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GROUNDWATER CONTAMINATION FROM LANDFILL LEACHATES - AN ANALYSIS FOR DEVELOPING COUNTRIES

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Abstract: **The waste generation in developing countries is going to increase due to rapid growth in urbanization and industrialization. In India, per person per day waste generation is about 0.65 kg. The waste generated in India was 1.80 billion tons per year and 1.75 billion tons was in Indonesia. The problems are mainly started due to the non-segregation of the wet and dry solid wastes, the composition of the solid waste dumping at the landfill sites as well as poor management of the landfill sites. The composition of the solid waste, as well as the rainfall conditions at a location, mainly determine the characteristics and composition of the leachates coming out from these landfill sites. In both countries, the management of the collection of the leachates from these sites affects the groundwater and thus, is a very important aspect for minimizing the adverse effects on groundwater quality. The management of leachates from landfill sites is different for India and Indonesia; as in some countries specialized technologies and practices are adopted for their management while in others, they are poorly managed. In this paper, a comparative scenario has been presented regarding the groundwater contamination from the leachates from the landfill sites located India and Indonesia. From this study, it was found that the unscientifically design of landfill and absence of liner allow leachate to percolate into the ground and contaminate the groundwater. The various factors affecting the groundwater contaminations from the leachates were also examined and it was found that the landfill sites in both the countries were not managed effectively. It was also revealed that the scientific disposal of the mixture of the solid waste was also not practiced.**

Keywords: *Municipal solid waste (MSW), leachate, landfill site, contamination.*

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I INTRODUCTION

Most of the developing countries are presently facing the problem of municipal solid waste management. Urbanization and industrialization have contributed more amount of generation of solid waste in developing nations [1]. In the USA, the waste generated per capita per day is 2 Kg whereas in India it is about 0.65 kg [2,3]. The worst situation has been developed due to the improper management and practising old traditional plans for the landfill sites. In India, as per 2001 census, the people living in the urban areas were 28.53 percent and which was increased to 30 percent in the year [4] and in the year 2007, a survey was conducted by United Nation State of the World Population and it was found that by 2030, 40.76 percent of developing countries i.e. India and Indonesia where the population is expected increase in urban regions in the world. Solid waste generated in most of the developing countries and developing countries have dumped the waste at random dumping sites which do not have the suitable standards. In major cities of the world, open and unsystematic dumping of solid waste has been practised at a very large scale [5]. In 2002, the United States Environmental Protection Agency reported that the municipal solid waste is the mixture of degradable and non-degradable substances which further seep into the ground and affect the different characteristics of both soil and groundwater [6].

The dumping sites in most of the developing countries are generally deep surface excavation ascending from uninhibited quarry-sites and burrow-pits and the waste is dumped without environmental regulation and with no evaluation of the effects on environment are examined of the municipal solid waste management (MSWM) which are a

basic component towards feasible metropolitan advancement, segregation, storage, collection, processing and disposal of solid waste to reduce and limit its unfavourable effects on the environment [7]. The landfill leachate generation can cause environmental and health effect due to soil, surface and groundwater contamination. The three main issues such as the design of landfill liner systems, finding and valuation of the degree of contaminants percolates in groundwater are the risk for human health and causing environment issues [8]. The groundwater quality monitoring systems are the main link among them since they help to determine the likelihood and severity of contamination problems. The MSW composition contains glass pieces, metals, papers, rags, plastics, ashes and flammable materials [9]. In addition to these solid wastes contains other substances as well such as discarded chemicals, paints, scrap materials, hazardous waste generated from hospitals, dead animals, industries and agricultural and horticultural residues as well as concrete and demolition waste. In developing countries, there are serious environmental problems due to the landfill sites which are not scientifically designed and there is the absence of proper leachate collection and control system. Leachate composition depends mainly on the composition of solid waste, annual rainfall, per capita waste generation and characteristics of the total waste.

II OBJECTIVE

In the present study, the groundwater contaminations due to the leachate from the landfill sites located in developing countries i.e. India and Indonesia have been analyzed and suggestions for minimizing the effects of landfill leachates on groundwater contamination have been reported.

III METHODOLOGY

An analysis has been done by considering three landfill sites from India i.e. Gazipur landfill site in East Delhi, Dhapa landfill site in Kolkata and Deonar landfill site in Navi Mumbai and another three landfill sites from Indonesia i.e. TPST Bantargebang in Jakarta, TPA Suwung in Bali and Jatibarang landfill site in Semarang of Indonesia have been selected for analysis. The Indonesia Climate Change Sectoral Roadmap (ICCSR), 2010 reported the growth in municipal waste in urban and rural areas. As per the report in the year 2005, in urban areas, the waste generation was 0.6 kg per capita per day which will increases to 1.2 kg per capita per day in the year 2030. Whereas in the rural area, the generation of waste was projected to increase from 0.3 kg per person per day in the year 2005 to 0.55 kg per capita per day in 2030. In the year 2015, the 0.7 kg per capita per day waste was generated in Indonesia [10]. According to London Waste Clearance, a list of 10 worst landfill site in the world was prepared in which TPST Bantargebang landfill site in Jakarta stands at the fifth position where waste dumped is about 6,000 tons per day [11]. Whereas in India, the population in the year 2011 was 260 million which produced 47.3 million tons of waste which estimated to increase to 107.01 million tons in the year 2036 [12]. According to World Atlas study, it was reported that Deonar landfill site in Navi Mumbai and Gazipur landfill site in Delhi come in the top ten worst landfill sites in the world [13]. For the landfill sites from India and Indonesia, the in the Tables 1 and 2 have been taken from the following sources [14, 15, 16, 17, 18].

Table 1 Location of Landfill Sites In India And Indonesia

City	Landfill sites	Location of landfill site	
		Longitude	Latitude (E)
India			
East Delhi	Gazipur	28°37'29.4"N	77°19'41.5"
Kolkata	Dhapa	22°33'46.4"N	88°26'49.1"
Mumbai	Turbhe	19°04'42.6"N	73°01'25.7"
Indonesia			
Jakarta	TPST Bantargebang	6°20'54.1"S	106°59'51.7"
Bali	TPA Suwung	8°43'17.6"S	115°13'17.2"
Semarang	TPA Jatibarang	7°01'24.5"S	110°21'30.2"

Table 2 Details Of The Landfill Sites Of India And Indonesia

*Landfill without liner, **Landfill site with liner

IV RESULT AND DISCUSSION

Landfill sites	Area of landfill (Hectares)	Waste Disposed (tons/day)	Year of Starting	Designed life Years
India				
Gazipur*	29.62	2,100	1984	24 (2008)
Dhapa*	21.74	3,500	1980	-
Turbhe*	66.00	550	2005	50 (2055)
Indonesia				
TPST Bantargebang*	120.00	6,250	1989	-
TPA Suwung*	38.00	800	1984	21 (2005)
TPA Jatibarang**	46.18	900	1995	-

The Table 1 and 2 illustrates the comparison of the landfill sites in the developing countries i.e. India and Indonesia. In India, Gazipur landfill site is located at 28°37′29.4″ N longitude and 77°19′41.5″ E latitude, East Delhi. The area of the landfill site was 29.62 hectares and the total disposal of waste was around 2,100 tons per day, where the liner was not installed to control the leachate

contamination to soil and groundwater [14]. On the other side, the area of Turbhe landfill site was 66 hectares. The dumping of waste at this landfill site was initiated in the year 2005 which will further continue for 50 years. The waste disposal at the site was around 550 tons per day which were less as compared to Gazipur and Dhapa landfill site [15]. Dhapa landfill located in 22°33'46.4"N and 88°26'49.1"E in Kolkata. The area of the landfill site was 21.47 hectares and the waste disposed to the site was 3,500 tons per day [16,17]. However, in Indonesia, TPST Bantargebang landfill site, Jakarta has the area of 120 hectares. The landfill site was located at 6°20′54.1″ S longitude and 106°59′51.7″ E latitude. The waste disposal was around 6,250 tons per day which is higher as compared to TPA Suwung and TPA Jatibarang landfill [18]. While from the study of landfill sites, it was found that among all landfill sites, only TPA Jatibarang landfill has the liner for leachate control [14,18**].**

Table 3 shows the waste generated per capita per day and characteristics of leachate. In India, the per capita waste generated in Mumbai was 0.65 kg per day [19]. Whereas, in East Delhi and Kolkata it was around 0.5 kg per day [18,20]. The waste generation depends upon the population. In Indonesia, the waste generation was very high at Semarang which was between 0.66 to 0.9 followed by Semarang per capita waste generation in Jakarta was 0.6 kg per day [21] and in Bali, it was around 0.7 kg per day [22]. The total solid waste consists of wet and dry waste at all landfills sites which contributed more leachates. At the waste collection point, segregation is not in practice due to that both types of waste wet and dry get mix. The waste must be segregated according to their characteristics such as dry and wet waste. If the waste gets segregated than it may reduce the dumping of waste at the landfill site, some waste gets recycled and reuse. The process of segregation also reduces the leachate generation and groundwater effects.

Table 3 Per Capita Waste Generated

Country	City	Population	Waste generated /capita/ day (kg)
India	East Delhi	7,707,725	0.5
	Kolkata	4,572,876	0.45-0.5
	Mumbai	1,119,477	0.65
Indonesia	Jakarta	10,154,134	0.6
	Bali	4,148,588	0.7
	Semarang	1,555,984	0.66-0.90

During rainfall, the solid waste in the landfill gets wet. As a result, harmful chemicals get mixed with the water and form a mixture of the organic and inorganic compound called as leachates. Accumulation of leachate occur at the surface of the landfill and infiltrate in the ground [23]. The level of contamination of quality of groundwater majorly depends upon the leachate's chemical composition and the average rainfall. Amounts of average annual rainfall have reported in Table 3.

Table 4 Average Annual Rainfall At Different Landfill Sites

Country	City	Landfill site	Avg. annual rainfall (mm)
India	East Delhi	Gazipur landfill	497
	Kolkata	Dhapa landfill site	1582
	Mumbai	Turbhe landfill site	2422
Indonesia	Jakarta	TPST Bantargebang landfill site	1855
	Bali	TPA Suwung landfill site	1741
	Semarang	TPA Jatibarang landfill site	2182

The leachate has been poorly managed at the landfill sites due to this many severe harmful chemicals are getting contaminated groundwater. The problem starts from the point where the waste collection starts. At the waste collection point, segregation is not practiced due this both wet and dry waste get mixed.

Table 5 Range Of Characteristics Of Landfill Leachates

Components	Unit	Range
BOD	mg/l	200 - 40,000
COD	mg/l	300 – 90,000
TSS	mg/l	200 – 1,000
Electrical conductivity	µS/cm	3,000 – 9,000
Calcium	mg/l	200 – 3,000
Magnesium	mg/l	50 – 1,500
Potassium	mg/l	200 – 2,000
Sodium	mg/l	200 – 2,000
Sulphate	mg/l	100 – 1500
Chloride	mg/l	100 – 3,000
Total iron	mg/l	25 – 2,500
Zinc	mg/l	25 - 250
Lead	mg/l	0.2 - 10
pH	-	4.2 – 7.8

Table 6 Characteristics Of Leachates At Landfill Sites In India And Indonesia

Characteristics	Units	Landfill sites of India			Landfill sites of Indonesia		
		Gazipur	Dhapa	Turbhe	TPST Bantargebang	TPA Suwung	TPA Jatibarang
pH	-	6.0	8.1	8.22	6.1	8.04	7.5
Lead	mg/L	2	0.42	-	0.09	0.45	-
COD	mg/L	30,000	9,128	11,000	22,000	8,341.33	2,846
BOD	mg/L	10,000	5,493	5,925	13,000	3,667.67	911
Iron	mg/L	60	10.15	287	780	36.90	547
Zinc	mg/L	50	0.56	0	5	6.70	5.33
Sodium	mg/L	500	9,734	1965	1340	-	240
Sulphate	mg/L	300	-		500	1,061.96	-
Chloride	mg/L	2,000	4,708	4,343	2120	-	2,612
Potassium	mg/L	300	4,889	221	1085	-	753.83
Magnesium	mg/L	250	-	108	470	-	3,400
Calcium	mg/L	1,000	-	-	1200	-	700
Electrical conductivity	µS/cm	-	15,700	15,700	-	13,161.78	-

Table 7 Groundwater Characteristics Of Different Landfill Site Of India And Indonesia

Parameters	India			Indonesia		
	Gazipur	Dhapa	Turbhe	TPST Bantargebang	TPA Suwung	TPA Jatibarang
pH	6.52	8.1	7.11	7.3	7.5	7.43
Electrical conductivity	1539	2585.71	771.00	-	630.00	-
TDS	1080	1810	720	906	640	631
Chloride	121.00	523.46	-	407.00	195.25	171.99
Sulphate	91	25.68	395	-	77.31	-
Nitrate	0.31	-	-	<0.08	9.88	18.62
Iron	0.67	1.12	-	0.04	4.50	0.30
BOD	-	3.70	8.00	-	23.60	-
COD	-	35.20	25.00	-	52.00	-

All in mg/l except Electrical conductivity (µs/cm) and pH

The collection of leachate involves the drainage pipes, drainage layer collection pipe and shaft. Almost all landfill sites in their countries have leachate control system but few developing countries lack behind it. Furthermore, with the proper channels and slopes rainwater control measurements help to decrease the formation of leachates. Along with this, heavy metal presence and biological treatment could be used for leachate treatment and through physicochemical methods can be used for removal of heavy metals like cadmium and the removal of ammonia.

Leachates is the solution of organic and inorganic compounds which are harmful to the environment. The characteristics of the leachate from these landfill sites in India and Indonesia are reported in Table 6. The data based on the studies [24,25,26,27].

In Table 6, Gazipur, TPST Bantargebang and TPA Jatibarang landfill sites were having the pH value was within permissible range and landfill sites such as Dhapa (8.1), Turbhe (8.22) and TPA Suwung (8.04) were having the pH value greater than the permissible limit. The increased in pH was due to the presence of high amount chemical which was basic in nature or the chemical with hydronium ion got mixed with leachate and increased its basic property. The following characteristics i.e. Lead, COD, BOD, iron, zinc, sulphate, and calcium lie within the permissible limit and are found to be suitable.

The infiltration of leachate in landfill increased the amount of sodium, about 9,734 mg/l in Dhapa landfill site which means the amount of leachate generation was very high at this site the chloride present in the leachate at Dhapa

landfill site (4,708 mg/l) and Turbhe landfill site (4,34 mg/l) are not in the permissible limit. Potassium content in leachate was observed higher in Dhapa landfill site (4,889 mg/l) which was higher than the standard limit and potassium content in the rest of the landfill was in the standard range. At TPA Jatibarang landfill site the magnesium (4,889 mg/l) was found higher than the permissible and due to the increase in the concentration of ions in the leachates at Dhapa and TPA Suwung landfill site, the specific conductivity was also increased. The specific conductive of leachate at Dhapa landfill site (15,700 µS/cm) and TPA Suwung landfill site (13,161.78 µS/cm) was very high which not lie in the standard limit.

Leachate contaminates the groundwater and change it characteristics shown in Tables 5 and 6, it was found that the leachate solute consists of heavy acidic chemical which increased the acidic nature of leachate solution, the value of pH was increased in Turbhe landfill site (7.11), TPA Suwung landfill site (7.5) and TPA Jatibarang landfill site (7.43) whereas the value of pH was increased in Gazipur landfill site (6.52) and TPST Bantargebang landfill site (7.3). The too much increase and the decrease in pH affect human health for groundwater pH must be in the range of 6-8.5 which mean pH all landfill sites are in the permissible range. Chloride, Iron sulphate content was reduced in groundwater after leachate contamination it was found that chloride decrease in all the landfill sites. The value of BOD and COD got decreased which means there was no organic matter present, the dissolved oxygen was also less which affects the living organism who consume it. Overall, due to leachate few important characteristics like pH, BOD, COD etc. were highly affected which further changes the water quality and responsible for causing diseases to the human. The landfill sites are not scientifically design due that the leachate easily percolate into the ground and contaminate the groundwater. Before the design of landfill, the soil the landfill site at must be well evaluated. The leachate produced at the landfill site can be controlled if the proper measurements should be taken such as hydrogeological and geological features that meaningfully reducing the hazard of contamination of leachate to groundwater. It must be necessary to collect leachate establish before dumping of waste. The proper design and collection may reduce the leachate generation of leachate

V CONCLUSIONS

The comparison of solid waste generation in India and Indonesia was studied. From the study, it was found that the unscientifically design of landfills causes degradation of groundwater quality due to the percolation of leachate through the ground strata. In both the countries, the waste will be going to increase in the upcoming year and which will increase the leachate generation because the landfill sites in both the country were not managed effectively. There are some the countries were not managed effectively. There are some characteristics of leachate which highly affects the groundwater quality such as pH, Iron, Chloride BOD and COD. All landfill sites do not have presence of liner except TPA Jatibarang landfill site.

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