Urban Solid Waste Management

Issues and Challenges of Sustainability

Edited by:

Sudipto Ghosh
Amit Bhandari

PALMVIEW

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About the Editors

Dr. Sudipto Ghosh, an Urban Planner, currently attached with Bansberia Municipality, Hooghly, West Bengal, dealing with improving the quality of life of urban places. He is a Ph D in sociology and is an expert in the fields of microfinance, entrepreneurship, planning, and livelihood. As a planning expert in the government, he has more than fifteen years of experience in the urban and rural sector. He is involved in the preparation of city planning and various development project reports for local government bodies. He has published several papers and books to international publishers. He has presented papers in the International Seminar on Solid Waste Management held at Jadavpur University and in the National Workshop on Sanitation in New Delhi in the year 2016 organized by the Government of India. He is also a Securities and Exchange Board of India (SEBl) resource person working for the Financial Literacy Programme and has been involved in advising the organization on social development issues.

Dr. Amit Bhandari is an Assistant Professor at the Department of Economics, Rishi Bankim Chandra Evening College, India. He is a Research Fellow at IZA Institute of Labour Economics, Bonn, Germany. He holds a Ph.D. in Economics from the Department of Economics at the University of Kalyani, India. Formerly, he was a lecturer in economics and finance at the Indian Institute of Social Welfare and Business Management (IlSWBM), Kolkata. His works have been published in reputed journals and books. He has a broad interdisciplinary research interest in behavioural, development and financial economics. His research work has been funded by the Indian Council of Social Science Research (ICSSR) and the University Grants Commission (UGC), India.

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Foreword

I was delighted when my erstwhile colleague Sudipto Ghosh asked me to write the Foreword to this book which has been edited by him and Professor Amit Bhandari. As a Municipal Urban Planner Sudipto Ghosh gathered close practitioner experience in the problems of waste management in a municipal town and I am aware that he was associated with Bansberia Municipality trying out several innovative approaches in waste management. Professor Bhandari has been intellectually active in finding out sustainable solutions to waste management in India. The subject of this book is close to my heart. During my tenure as Principal Secretary, Environment Department, Government of West Bengal, I have seen how crucial effective waste management is to providing a good enough healthy environment for the citizens and especially children in our cities and towns. The theme of the book i.e., sustainable waste management practices is the need of the hour. As Municipal Commissioner of Kolkata, I have experienced all the problems of big city waste management and seen how the adoption of good practices along with sincerity of implementation can bring about positive changes. This book comes at the right time when the country is moving forward towards adopting better practices in waste management and will be useful to practitioners, academics and citizens at large.

Over the past few decades, the scope, expanse and complexity of waste management practices in India have increased manifold. What started out as the collection and disposal of kitchen waste in a few cities has now expanded into the collection, transportation and effective disposal of organic waste, liquid waste, plastic waste, construction and demolition waste, biomedical waste and e-waste in cities, towns, and rural areas. New challenges call for new solutions and technology. This book provides a window to new thought, approaches and technology. Some of the articles discuss examples of good practices in tackling waste management. Recycling of wastes

has been tried in many places but most have been short-lived. Some articles in this book provide newer ideas on the recycling of wastes and inform about practices that can be sustainable in the long run. The informal sector comprising of kabadiwallas, ragpickers and others have for long been a significant player in waste management in India. Yet they are mostly ignored and left out of the stakeholders when policies on waste management are framed. Regulations and enforcement have lagged behind international best practices and this is an area which will become more important in the coming years. Putting all together to make for an effective waste management system is the policies that are taken up for addressing it. Shri Anjor Bhaskar in his article on sustainable municipal solid waste has reviewed the practices and policies and points out the improvements needed. Overall, the editors of this publication have chosen the articles with care and have addressed important aspects of waste management

This book is a compilation in one place of various experts in the field presenting their studies on most of the facets of waste management. Readers who are stakeholders or interested persons can be acquainted with new ideas and thoughts and also get a broad idea of the whole spectrum of waste management in India. I am sure the articles will provoke thought and discussion and will inspire several readers to become advocates for better waste management. I was excited to go through the ideas presented by several distinguished contributors. It has been an honour to be invited to write this foreword and I thank the editors for the opportunity.

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Principal Secretary
Consumer Affairs Department
Government of West Bengal

Chapter 5

Risk Assessment of Biomedical Wastes Generated in Hospitals of Chandigarh and Shimla, India

Rajiv Ganguly, Prachi Vasistha and Ashok Kumar Gupta

1. Introduction

Rapid globalization and urbanization have to lead to increased production of wastes including biomedical wastes generated from different health care services (Denboss and Izapanah, 2002; Oweiss et al., 2005). Biomedical wastes generated are of prime importance as they can severely affect the surrounding environment and consequently human health due to the transmission of pathogens (Patwary et al., 2009; El-Salam, 2010). The problem has been further compounded due to inappropriate legislations and management techniques of such biomedical wastes particularly in developing countries (Narendra et al., 2013). The amount of biomedical waste generated is quite small in comparison to the total amount of solid wastes generated but are highly significant due to its potential health risks (Cheng et al., 2009). The quantities of biomedical waste generated depend on numerous factors including patient intake of the healthcare facility, the different treatment specializations (Pruss et al., 1999; Debere et al., 2013). In the general context, about 85% of medical wastes generated in hospitals are non-hazardous in nature, about 10% are classified as infectious wastes and about 5% as non-infectious but hazardous waste (Liao et al, 2014). Advancement in health care facilities around the world has led to serious improvement of biomedical waste

management in developed countries with strict regulations and guidelines. In Indian context, strict regulations were put forward by the Ministry of Environment and Forest (MOEF) notifying the Bio-medical Waste Management and Handling Rules in 1998 (amendments in 2003 and 2011) under the Environmental Protection Act 1986 (MOEF, 2011) and was one of the first countries to successfully implement these rules (Gupta et al., 2009; IPEN, 2014). However, despite strict regulations and legislative guidelines, in an Indian context the paradox of the situation is that the healthcare facilities often themselves pose health risk due to improper management of waste, and often lack of awareness of the existing regulations (Narendra et al., 2013).

Since medical wastes consist of pathogens, they need to be handled carefully to minimize risks to all personals present in the healthcare facility (doctors, nurses, administrative personals, patients, etc.) (Rao,2009). The problem is further compounded as often the risks associated with handling of biomedical wastes are unknown to workers in healthcare facilities (Nema et al., 2011). Research studies have shown that several injuries and infections arise due to such mismanaged biomedical wastes in and around healthcare facilities including infection of nurses in Operation Theatres (OT) (Rao et al., 2004, due to indisposed medicines and broken syringes and general medical wastes which become toxic when remain exposed over very long time (Bokhoree et al., 2014).

In the above context, it is important to identify the risk associated with the different waste types generated in a healthcare facilityto take appropriate and necessary follow-up actions to avoid any mishap. The paper presents the results of risk assessment analysis conducted over four hospitals in two cities obtained using the PHA methodology and evaluated further using a matrix methodology.

Preliminary Hazard Analysis (PHA) is a semi quantitative analysis which is generally performed to identify the potential hazards that may lead to any accidental event that may be large or small, to rank these accidental events according to their severity and likelihood so that appropriate hazard controls and necessary follow-up actions can be taken (Rausand, 2008). PHA applications have been utilized for conducting vast

number of different studies including assessing risk management in pharmaceutical industry (Charoo and Ali, 2013), reliability for fractional column in refinery (Ibrahim and Nafaty, 2016), risk management study in medical device industry (Dumbrique, 2010). However, very limited literature is available on application of PHA for risk assessment of biomedical wastes. In one such study carried out in Batna city of Algeria reported by Sefouhi et al.,2013.PHA was used to identify and assess the risks that occur in the hospital due to the presence of hazardous elements in hospital waste in terms of severity associated with these waste types. The main categories of waste that represented most possible and acute hazards were Sharps, Infectious Waste and Anatomical Waste (Sefouhi et al.,2013). The conclusion drawn from the study was that all necessary steps were followed in the hospital at Batnacity for proper management of biomedical wastes however there was a significant scope for attention and improvement (Sefouhi et al.,2013). The PHA analysis carried out in the study helped the identification of various hazards that could take place in the hospital and plan the necessary follow-up actions relevant to the hazard (Sefouhi et al.,2013).

Different healthcare facilities produce different types of wastes dependent on different factors including type of healthcare facility, patient intake etc. (Komilis et.al, 2011), hence the techniques of risk assessment varies from hospital to hospital due to difference in waste characteristics. However, it is important to note that Risk causing Healthcare Waste or Risky Healthcare waste (RHCW) production percentages are almost same for all hospitals. The general production of Risky healthcare Waste in a hospital is considered to be about 10-25% (Shinee et.al. 2008; Srivastava et al., 2012)

The major RHCW generated in hospitals are Waste Sharps, Pharmaceutical and Chemical Waste, Infectious Waste and Anatomical Waste (Gupta et al., 2009; Kumar et al., 2014). The severity of these wastes varies from minor effects to catastrophic effects. In this study, we have used the PHA technique to determine the risk assessment from such RHCW.

Site Locations

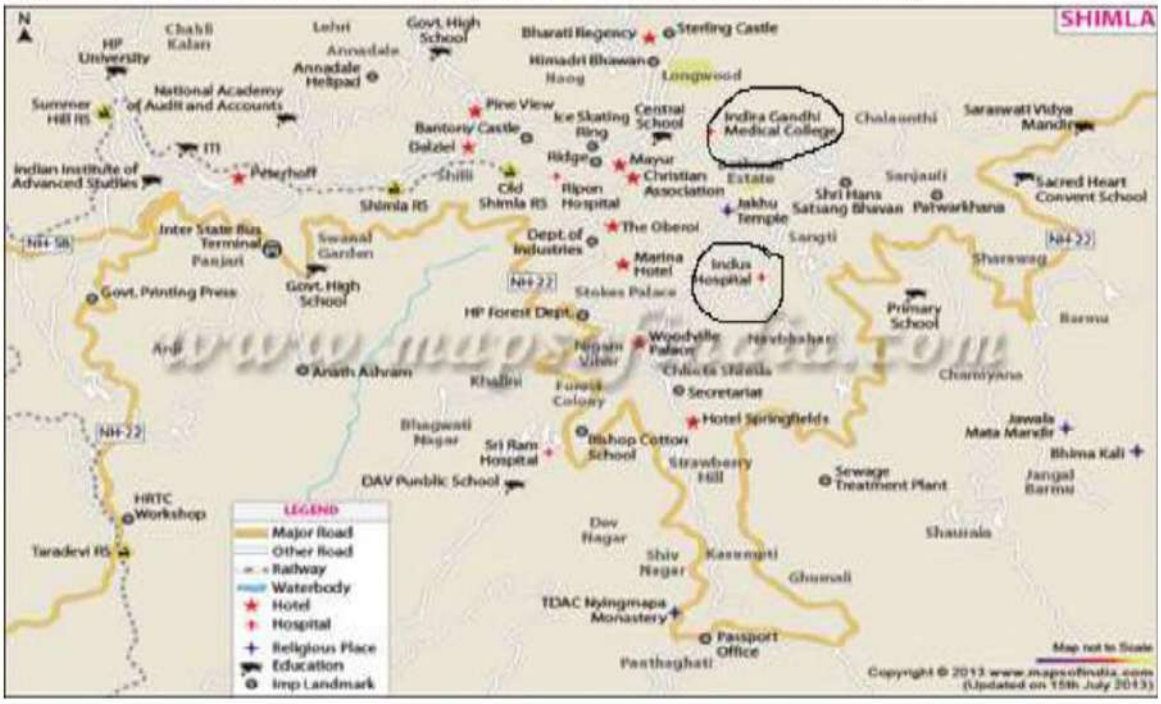
The study areas were selected keeping in view of the different biomedical waste practices in major hospitals located within 100 km radius. The nearest cities were Shimla (2 hospitals considered) and Chandigarh (2 hospitals considered) wherein these hospitals were located. (Distance between Shimla and Chandigarh is 100 km's). Further both public and private sector hospitals were considered in Shimlaand only private hospitals in Chandigarh to evaluate the risks associate with the management of biomedical waste and their compliance with Indian guidelines. Brief descriptions of these hospitals have been mentioned in the next few paragraphs.

In Shimla the two hospitals that were chosen were IGMC Hospital (Public sector hospital) comprising of 33 departments. The biomedical waste management is handled by a team of 3 members headed by medical superintendent who looks after the entire management of healthcare wastes from generation to disposal (Personal Communication with IGMC Hospital Administration). The average inpatients are 669 with average bed occupancy of 84. According to the annual statistical report of the hospitalthe total number of patients admitted each year were about 31,872 of which 31,771 patients were discharged disposal (Personal Communication with IGMC Hospital Administration). The total number of patient treatment days to be around 2, 44,503 with average length of stay for patient to be 8 days disposal (Personal Communication with IGMC Hospital Administration). The location of the hospitals in Shimla city has been shown in Figure 1.

The INDUS Hospital (in Shimla) is a private hospital with a 6 storied hospital building comprising of eight major departments includingsurgery, medicine, ayurveda, radio diagnosis and imaging, pediatrics, and adolescent medicine, gynecology and maternity, orthopedic surgery, dentistry and oral health, and department of physiotherapy (Personal Communication with INDUS Hospital Administration). In this hospital, the biomedical waste management is maintained by team of 2 main members, one of these being the head of the nurses training department and other person being administrative head

supported by workers for collection and disposal of the waste from hospital wards(Personal Communication with INDUS Hospital Administration).Though the premises of the hospital small but the hospital wards are well equipped with attached washrooms and intercom facilities in general wards and ventilators, defibrillators, piped oxygen, central suction and compressed air in the intensive care units. The hospital is looked by a team of 19 doctors and operates on a 24-hour basis with assigned house physician on duty round the clock (Personal Communication with INDUS Hospital Administration).

Figure 1: Location of two hospitals selected in Shimla city

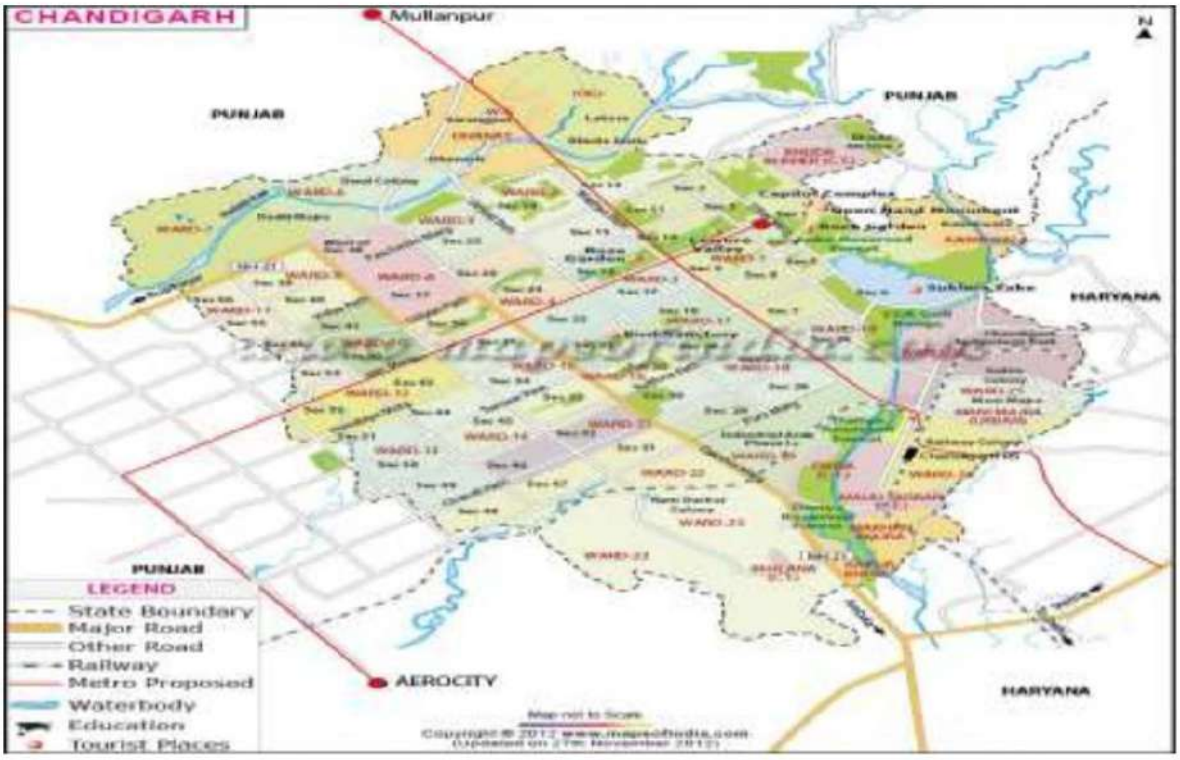


In Chandigarh the hospitals that were taken for study purpose were MAX Super Specialty Hospital and the IVY both being both large Private Sector hospitals located in Mohali area.The view of Chandigarh City has been shown in Figure 2 below.MAX Healthcare is India's first provider of integrated and comprehensive world class healthcare services. There are 11 facilities for the healthcare services distributed in North India specializing in over 32 disciplines (Personal Communication with MAX Hospital Administration).

The hospital is well equipped with technically advanced equipment's for providing excellent medical facilities to its patients. The Hospital has been renowned with various accreditations from NABH, NABL and

LEED making it highest quality service provider (Personal Communication with MAX Hospital Administration). The various services provided in the hospital includes Obstetrics, Child Birth, Joint Replacement, Orthopedics, Gynecology, OPD facility, Dermatology, Plastic Surgery, Aviation Medicine, Nuclear Medicine, Ophthalmology, Urology, Thoracic Surgery etc. (Personal Communication with MAX Hospital Administration).

Figure 2: A view of the Chandigarh City



IVY Hospital is the largest tertiary Healthcare provider in Punjab. It has a total bed capacity of 205 beds and more than over 25 super specialty departments with more than 125 consultants, 1500 paramedical and nursing staff and 3000 complex surgeries and is NABH accredited (Personal Communication with IVY Hospital Administration). The total number of patients treated annually is more than 1.25 lakhs in number (Personal Communication with IVY Hospital Administration). The hospital provides expertise in Heart, Brain, Cancer, Bones and Joints, Kidney and Bladder, Stomach, Liver and Digestive System, Women Health, Child Care, Diabetes, Lungs, Internal Medicine, Psychiatrist, General Surgery, Skin, ENT etc. (Personal Communication with IVY

Hospital Administration).The hospital has been providing subsidized and free treatment to people below poverty line and to people with yellow cards. Medical checkup camps are organized every year along with awareness campaigns in nearby schools and villages as a part of social responsibility (Personal Communication with IVY Hospital Administration).

Another reason for selecting these hospitals was that these hospitals are highly reputed in the respective areas and washighly willing to share their information and contribute to the study purpose.

Materials and Methods

The methodology for the study involved a Questionnaire session which was conducted during the research period and which was filled by the doctors and all appropriate personals involved in the process of the biomedical waste handling at these selected hospitals according to their past experiences and observations. The Questionnaire was prepared for ranking of the different risky waste categories according to the severity and likelihood by the doctors and the nurses involved directly in handling and management of the wastes. The result from this questionnaire survey was used for determining the risk assessment using a matrix methodology.

The first section of the questionnaire contains personal information of the person filling the responses including their names, designation, place of work, and years of experience. The second section consists the matrix for quantification of likelihood and severity of the waste categories obtained from the analysis. The likelihood and severity both are indexed on a five point scale with 1 being the lowest and 5 being the highest value. The likelihood is ranked as *very unlikely, unlikely, possible, likely, very likely* whereas the severity is ranked as no effect, minor, major, hazardous and catastrophic with each ranking given a value for the quantification of results. The boxes in the matrix show high, low and medium risk regions where each region is specified with a definite colour i.e., red, green and yellow respectively. This is shown in Table 1and the severity of the consequence criteria in Table 2. The third section contained table with different waste categories with their potential hazardous elements, the probable causes for the accidental events and the accidental events that

may occur due to mismanagement at the different hospital sites. The table also contains columns for ranking of waste categories in terms of severity and likelihood. The questionnaire has been attached as supplementary document S1.

The PHA methodology is a semi-quantitative method for risk assessment. A matrix method of evaluation was utilized and ranking of the different RCHW was determined so that the hospital could take precautionary measures and prepare the necessary follow-up action plans in case of any hazardous event or outbreak that takes place in the hospital premises. This procedure was repeated for all the four hospitals.

The matrix method of evaluation of the questionnaire analysis is a novel approach and very less literature is available. The method of evaluation has been discussed further in the next few paragraphs. The major indices calculated were Likelihood Index (L.I), Severity Index (S.I) and Hazard Index (H.I).

Table 1: Matrix Evaluation for Risk ranking and follow up actions For Different Categories of Waste.

		Hazard Severity				
		No Effect 1	**Minor 2**	**Major 3**	**Hazardous 4**	**Catastrophic 5**
Likelihood Of Occurrence	***Very Unlikely 1***	Low	Low	Low	Low	Medium
	Unlikely 2	Low	Low	Low	Medium	Medium
	Possible 3	Low	Low	Medium	Medium	High
	Likely 4	Low	Medium	Medium	High	High
	Very Likely5	Low	Medium	High	High	High

The maximum likelihood grading score that could be provided to each waste type was denoted as 'A' and the value was taken as 5 (based on 5-point grading system). The likelihood count for each type of the wastes

varied from 1-5 and was denoted as ‘a’ and the number of persons referring to particular likelihood count were taken as ‘n’.

Table 2: Severity of Consequence criteria

No effect	Has no effect on health
Minor	Minor injury
Major	Major injury
Hazardous	Serious or fatal injury
Catastrophic	Death

The likelihood Index for each waste type was calculated separately according to formula Likelihood Index (LI) = ∑an/AN. Each likelihood count that could be referred to by personnel filling the Questionnaires at the Hospital was taken in first column of the table (a). The number of persons referring to these particular Likelihood counts was taken in the second column (n). In the third column every likelihood count was multiplied with the number of persons referring to these particular counts. The values were represented as a*n. These values were then added up and the Likelihood Index was calculated according to the formula LI = ∑an/AN where A and N were taken as 5 and 15 respectively. This is shown in Table 3 and is shown as an illustrative example. Hence, likelihood index (L.I) for infectious waste at MAX hospital was 56/75 = 0.75 (75%). Similar calculations were performed for the other three waste types namely Sharps, Anatomical Waste and Pharmaceutical & Chemical Waste for the calculation of Likelihood Indexes.

Similar methodology as described above was performed for the calculation of Severity Index (S.I) for each waste type. The value of the L.I for each waste type was multiplied with its corresponding S.I to obtain the Risk value for each waste type. This process was repeated for all the different waste types and for all the different hospitals.

Table 3: Calculation of Likelihood Index for Infectious Waste at MAX Hospital.

Likelihood count (a)	No of persons referring to particular count (n)	a*n
1	0	0
2	0	0
3	6	18
4	7	28
5	2	10
	∑an =	56
	L.I. =	0.75

Results and Discussions

The questionnaire was ranked up by group of 15 personals including doctors and nurses and all major personals involved in management of biomedical waste at all the four different hospitals. Likelihood Index (L.I), Severity Index (S.I) and Risk Index (R.I) were calculated for all the different types of the wastes generated and for all the four hospitals. The values of L.I, S.I and R.I for each waste type of each hospital have been tabulated in Table 4 below.

Table 4: Likelihood, Severity and Risk Values for various waste types in different Hospitals.

IGMC Hospital Shimla			
Waste Type	L.I.	S.I.	R.I.
I.W	0.93	0.89	0.83
Sharps	0.83	0.79	0.66
A.W	0.76	0.67	0.51
P&C.W.	0.69	0.61	0.43
Indus Hospital Shimla			
Waste Type	L.I.	S.I.	R.I.
Sharps	0.73	0.71	0.52
P.&C.W.	0.61	0.47	0.29
I.W.	0.56	0.63	0.35
A.W.	0.48	0.47	0.22
Max super Specialty Hospital Mohali			
Waste Type	L.I.	S.I.	R.I.
I.W.	0.75	0.79	0.59
Sharps	0.73	0.77	0.57
P.&C.W.	0.63	0.65	0.41

A.W.	0.57	0.63	0.36
IVY Hospital Mohali			
Waste Type	L.I.	S.I.	R.I.
Sharps	0.80	0.95	0.76
I.W.	0.73	0.87	0.64
P.&C.W.	0.67	0.76	0.51
A.W.	0.51	0.6	0.30

In Table 4, the waste categories are represented by Sharps, Anatomical Waste (A.W), for Pharmaceutical & Chemical Waste (P&C.W) and Infectious Waste (I.W). It is observed from Table 4 that for the hospitals located in Shimla city, for IGMC hospital, the L.I values is highest for Infectious waste (L.I = 0.93) while it is highest for sharps in Indus hospital (L.I = 0.73). From the L.I values that for IGMC Hospital handling of Infectious waste demands maximum attention because of the infections that may be caused by the waste kind if not handled properly. For Indus Hospital Sharps indicate maximum likelihood and needs to be handled carefully because Sharps can cause cuts and punctures to workers and these wounds may get further infected by pathogens thereby posing a threat of double risk (Sefouhi et al.,2013). Similarly, it was observed that for the hospitals located in Chandigarh city, for MAX Hospital (L.I = 0.75) the value was highest for infectious waste and for IVY hospital (L.I = 0.80) the maximum likelihood was for sharps.

Comparison of the R.I values as observed from Table 4 showed that for IGMC and MAX hospital, the maximum values were observed for Infectious waste (R.I = 0.83 and 0.59 respectively) whereas for INDUS hospital and IVY hospital, the R.I values were highest for Sharps (R.I = 0.52 and 0.76 respectively). Of the four study hospitals, anatomical waste deemed least risk producing category for three hospitals excepting IGMC wherein the Pharmaceutical & Chemical Waste was observed to be less risky. The risk posed by Pharmaceutical & Chemical Waste is highly variable depending on the number of laboratories and the amount of chemicals being used. Infectious Waste and Sharps were found to be higher risk as has been reported in earlier literature (Carvalho and Silva,2002).

A risk matrix was plotted with likelihood on the y-axis and the severity at x-axis therefore showing the different zones in which each

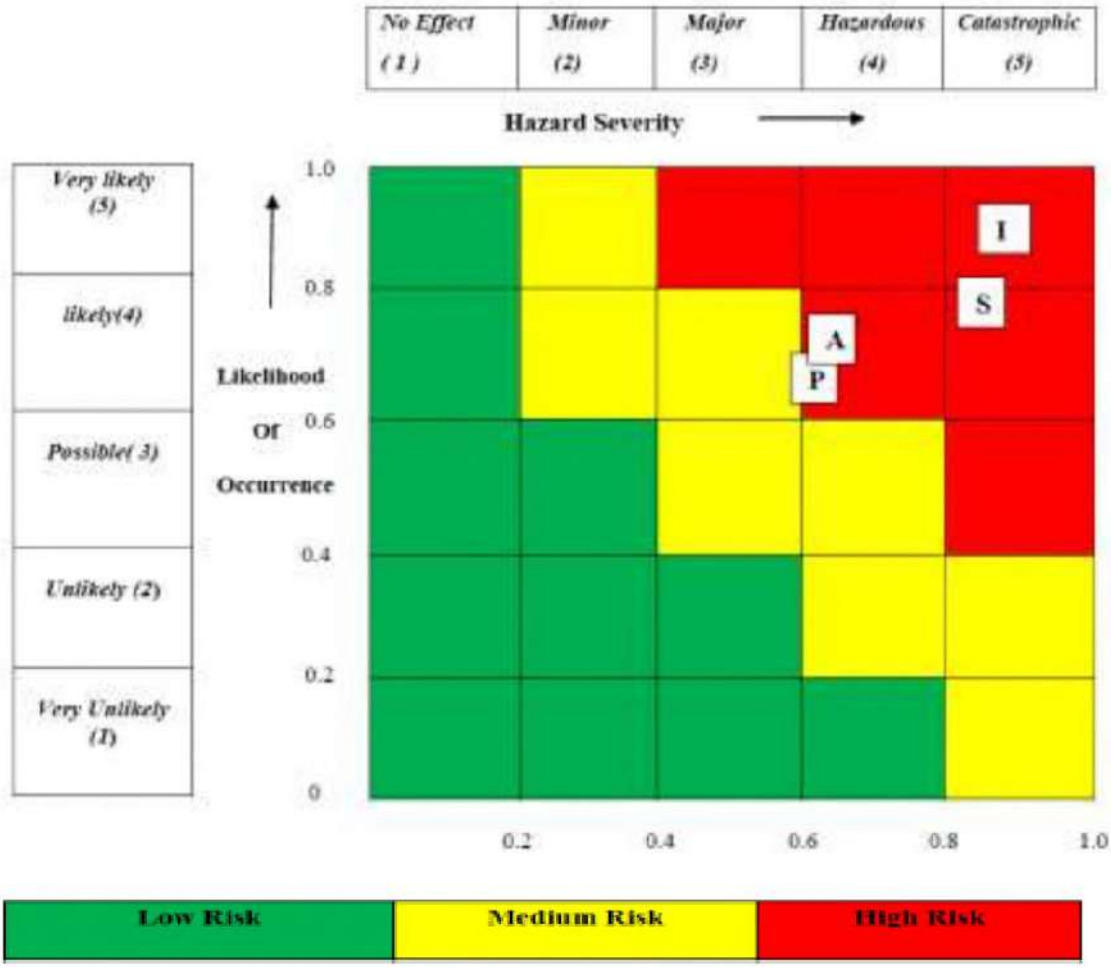
waste category could fall showing the amount of risk posed by them. The values for the likelihood and the severity were then plotted on the risk matrix. The risk matrix for each hospital has been shown in Figures 3-6 respectively. The matrix shows the waste categories represented by 'S' for sharps, 'I' for Infectious Waste, 'P' for Pharmaceutical & Chemical Waste and 'A' for anatomical Waste.

The values for Likelihood and Severity were plotted for the IGMC Hospital; Shimla to obtain the zone in which risk associated with each category felled the matrix clearly shows that the risk associated with all the different waste categories was high risk category due to the large waste quantities generated at the hospital site thereby imposing a risk of mismanagement leading to a hazardous event. This has been shown in Figure 3.

The risk matrix for the INDUS Hospital has been shown in Figure 4. The matrix clearly shows that the waste category Sharps falls in red region thereby showing High Risk Category whereas the remaining three categories of waste falls in yellow region showing medium risk category. One of the probable causes being that this hospital generates less amount of waste than IGMC.

The risk matrix for the MAX Hospital has been shown below in Figure 5. The matrix clearly shows that the waste category Sharps, Infectious Waste and Pharmaceutical and Chemical Waste falls in red region indicating a high-risk range whereas the Anatomical Waste category falls in yellow region showing medium risk range.

Figure 3: Matrix for Risk Ranking of different waste type at IGMC Hospital



The risk matrix for the IVY Hospital has been shown below in Figure 6. The matrix clearly shows that the waste category Sharps, Infectious Waste and Pharmaceutical and Chemical Waste falls in Red region showing a high-risk range whereas the Anatomical Waste category falls in yellow region showing medium risk range.

The risk matrices above clearly showed the risk associated with different waste categories and the range in which they fall as high medium and low respectively. The risk matrix is also very helpful in quickly identifying the potential risks associated with biomedical waste management process and proper steps needed to control it.

Figure 4: Matrix for Risk Ranking of different waste types at INDUS Hospital.

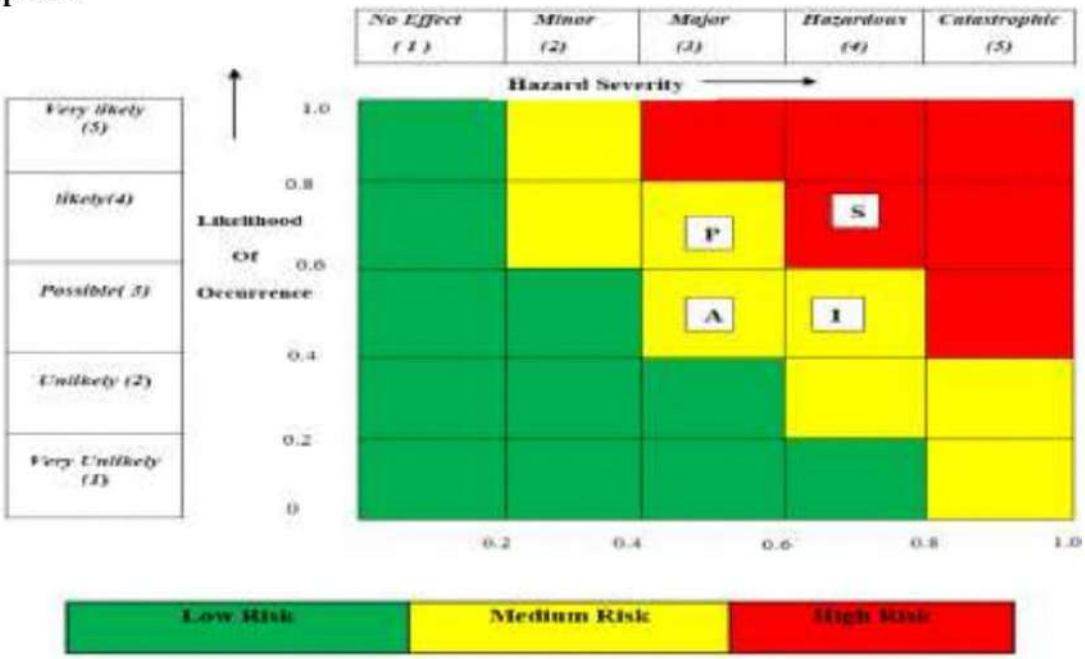


Figure 5: Matrix for Risk Ranking of different waste type at MAX Hospital

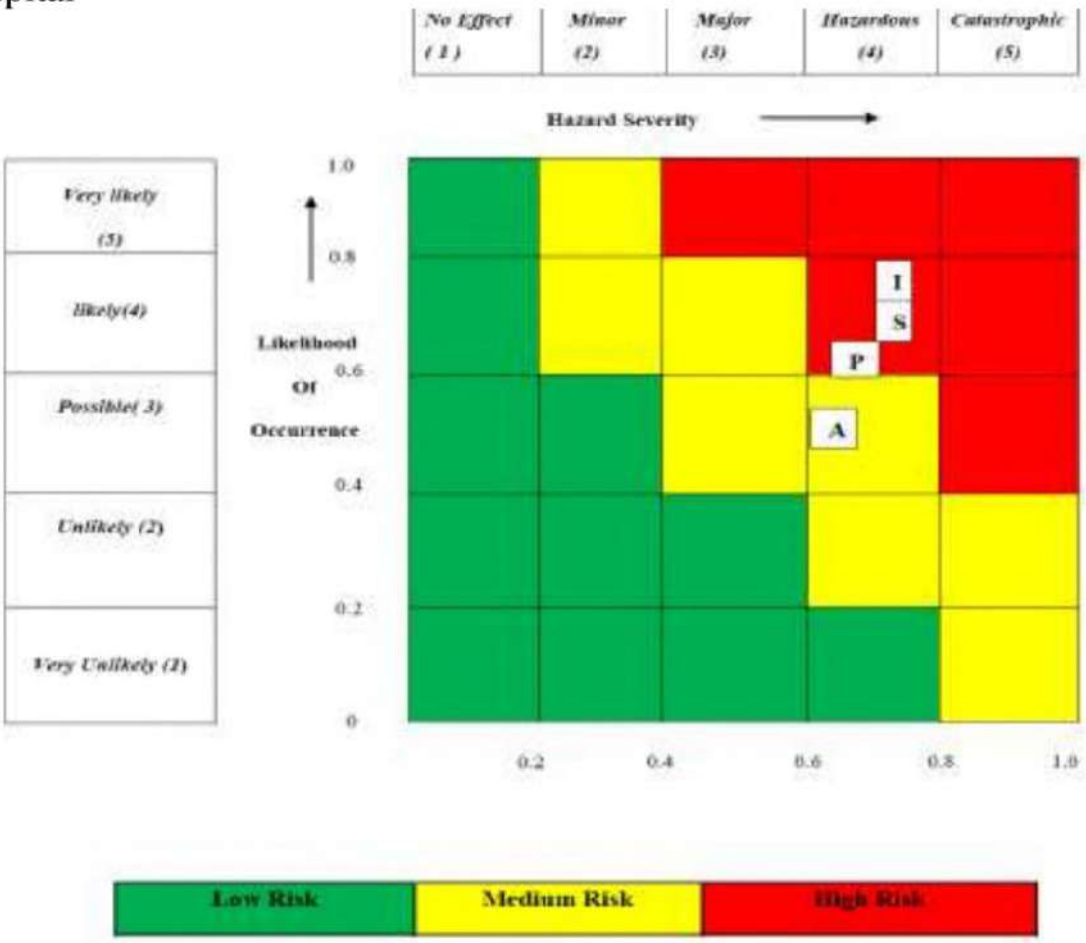
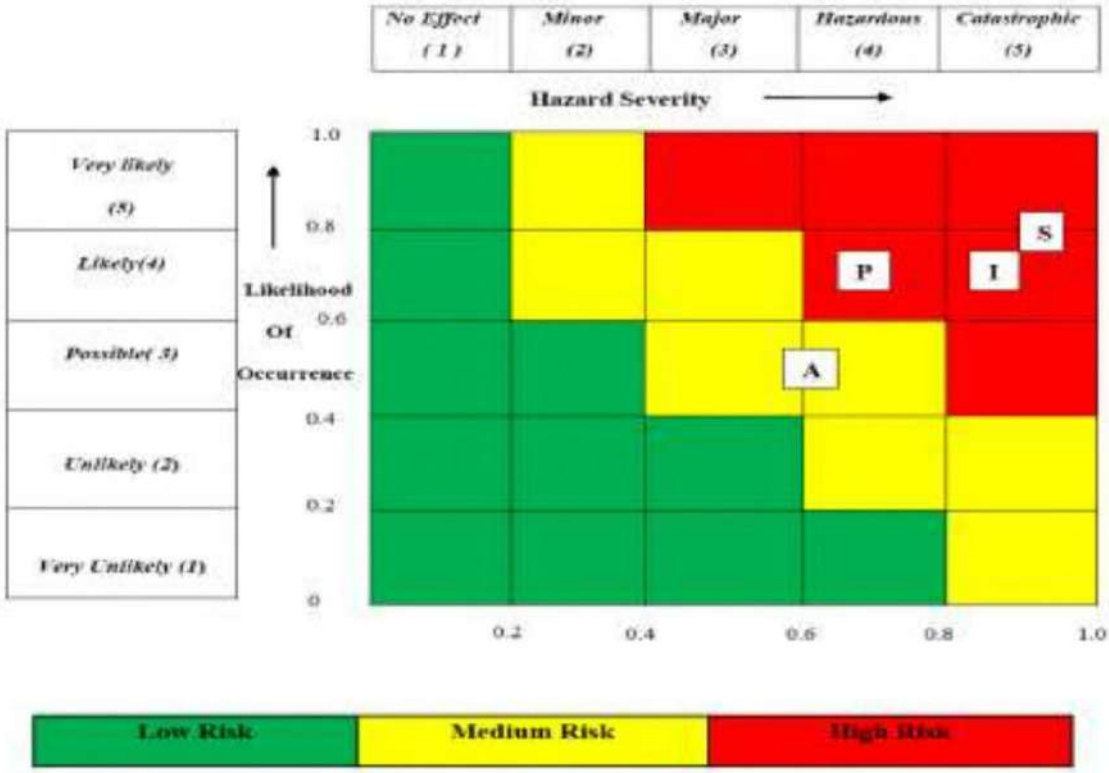


Figure 6: Matrix for Risk Ranking of different waste type at IVY Hospital



Conclusions

The paper analyses the risks of biomedical waste management practices followed by four different hospitals located in two different cities of Shimla and Chandigarh within a 100 km radius using a matrix method of evaluation. The study results showed that the maximum risk was from infectious waste in IGMC in Shimla and MAX hospital in Chandigarh whereas; the maximum risk was from Sharps from INDUS hospital in Shimla and IVY hospital in Chandigarh. Risk matrices were plotted to categorize the risk assessment values being classified as high risk, medium risk and low risk. In general, all the waste types were classified as High Risk for IGMC and only Sharps were classified as High Risk for INDUS hospital, with rest of the categories being Medium Risk. In MAX and IVY hospitals, all the waste types were classified as High Risk with the exception of Anatomical waste which was classified as Medium Risk.

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References

Abd El-Salam, M.M., (2010). Hospital Waste Management in El-Beheira Government, Egypt. *Journal of Environmental Management*, 91, 618-629.

Bokhoree, C., Beeharry, Y., Makoondlall-Chadee, T., Doobah, T., Soomary, N. (2014). Assessment of Environmental and Health Risks Associaed with the Management of Medical Waste in Mauritius. *APCBEE Proceedia*, 9, 36-41.

Carvalho, S.M.L., Silva, M.G.C. (2002). Preliminary Risk Analysis Applied to the Handling of Health-Care Waste. *Brazilian Journal of Chemical Engineering*, 19(4), 377-381.

Charoo, N.A., Ali, A.A. (2012). Quality risk management in pharmaceutical development. *Drug Development and Industrial Pharmacy*, 39(7), 947-960.

Cheng, Y.W., Sung, F.C., Yang, Y., Lo, Y.H., Chung, Y.T., Li, K.C. (2009). Medical waste production at hospitals and associated factors. *Waste Management and Research,* 29(1), 440–444

Debere, M.K., Gelaye, K.A., Alamdo, A.G., Trifa, Z.M. (2013). Assessment of the healthcare waste generation and its management system in hospitals of Addis Ababa, Ethiopia, 2011. *BMC Public Health*, 13:28. Available online at http://www.ncbi.nlm.nih.gov/pmc/articles/PMC3565894/pdf/1471-2458-13-28.pdf

Denboss, A., Izapanah, A. (2002). Building Capacity for comprehensive medical waste management in Asia. *EM The Urban Environment,*18-20. Available online at http://pubs.awma.org/gsearch/em/2002/10/urbanenvironment.pdf

Dumbrique, R. (2010) Implementation of risk management in the Medical device Industry. Masters Thesis, Paper 3855. San Jose State University. Available online at http://scholarworks.sjsu.edu/etd_theses/3855/

Gupta, S., Boojh, R., Mishra, A., Chandra, H. (2009) Rules and management of biomedical waste at Vivekananda Polyclinic: a case study. *Waste Management*, 29,812-819.

Ibrahim, A., El-Nafaty, U.A. (2016). Assessment of the Reliability of Fractioner Column of Kaduna Refinery using Failure Modes Effects and Critically Analysis (FMECA). *American Journal of Engineering Research*, 5(2), 101-108.

INCLEN Program Evaluation Network (IPEN) study group (2014). Bio-medical waste management: situational analysis& predictors of performances in 25 districts across 20 Indian States. *Indian Journal of Medical Research*, 139, 141-153.

Komilis, D., Katsafaros, N., Vassilopoulos, P. (2011) Hazardous medical waste generation in Greece: case studies from medical facilities in Attica and from a small insular hospital *Waste Management and Research,*29(8), 807-814.

Kumar, R., Gupta A.K., Aggarwal, A.K., Kumar, A. (2014) A descriptive study on evaluation of bio-medical waste management in a tertiary care public hospital of North India. *Journal of Environmental Health Science and Engineering,* 12:69. Available online at https://jehse.biomedcentral.com/articles/10.1186/2052-336X-12-69

Liao, C.J., Ho, C.C. (2014). Risk Management for outsourcing biomedical waste disposal – using the failure mode and effects analysus. *Waste management,*34(7), 1324-1329.

Ministry of Environment and Forests. Government of India. Draft Bio-Medical Waste (Management and Handling) Rules, 2011. Available online at http://moef.nic.in/downloads/public-information/salient-features-draft-bmwmh.pdf,

Narendra, M., Kousar, H., Puttaiah, E.T., Thirumala, S. (2013). Assessment of biomedical waste of various hospitals in mysore City Karnataka, India. *International Journal of Current Microbiological and Applied Sciences*, 2, 1-5.

Nema, A., Pathak, A., Bajaj, P., Singh, H., Kumar, S. (2011). A case study: biomedical waste management practices at city hospital in Himachal Pradesh. *Waste Management and Research,*29(6), 669-673.

Oweiss, R., Al-Widyan, M., Ohood Al-Limnoon. (2005). Medical waste management in Jordan: a study at King Hussein Medical Center. *Waste Management,*25, 622-625.

Patwary, M.A., O'Hare, W.T., Street, G., Elahi, K.M., Hossain, S.S., Sarkar, M.H. (2009). Quantitative assessment of medical waste generation in the capital city of Bangladesh. *Waste Management,*29(8), 2392-2397.

Pruss, A.,cGiroult, E., Rushbrook, P. (1999)Definition and characterization of health-care waste. *Safe Management of Wastes from Healthcare Activities*. 2-19. WHO.

Rao, H.P. (2009). Hospital waste management system – a case study of a south Indian city. *Waste Management and Research,*27(4), 313-321.

Rao, S.K.M., Ranyal, R.K., Bhatia S.S., Sharma, V.R. (2004). Hospital waste management system – a case study of a south Indian city. *Medical Journal Armed Forces India,*60, 379-382.

Rausand, M. (2004). Preliminary Hazard Analysis'. *System Reliability Theory (2nd edition)*, Wiley International.

Sefouhi, L., Kalla, M., Bahmed, L., Aouragh, L. (2013). The Risk Assessment of the Healthcare Waste in the Hospital of BAtna City, Algeria. *International Journal of Environmental Science and Developmen,*4(4),442-445.

Shinee, E., Gombojav, E., Nishimura, A., Hamajima, N., Ito, K. (2008). Healthcare waste management in the capital city of Mongolia. *Waste Management*, 28(2), 435-441.

Srivastav, S., Mahajan, H., Mathur, B.P. (2012). Evaluation of Bio-Medical Waste Management Practices In a Government Medical College and Hospital. *National Journal of Community Medicine*, 3(1), 80-84.