International Journal of Advanced Engineering, Management and Science (IJAEMS) *[Vol-2, Issue-6, June- 2016]*
Infogain Publication (Infogainpublication.com) *ISSN : 2454-1311*

Contaminated Land Area due to Industrial Hazardous Waste Generation and its Remediation in India

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Abstract— *The rapid growth of industrialization, urbanization and use of pesticides in agricultural fields in India has contributed to the generation of contaminated land. The uncontrolled and non-engineered waste disposal is one of the major causes of ground water contamination, air contamination and land contamination leading to health risks of human beings, animals and ecosystems. This paper is mainly focused on estimating contaminated land area to industrial hazardous waste generation and disposal practices. Presently in India, there is reported 7.2 million tonne hazardous waste generation from more than 40,000 registered industries according to Controller and Auditor General's report(CAG-2012). This study also summaries the advantages and disadvantages of different methods which are useful to manage a contaminated site by a geo–environmental engineer. For a specific superfund site, there is not only one remediation technique is applicable but also more than one techniques are applicable on the basis of different criteria.*

Keywords— Contaminated Land, Hazardous Waste, Remediation Techniques.

I. INTRODUCTION

Land is the upper portion of the earth's surface which is directly exposed to nature and interacts with the human beings. If the quantity of chemicals and other substances present in the soil are more than a threshold limit and the soil becomes hazardous to the human being and ecosystem then it is called contaminated land. Contaminated land is basically generated by deposition and interaction of different types of wastes (solid, sludge and liquid forms).

Land can become contaminated and a health risk when the hazardous substances are not disposed off in a safe manner. Contamination is not always limited the specific region. It may spread out to nearby land, surface water bodies and ground water. Hazardous substances may seep through the soil into ground water or be carried to nearby land and waterways through rainwater or transported through air.

Contamination of land may be due to the disposal variety of wastes and chemicals on or in the soil.

The scope of this study is limited to industrial hazardous waste generation and land being contaminated due to the component of hazardous waste not treated in the disposal facilities.

The contamination can take a variety of forms; therefore its impact also can be in variety of ways. Depending upon the type of contaminant present in the soil, its concentration and the pathway through which it reaches the target and consequent risk level one can predict the harm which may be caused to human health, crop, property and ecological system.

Land contaminants include both chemicals and pathogens. These contaminants may cause a variety of health problem starting with minor problems like headaches, fatigues, skin rash, and eye irritation to major health issue e.g.

- Cancers: through land contaminated with chemicals (e.g. Gasoline or other petroleum products containing benzene).
- Nervous system damage: especially by lead in soil affecting especially children.
- Neuromuscular blockages.
- Kidney and liver damage: caused by chemicals such as Mercury.
- Problems in the respiratory system
- Problems of skin
- Long term illness

And the ultimate risk of death and Genetic effects.

In case of ecosystem, land contaminants can negatively affect the plant, animal health and microbial activities. Some contaminants may change the plant metabolic processes and reduce yield or cause visible damage to crops.

Dutta et. Al. (2006) has summarized the health effect of hazardous waste as presented in **Table1** .

According to the report of **Supreme Court monitoring committee (2004),**The number of industries issued authorization by Andhra Pradesh Pollution Control Board (APPCB) had gone up from 1,286 in January 2004 to 1,532 in October 2004 and the total quantity of hazardous waste generated rose from 1,45,000 tonnes per annum to 2,42,706 tonnes per annum. The data provided by APPCB that recycled, disposed and incinerable portion of hazardous waste is of 52.1%, 45.4% and 2.5% respectively which is different than the figures reported for generated waste in the three categories in other states where there are equivalent industries. According to **Pappu, Saxena and Asolekar (2007),** the total waste generation in India is about 960 million tonnes annually as by products during industrial, mining, municipal, agricultural and other activities. Out of this, 350 million tonnes are organic waste from industrial and mining sectors, 4.5 million tonnes are hazardous in nature. Globally, the estimated quantity of waste generation is 12 billion tonnes in year 2002 of which 11 billion tonnes were industrial waste, 1.6 billion tonnes were municipal waste. About 19 billion tonnes of solid waste is expected to be generated annually by the year 2025. By year 2047, municipal solid waste generation in India is expected to reach 300 million tonnes and land required for disposal of this waste would be 169.6 km^2 as against which only 20.2 km^2 that were occupied in year 1997 for management of 48 million tonne. The generation of inorganic industrial waste is estimated around 290 million tonne per annum and hazardous industrial waste is around 4.5 million tonne per annum in India from different industries. According to **Narayan, Mazumdar and Bhattacharya (2008**), risk and threats to public health arising due to improper handling, storage and illegal dumping can be reduced if scientific management practices of waste in designated facilities are adopted. Hazardous waste generated in the country based on 18 categories of wastes appearing in the hazardous waste management rules (1989) was around 4.43 million tonne per annum arising from 13011 industries of varies types distributed over 21 states. Out of the total waste estimated, 1.72 million tonnes per annum (39%) was recyclable, 0.18 million TPA (4%) incinerable, and remaining 2.53 million TPA (57%) was disposal in safe landfills (SLF). But according to revised state-wise reports provided in year 2000- 2003, total quantity of hazardous waste generated had almost doubled. According to the revised state-wise inventory (2006), total quantity of hazardous waste generated in the country is around 8.26 million TPA while the total number of hazardous waste generating industrial units became 29725. Narayan et.al.(2008)concluded that for minimizing environmental pollution and waste.

Table 1: Health effect of hazardous waste(Dutt et.al.2006)

Hazardous waste	Source	Health effect
Heavy metal		
Arsenic	Mining, non anthropogenic geo-chemical formation	Carcinogenic, cardiac disorders, anaemia
Chromium	Mining, fertilizer industry, battery waste	Carcinogenic, damage to livers and kidneys, chronic obstructive pulmonary diseases, cardiovascular and skeletal disorders
Cadmium	Mining areas, Tanneries	Kidney damage, skin disease, acute tubular damage.
Lead	Lead acid battery smelters	Lead poisoning, neurotoxin, mental impairment in children, damage to brain, kidney and liver.
Manganese	Mining areas	Respiratory disease, neuropsychiatric disorder.
Mercury	Chlor-alkali industries, health care institutes	Mercury poisoning affects human brain, central nervous system, kidneys and liver. High Hg exposure causes vision, speech and hearing impairment. May lead to death.
Nickel	Mining, metal refining	Lung and nasal cancer, damage to gastrointestinal system, cerebral edema, respiratory failure
Hydrocarbons		

Benzene	Petrochemical industries, solvents	Headaches, nausea, leukemia, damage to bone marrow
Vinyl Chloride	Plastics	Carcinogenic (liver and lung cancer), depression of central nervous system, embryo toxic
Pesticide	Insecticides	Cancers, genetic damage, stillbirths, immune system disturbances, embryo damage
Organic chemicals		
Dioxins	Waste incineration, herbicides	Cancer, birth defects, skin disease
PCBs	Fluorescent lights, E-waste, Hydraulic fluid	Skin damage, possibly carcinogenic, gastro-intestinal damage

There are two concept
"Clean Production Technology" and "Cleaner production". The present trend in the developed countries clearly depicts a shift from 'land filling of waste' to clear production technologies.

During study of soil contamination in the area of Patancheru located north of Hyderabad, **Dasaram et.al. (2011)** collected 15 soil samples from an area of about 124 $km^2$of the Patancheru industrial area. The toxic metal (Ba, Co, Cr, Cu and Ni) in all the soil samples were determined using a wavelength depressive X-ray fluorescence spectrometry. On the basis of experimental results they concluded that soil is the sink for toxic trace metal in Patancheru industrial area and the level of excessive of each metal is varying depending on its chemical characteristics. The soil from residential area is moderately contaminated by Cr, Ni and Pb. The percentage wise distribution of wastes of different categories generated currently in India is presented in **Figure 1.** The quantity of hazardous waste generation reported was 4.42 million tonne per annum from 373 districts out of 524 in year 2008.

According to **Das (2012),** the municipal solid waste generation is 39,031 tonnes per day in 59 cities (35 metro cities and 25 states capitals) reported on the basis of survey conducted by Central Pollution Control Board (CPCB) through National Environmental Engineering Research Institute (NEERI) in year 2004-2005. In a similar way, the municipal solid waste generation is about 50,592 tonnes per day, reported on the basis of survey conducted by Central Institute of Plastics Engineering and Technology (CIPET) for the same 59 cities in year 2010-11.

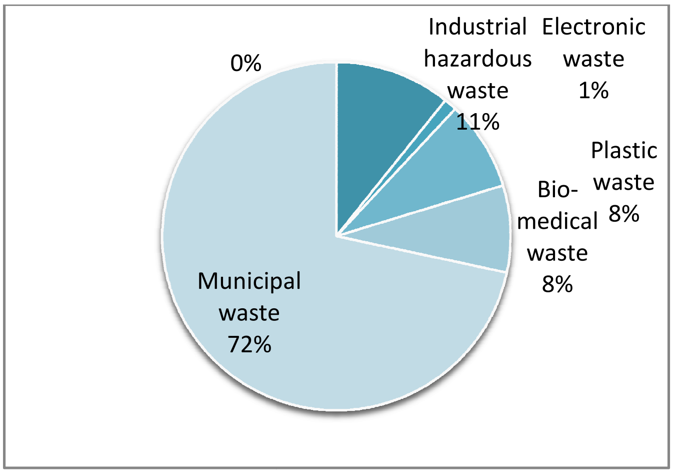

Fig.1:Percentage wise distribution of wastes of different categories in India

II. CONTAMINATED LAND ESTIMATE

Assuming that major health risk is caused due to industrial hazardous waste disposal practice which is only 11% of the total waste generation.

For the calculation of an annual generation of contaminated land in India, following methodology has been adopted.

1. Determination of no. of hazardous waste generating industries and their waste generation quantity in tonne per annum (TPA) on the basis of data provided by SPCB/CPSB/PCCs of the states.
2. Determination of hazardous waste generation District-wise in each state.
3. Classification of hazardous waste with quantity of waste generation in tonne per annum (TPA)
   - Landfill able
   - Incinerable
   - Recyclable
4. Detailed data collection of landfillable and Incinerable hazardous waste generation state- wise.

5. Convert the quantity of HW to volume (m^3) using the density of 0.85 Tonne/m^3 on the basis of landfill design consideration (eqn.1).

Volume = mass/ density

Volume(m^3)=mass/0.85………….………… (1)

6. Assuming the height of landfill as (a) 5.0 m. and (b) 7.5 m. on the basis of landfill design consideration (eqn.2).

Area of required land $(m^2) = \frac{volume}{height}$…….. (2)

7. Thus with the help of height and volume, a range of land area can be calculated which will be required used for Hazardous waste disposal.
8. Convert the area in hectares(eqn.3). **Area of land (hectares)**

$= \frac{\text{areaofland}\ (m^2)}{10000}$**……..** (3)

III. DATA COLLECTION

To determine the contaminated land area, following data are required:

Total number of hazardous waste generating industries in India and their state wise distribution.

According to National Inventory of Hazardous Waste Generating Industries & Hazardous Waste Management in India (2009):

In India, there are 36,165 nos. of hazardous waste generating industries, generating 62, 32,507 Metric Tonnes of hazardous wastes every year. The category-wise classification of this quantity is as follows.

- Land Fill able HW- 27, 28,326 TPA
- Incinerable HW -4, 15,794 TPA
- Recyclable HW - 30, 88,387 TPA

It is observed that the recyclable portion of HW is in the range of49.55% and is more than other two categories. The land disposable portion and incinerable portion are of the order of 43.78 % and 6.67 % respectively.

Table 2. presents state wise number of hazardous waste generating industries and of the three types of (landfillable, incinerable and recyclable) hazardous waste category (State-wise) obtained from the National Inventory of Hazardous Waste Generating Industries & Hazardous Waste Management in India (2009).

IV. ANALYSIS & DISCUSSION

4.1 Contaminated land area : There are two ways to dispose of hazardous waste generated by the industries:

1. Safe disposal of hazardous waste in the engineered landfills.
2. Illegally dumped waste in open dumps.

Safe disposal of hazardous waste: Incineration is appropriate for some hazardous waste because the high temperatures can destroy various synthetic compounds. Other methods include deep burial and deep-well injection. Chemical treatments such as catalysis alter the chemical structure of Hazardous waste, rendering it harmless. Biological treatments use microorganisms, both natural and genetically engineered, to decompose waste. Even then some industrial waste still ends up in local landfills.

In India, treatment, storage, disposal facility (TSDF)is provided to manage the hazardous waste generation from industries. The land used by TSDF to dispose the hazardous waste depends upon the capacity of that treatment plant.

Table 2: state wise number of hazardous waste generating industries and hazardous waste generation (National Inventory of Hazardous Wastes Generating Industries & Hazardous Waste Management in India (2009) :

S. No.	Name of State/UTs,	No. of HW Generating units	Quantity of hazardous waste generation(MTA)		
			Landfillable	Incinerable	Recyclable
1	Andhra Pradesh	1739	211442	31660	313217
2	Assam	55	3252	-	7480
3	Bihar	41	3357	9	73
4	Chhattisgarh	174	5277	6897	283213
5	Delhi	1995	3338	1740	203
6	Gujarat	7751	1107128	108622	577037
7	Goa	630	10763	8271	7614
8	Haryana	1419	30452	1429	4919
9	H.P.	1331	35519	2248	4380
10	J.&K.	291	9946	141	6867

11	Jharkhand	435	23135	9813	204236
12	Karnataka	2076	18366	3713	54490
13	Kerala	524	59591	223	23085
14	Madhya Pradesh	1093	34945	5036	127909
15	Maharashtra	4909	568135	152791	847442
16	Manipur	264	-	115	137
17	Meghalaya	43	19	697	6443
18	Mizorum	44	90	Nil	12
19	Nagaland	3	61	Nil	11
20	Orissa	335	74351	4052	18427
21	Punjab	3023	13601	14831	89481
22	Rajasthan	442	165107	23025	84739
23	Tripura	135	0	30	237
24	TamilNadu	2532	157909	11145	89593
25	Uttar Pradesh	1915	36370	15697	117227
26	Uttaranchal	70	17991	580	11
27	West Bengal	609	120598	12583	126597
28	Daman, Diu, Dadra& Nagar Haveli	1937	17219	421	56350
29	Pondicherry	90	132	25	36235
30	Chandigarh	260	232	-	723
	TOTAL	**36165**	**2728326**	**415794**	**3088387**

Total contaminated land area due to illegal dumping and land utilized for TSDF (state-wise) as obtained from the methodology used is presented in the **Table 3.** Thus approximately **64.193 hectare** land is utilized due to disposal of industrial HW in TSDF facility and illegal dumping of HW disposal. This land is obviously an area which is itself as contaminated and results in further development of contaminated land in its vicinity due to movement of contaminants in surrounding area.**Figure.2** graphically represents state wise contaminated land areas (in hectares). is much less than the present generation of27, 28,326 TPA of land-disposable HW. The deficit of TSDF capacity is 12, 27,758 TPA. It is obvious that the additional TSDF to the tune of 15, 00,000 TPA must be developed to accommodate the present and future quantities of land disposable HW. This contaminated land area is in the range of **42.8 to 64.2 Hectare.**

As per the information provided by the Central Pollution Control Board (CPCB-2012), the amount of hazardous waste generated in the country is about 7.2 million tonne per annum. Maharashtra (22.84%), Gujarat (22.68%) and Andhra Pradesh (13.75%) are the top three hazardous waste generating states in the country followed by Rajasthan, Tamil Nadu, Madhya Pradesh and Chhattisgarh.

Table 3: State-wise contaminated land area (in hectare) (Dixit et al. 2016)

S.No.	**Name of state**	**Hazardous waste earmarked for land disposal (Metric tonne per annum)**	**Land utilization(hectare)**	
			Assuming height of landfill 7.5 meter	**Assuming height of landfill 5.0 meter**
1	Andhra Pradesh	211442	3.316	4.975
2	Assam	3252	0.051	0.077
3	Bihar	3357	0.052	0.079

4	Chhattisgarh	5277	0.082	0.124
5	Delhi	3338	0.052	0.079
6	Gujarat	1107128	17.366	26.050
7	Gao	10763	0.168	0.253
8	Haryana	30452	0.477	0.717
9	Himachal Pradesh	35519	0.557	0.835
10	Jammu &Kashmir	9946	0.156	0.234
11	Jharkhand	23135	0.362	0.544
12	Karnataka	18366	0.288	0.432
13	Kerala	59591	0.934	1.402
14	Madhya Pradesh	34945	0.548	0.822
15	Maharashtra	568135	8.911	13.367
16	Meghalaya	19	0.000	0.000
17	Mizoram	90	0.001	0.002
18	Nagaland	61	0.001	0.001
19	Odisha	74351	1.166	1.749
20	Punjab	13601	0.213	0.320
21	Rajasthan	165107	2.589	3.885
22	Tripura	0	0.000	0.000
23	Tamilnadu	157909	2.477	3.716
24	Uttar Pradesh	36370	0.570	0.856
25	Uttaranchal	17991	0.282	0.423
26	West Bengal	120598	1.891	2.838
27	Daman, Nagar Haveli	17219	0.270	0.405
28	Pondicherry	132	0.002	0.003
29	Chandigarh	232	0.004	0.005
	TOTAL	**2728326**	**42.786**	**64.193**

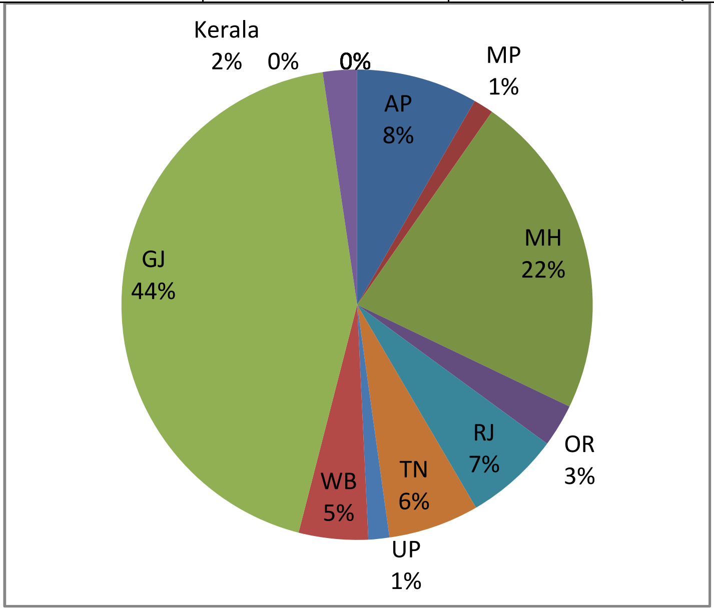

Fig.2: Percentage wise contaminated land area (hectares) in different states in India (Dixit et al. 2016)

These seven states together are generating about 82% of the country's total hazardous waste.

4.2 Remediation option selection

To remediate the contaminated land, the matrix (Table 4) provide different remediation option techniques as per the requirement of the authorised body.

V. CONCLUSION

On the basis of the study carried out following conclusion can be drawn:

- Generation of hazardous waste is approximately 2.73 million tonne per year while the official capacity to treat and dispose off is only 1.5 million tonne per year. **Hence there is a need to create additional facility for treat and dispose of around 1.23 Million tonnes per year**. Unregistered hazardous waste producing industries and the amount in India is any body's guess.
- The performance of the states Gujarat, Maharashtra, Tamilnadu, West Bengal for safe disposal and treatment of their HW is not good and lot of area become contaminated every year due to open dump sites.
- The selection of one or more particular remediation technologies for a contaminated site is complex in decision making because of the different parameters like soil type, contaminant nature, concentration of contamination at site involve in this process.

Table.4:Remediation options for different selection criteria

Contaminant Category	Cost efficient	Duration	Risk reduction
PAH compound	Biopiles Phytoremediation Soil Flushing	Soil washing Slurry Phase Bio treatment Bioventing	Soil washing Soil air suction Steam injection
Heavy Metal	Soil Flushing, Phytoremediation Thermal desorption	Electrokinetic, Soil washing, Thermal desorption	Electrokinetic Vitrification Thermal desoption
BTEXS compound	Soil Flushing Bioventing Landfarming	Soil Flushing Bioventing Vitrification	Bioventing Soil Vapour Extraction Vitrification
Halogenated Organic compound(PCBs)	Thermal desorption Phytoremediation Soil Flushing	Chemical Dehalogenation Soil washing Soil flushing	Dual Phase soil vapour extraction Chemical dehalogenation Bioventing
Non Halogenated Organic compound	Biopiles, Phytoremediation, Soil Flushing	Soil washing Soil flushing Soil vapour extraction	Dual phase soil vapour extraction Chemical oxidation Solvent Extraction
Pesticide	Biopiles, Phytoremediation, Soil Flushing	Soil washing Slurry phase Biotreatment Bioventing	Bioventing Soil washing Bioplies
Volatile Organic compound	Biopiles, Phytoremediation, Soil Flushing	Slurry Phase Biotreatment, Soil Flushing Thermal Desorption	Slurry Phase Biotreatment Soil Vapour Extraction Thermal Desorption
Semi Volatile Organic compound	Bioventing, Landfarming, Soil vapour extraction	Soil washing Bioventing, Landfarming	Soil washing Soil vapour extraction Bioventing
Total Petroleum Hydrocarbon	Bioventing, Phytoremediation, Bioremediation	Soil washing Bioventing Steam enhanced extraction	Steam Enhanced Extraction Electrical resistance heating Dynamic underground Stripping

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