications, 72.72% are covered by the two journals namely
Waste Management and Research & Waste Management.
- 42% of studies have been done in China, Iran, Greece, India and the UK.
- 60% of the articles are related with general health care waste management practices;
- Lest deal with the disposal and impact of BMW.

When publication scenario for both solid and liquid BMW was done by (Parida et al.,2022), it was found that

1) Literature concerning the environmental and health issues arising due to the various categories of BMW gained momentum after 2008 for solid BMW (73% of research articles were published from 2008- 2020, concerning the BMW generation rates, its composition, segregation and disposal options) and for liquid HWWs after 2012 (82% research articles were published from 2012- 2020,highlighting the composition of HWW, treatment and discharge options).

2) A logistics model was used to make an S curve simulation to understand the prevailing research trend in BMW and also to predict future research status of BMW. The results of this model showed that research of both solid BMW and HWWs exist in growth phase and will attain maturation by 2040-2050 and saturation by 2060-2070.

1) In the year 2020 when Scopus database was searched for research articles on BMW a total of 1900 articles were shortlisted,of which 1200 had data relevant to infectious, pathological,chemical, pharmaceutical and radioactive waste, rest were concerned with sharp medical waste. Similarly for HWW there were a total of 950 publications ;385 were for pharmaceutical active compounds(phAcs), 300 for pathogenic analysis, 70 for disinfectants, 50 were confined to ARBs and ARGs, the rest 140 dealt with treatment options , discharge values and rules and regulations.

The biggest complication in BMW M arises due to the use of different terminologies across the world for defining waste generated from HCFs(Diaz et al., 2008). To quote them WHO defines this waste as Health care waste, the secretariat of Basel convention uses the term BMW and health care waste(HCW) and the(ICRC 2011) uses the term medical waste. This waste has some more synonyms in its pocket such as hospital waste, clinical waste, hazardous waste, regulated waste,hazardous health care waste (Nepal), infectious waste (Iran), hazardous medical waste (Croatia).In India we call it Bio Medical Waste (BMW). Not only this for different categories of BMW again confusions exist ; to quote in developing countries BMW is classified as bio hazardous / pathological waste and non bio hazardous / non pathological waste. Bio hazardous waste is further classified as infectious, pathological, sharp waste, pharmaceutical waste, genotoxic waste, chemical waste and radioactive waste. In developed countries it is categorised in 05 groups as

Group A - soiled waste
Group B- sharp waste
Group C- laboratory and culture waste
Group D- pharmaceuticals
Group E - waste containing human urine and excreta (Lydia Hangulu,2018).

Rules and Regulations for effective management of BMW are based on the definitions for different categories of the above waste and thereby different handling and disposal options are accordingly decided for each category and as such variations are seen in these also across different countries.In developed countries BMW is either regulated by specific legislations(Croatia) or by issuing of ordinances(all european countries) (Muhlich, 2003).In

rest other countries rules are framed under the guidance of Ministry of health / environment.When a detailed insight into the BMW M rules was undertaken in our literature study it was found that only a few countries across the globe have complete and detailed framework of regulations as per international guidelines pertaining to BMW M.

Continent	Country /ies
Africa	South Africa
Asia	China, India, Japan, South Korea and Taiwan
Europe	All countries except Serbia
Latin America	El Salvador and Brazil
Middle East	Bahrain, Saudi Arabia and Turkey
North America	All states
Australia	Rules exist as per international guidelines

Thus specifically middle and lower income group countries still do not have well defined legal guidelines for BMW M (Canito et al., 2015). When literature review of BMW M for Indian hospitals was done it was found that these are confined for larger HCFs only and that too of particular states ie Uttar Pradesh, Delhi, Himachal Pradesh, Madhya Pradesh, Maharashtra, Karnataka, West Bengal. In India BMW M studies were done by Kishore et al., 2000; Patil and Shekdar., 2001; Singh et al., 2001; Khan et al.,2004; Singh et al., 2004; Rao et al.,2004; Pandit et al.,2005; Patil and Pokhrel, 2005; Chitnis et al., 2005; Verma and Srivastava, 2006; Gupta and Boojh, 2006; Sharma and Chauhan, 2008; Hanumantha Rao, 2008; Boss et al., 2009; Gupta et al., 2009; Hanumantha Rao, 2009; Khajuria, 2009; Nema et al., 2011; Basu et al., 2012; Pant, 2012; Ujwala et al., 2012, Dohare et al., 2013; Sharma et al., 2013; Chethana et al., 2013 but the limitations of such studies are that they are confined to limited regions, thus BMW M needs a comprehensive approach in India. BMW M literature survey on Scopus from 2000-2015 by Canito et al., revealed that most of the studies regarding BMW issues were done in Asia, Africa and Middle east countries and were structured as under

Studies	percent	Various aspects of BMW M
44	39.3	BMW M practices
14	12.5	Regarding knowledge and attitude on BMW
13	11.6	Segregation and or quantification of BMW
12	10.7	Risk associated with BMW
11	9.8	Treatment and disposal options for BMW
09	8.0	Rules and regulations for BMW
09	8.0	Models for BMW M

It is worthwhile to mention here that BMW M benchmark years are 1970 when in North America BMW was found littering on its beaches and voice for its safe management was raised, then in 2000 when the first edition of Blue Book by WHO was published which is a milestone for safe and sustainable practices of BMW M.
BMW M includes four stages
Stage I Waste generation and waste minimisation strategies
Stage II Waste segregation and waste collection practices
Stage III Waste storage and waste transportation to CBWTF
Stage IV Waste disposal includes incineration, land filling, recycling and reuse.
Waste management includes estimation of the quantity of waste generated (Karamouz et al., 2007).Lacunae in the quantity of BMW generated exists as in most of the studies an estimation of the BMW generated is project based,

still others do not clearly state the details of the basis of estimation of BMW generation rates (Patwary et al., 2009).Also data of ward wise generation of BMW is missing in most of the studies. In Indian scenario BMW generation rates have been studied by following researchers-

City	No of HCF studied	Quantity of waste generated	Reference
Belgaum	1	0.50	Patil and Pokhrel,2005
Lucknow	1	0.5	Gupta and Boojh,2006
Lucknow	8	0.56	Manar et al., 2014
Karnataka	3	0.16-0.56	Onursal,2003
Maharashtra	14	0.08-1.04	Onursal, 2003
West Bengal	8	0.19-0.51	Onursal, 2003
Delhi	3	1.02-1.60	Patil and Shekdar,2001

As for waste segregation colour coded bins are used but due to lack of training and scientific aptitude towards BMW mixing of waste is frequently seen in most of the HCFs across India (Gupta and Boojh,2006).Regarding waste disposal and recycling it is seen that illegal sale and unauthorised recycling of waste is another major defiant of BMW M rules in India.

Liquid BMW M Literature Review

A large proportion of BMW is in the form of hospital wastewaters. Hospitals consume an important volume of water per day because it is a well-known fact that water is a convenient and universal solvent, which is used to transport waste products away from the site of production and discharge, and thus hospital wastewaters are an incontestable release source of many chemical compounds (Vijay U, 2012).

An in-depth literature review has been conducted on conventional pollutants of wastewaters from hospitals (Emmanuel et al., 2001,2004; Altin et al., 2003; Chiang et al., 2003; Brown et al.,

2006; Pauwels et al., 2006; Kajitvichyanukul and Suntronvipart 2006; Gautam et al., 2007; Machado et al., 2007; Sarafraz et al., 2007; Tsakona et al., 2007; Verlicchi et al., 2008 and Mesdaghinia et al., 2009). High concentrations of Organochlorine Compounds, heavy metals, alkaline pH, low concentrations of bacteria flora (marking antibiotic resistivity), high BOD and

COD were seen in hospital wastewater (Prayitno et al., 2013 & Akin B S, 2016). Along with the presence of bio-accumulable pharmaceutical drugs (Jean J et al.,2012), posing an adverse effect on the community of organisms in charge of the biological decomposition of the organic matter (Emmanue. E et al., 2004). The effect of emerging contaminants (EC's) on the environment is not known aptly as there is insufficient data on their toxicity assessment and this may be one of the main reasons that only a handful of countries across the world have issued standards and protocols related to HWW discharge. Among them is the European Union, Iran, China, Switzerland who have relevant guidelines regarding the wastewater treatment plant (WWTP)discharge limits for EC's. Conventionally designed WWTP mainly works by reducing suspended solids, organic matter & nutrient concentrations.The most notable feature of hospital waste water is that it does not need to persist in the environment to cause negative effects as it has a variety of chemicals in it, which have high rate of transformation / removal and are being continuously introduced in the environment and if these so called “emerging pollutants” are monitored regularly for their health impact then they may be candidates for future regulations (Verlicchi P et al., 2010). To summarise, hospital wastewaters significantly change the degree of contamination and pollution loads as compared to sewage water (Akin B S, 2016).

Water is a very precious natural resource which is extensively threatened due to its intense over exploitation by the ever increasing demands of the growing population and also due to the increasing pollution of the natural water bodies. Hospital waste waters are the source of a large number of micro pollutants among which the position of emerging contaminants is held by pharmaceuticals which persist in the aquatic environment and

denature the physico chemical parameters of water.Approximately 3000 natural / artificial compounds are used as medicines with an annual production of hundreds of tons(Kummerer, 2009;Sim et al .,2011).A wide variety of chemicals are used by health care sectors such as pharmaceuticals, disinfectants, solvents etc for treatment, diagnosis and research. Thus any health care centre is a major source of two types of pollutants - air and water.Hospitals being major consumers of water generate reciprocally large volumes of waste water which in majority of cases is discharged without any treatment into the aquatic environment or into the municipal sewer system.Generally HWW has 2-3 times higher concentrations of BOD, COD, TSS as compared to municipal waste water.(Verlicchi et al., 2010b). It also contains notable concentrations of pathogens such as E. coli & total coliform that are the vehicles for antibiotic resistance.(Hoquet et al.,2016).

Solid BMW M Literature Review

Our review now focuses on the solid (hazardous waste disposal). In 2016, the government of India, amended part II, section 3, subsection (i) of bio medical waste rules 1998; which was published vide notification number S.O.630(E) dated July 20th 1998. In the erstwhile Ministry of forests and environment (CPCB), where Incineration followed by disposal of the resultant ash by landfilling is the principal method adopted widely for hazardous waste disposal(Altin et al., 2003, Jang et al., 2006,Xie et al., 2009). The process destroys pathogens and reduces the waste volume by 90% and weight by 75% (Rajor A et al., 2012). However,incineration of medical waste results in release of Organic poly chlorinated dibenzo p-dioxin(PCDD), Dibenzo furan(PCDF) and polycyclic aromatic hydrocarbons (PAHs) and inorganic (heavy metals such as Cd, Pb, Hg, Cr, As, Mn, Ni) compounds in the form of stack gases, bottom ash and fly ash (Singh S , Prakash P, 2007, Zhao et al., 2008, Gidarakos et al., 2009, Kougemitrou et al., 2011, Rajor A et a.,l 2012, Minjiang et al., 2012). These compounds are a threat to the environment. Moreover, the ash generated by incineration after testing for leachate property is disposed as land filled which requires vast areas of uninhabited land that is again a major problem for an over populated country like India.In Indian scenario, only 6.67% of waste is incinerated rest goes directly to landfilling and is recycled again(CPCB,2012).The incineration of 3.28-lakh MetricTons Per Annum (MTA) hazardous waste generates approx. 0.82 lakh MTA of ash throughout the country, which requires vast stretches of land for disposal, a serious issue to be dealt with. Considering the delirious effects of BMW on society, the proposed study plans to assess bio medical waste handling practices of our district.In industrialised countries such as USA and Germany BMW is managed by opting autoclaving, microwaving and recycling as major techniques of disposal rather than Incineration.(Adama et al., 2016). Since BMW is hazardous in itself, consequently the ash that is generated from MWI (medical waste incinerator) must essentially undergo post treatment options such as landfilling, solidification and or vitrification.Moreover the emission concentrations of PCDD/Fs depends on the characteristics of BMW ie its composition which is largely affected by the aptitude and the segregation practices followed by the staff involved in BMW M.PCDD/F formation due to the use of incineration technology can be explained in 3 ways

1 BMW that is being feeded in the incinerator already contains PCDD/F.
2 They can be formed in the presence of Cl as BMW contains Cl.
3 They can be formed by de novo mechanisms i.e. when an incinerator is operated at low temperatures.

PAHs are 2 to 8 ringed semi volatile organic compounds formed primarily during incomplete combustion of BMW.The emission concentrations of PAHs is directly correlated to incineration temperature.(Singh and Prakash, 2006).PAHs are omnipresent environmental pollutants having carcinogenic and mutagenic effects.The USEPA(1997a) has listed 16PAHs as priority pollutants. The IARC(International agency for research on cancer) has classified carcinogens into 5 groups as Group 1 Human carcinogens
Group 2A Probable human carcinogens(includes 3 PAHs)
Group 2B Possible human carcinogens(includes 3 PAHs)
Group 3 and 4 include non carcinogens

During combustion PAHs are formed from 2 processes pyrolysis and pyrosynthesis.Partial thermal decomposition of organic compounds into small unstable fragments is called as pyrolysis which results in formation of reactive free radicals from which through recombination reactions ie pyrosynthesis PAHs are formed. Investigations by Zhao et al., 2008a have found that the mean levels of PAH are from the range of 4.16 to 198.92 mg /kg in MWI ash . Bottom ash consists of low molecular weight (LM)PAHs which are 2 to 3 ringed and medium molecular weight (MM)PAHs which are 4 ringed. On the other hand Fly ash mainly consist of MMPAH and high molecular weight (HM)PAHs which are 5 to 6 ringed. Also bottom ash mainly consists of CaCO3, SiO2 and Ca(OH)2(Zhao et al., 2010). The compositions of fly ash are generally more complex. Bottom ash also consist of large amounts of heavy metals ;present as residual fractions containing Ba, Cr, Ni and Sn existing as oxides of Fe-Mn in Fe Mn oxide fraction and Cu in inorganic fraction (Zhao et al., 2008a).Almost all types of MWI emit heavy metals.The prominent heavy metals present in bottom and fly ash are Cd, Pb, Cr and As. Hg is mainly vented as a flue stack as per national research council (NRC ,2000).It has also described various types of toxicity and health hazards associated with heavy metals. Burned plastics are a major source of Pb in MWIs. Careful and

diligent segregation practices along with adequate management policies reduce about 80% quantity of waste that is to be incinerated thereby eliminating Hg and Pb.

IV. Results and Discussions:

1. The Literature explorations on the major research engines for BMW has revealed that the biggest lacuna in BMW M arises due to the different terminologies used to symbolise this waste which leads to improper segregation and inappropriate disposal
2. The bulk of studies for BMW M issues were concentrated in the developing countries, though the amount of waste generated is more in the developed countries but due to lack of resources, financial constraints, unscientific aptitude towards BMW M, handling of waste by untrained staff, illegal and unauthorised reuse and recycling of BMW in these countries this problem has been aggravated in the Middle and Low income group nations consequently a need for more research.
3. In India though the BMW M rules, 1998 which were later on made more stringent in 2016,monitored by Central Pollution Control Board(CPCB) under the Ministry of Environment Forest and Climate change(MoEFCC) are followed but due to violations both by the health care facilities(HCF) and the Common Biomedical Waste Treatment Facility(CBWTF) open dumping and open burning of waste is seen.
4. The studies related to BMW in India are mostly centred around some big hospitals of big cities, such studies revolve around BMW M issues such as waste quantification ,waste segregation knowledge and attitude regarding BMW, very few studies are based on qualitative analysis of HWWs and solid incinerated ash. Also a handful of the studies based on the quantity of BMW generated from individual departments of a multispeciality hospital were encountered.

V. Conclusions:

BMW in the Indian context needs a more comprehensive, scientific approach. The CBWTFs need to be upgraded and should be regularly monitored.

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