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CHARACTERIZATION OF LEACHATE FROM SELECTED LANDFILLS AND ITS EFFECTS ON GROUNDWATER RESOURCES -A REVIEW

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Abstract: **Managing landfills unscientifically and the leachate migration from these landfills poses a serious environmental degradation of groundwater resources causing these resources unfit for water withdrawals for human, agricultural and other uses. The major prospective environmental influence of the landfill leachate is pollution of the groundwater as well as surface water. The magnitude and type of environmental degradation of groundwater resources depends on the leachate characteristics which predominantly relies on the configuration of the solid waste dumped at the landfill sites, age of the landfill, hydrology in terms of precipitation of the area where landfill is located, leachate collection and treatment systems. In this paper the leachate characteristics in terms of different components namely BOD, COD, Total Dissolved Solids, Nitrates, Calcium, magnesium, total Iron, Sulfates Zinc, Lead, EC & pH and other toxins from selected landfills located in different metropolitan cities in India were reviewed from published literature. Based on these characteristics of the leachate from the landfills, the contamination effects on the groundwater resources available at the landfill sites were reviewed. The various factors contributing to groundwater pollution were also reviewed and based on these the strategies for managing, collection and treatment of the leachate were suggested so as to curtail the effect of leachate on the quality of the groundwater.**

Keywords: *groundwater, leachate, landfills, municipal solid waste, strategies, environmental degradation.*

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I INTRODUCTION

A consequential increase has been observed in solid waste generation due to industrialization, urbanization and population growth. The high rate of urbanization along with absence of effective management in disposal of solid waste results into various environmental problems including health hazards [1].

Land filling of waste still continues to be the main and most accepted practice of disposition of municipal solid wastes (MSW) in India. The composition of waste produced in our nation mainly comprises of a large part of organic component, paper, metal and other hazardous component and a fewer plastic material when compared to other countries. The composition of wastes produced in our country is the only basic difference between the wastes generated in the other countries. The waste consists of a lot of organic component followed by a fewer plastic material, paper, metal and other hazardous materials. This is caused by the insufficiently developed choosing of the waste materials. Inaccurately captured and mistakenly operated MSW landfills offer a severe risk to the environment, primarily to the surface water and groundwater.

II LITERATURE REVIEW

MSW & Leachate: Introduction, Characteristics and Composition.

Leachate is a hazardous liquid produced when moisture interacts with municipal solid waste (MSW) which can be either from the liquid already present in waste or from the rainwater passing by the municipal waste. The extent of leachate produced is determined by the accessible water, landfill components, its surface and the soil in the foundation. India is the 2nd rapidly developing economy and the 2nd highest colonized nation in the world with a raise in population of 36% in 26 years, at the proportion of annual percentage of 3.35% [2]. Due to the level of urbanization in the last 60 years, which has reached 31.2% from 17.35%, it is predicted that about 50% of the population in India will dwell

in cities/towns in the coming 10 years [3].

Thousands of tones of MSW is generated every day due to the expeditious mechanization, industrialization and population growth leading to the movement of population from rural to urban areas and is likely to rise significantly as India battles to accomplish the status of "Industrialized Nation" by the year 2020 [4]. A significant aspect of urbanization in India is the remarkable congregation of the population as portrayed by the rise in the count of metropolitans to 46 from 35 in the last decade amounting to about more than 1 million in Class I cities and urban cities [2]. Table 1 gives the top five metropolitan cities/ urban agglomeration (UA) in terms of population according to the census 2011 in India.

Table 1 Top Five Metropolitan Cities/ Urban Agglomeration (Ua) In Terms of Population [2]

Cities	Population (in millions)
Mumbai (Greater Mumbai)	18.5
New Delhi	16.4
Kolkata	14.2
Chennai	8.7
Bengaluru	8.8

According to reports, it is estimated that urban India is generating about 68.8 million tons of solid waste per year [5]. Due to absence of an appropriate resource to dispose bulk volume of MSW, it is typically disposed off in sunken areas without taking any type of operation control which results into one of the dominant environmental problem of Indian metro cities. In majority of the cities in India, MSW Management system involves only 4 activities viz. generation of the waste, waste collection, waste transportation, and disposal of the waste; thereby leaving out the depository and transfer of MSW. The generation of MSW is governed by a number of factors like season, living standard, food patterns and nature as well as extent of commercial exercises and its study can be utilized in proper planning for collection and disposal [6]. A survey (Table 2) conducted by the Central Pollution Control Board (CPCB) for Solid Waste Management (SWM) in 299 cities identified the waste generation for different cities in India.

Systematic studies on the leachate show that the amount of leachate water produced in the landfills primarily reply upon the climatic elements in its environs, composition of solid waste, primary moisture content, composition of the solid waste and also bio-chemical and physical conversions occurring in those wastes [7].

Table 2 Waste Generation In Different Cities In India According To CPCB

State's Name	Cities (in no.)	Population	MSW (tons/day)	Per capita waste generated (kg/day)
Uttar Pradesh (including Utrakhand)	41	14480479	5515	0.381
Karnataka (including Telangana)	21	8,283,498	3118	0.376
Bihar	17	5,278,361	1480	0.279
Gujarat	21	8,443,962	3810	0.450
Haryana	12	2,254,353	625	0.277
Chandigarh	1	504094	200	0.397
Meghalaya	1	223366	35	0.157
Kerala	146	3107358	1220	0.393
Tamil Nadu	25	10745773	5021	0.467
Rajasthan	14	4979301	1768	0.355
Manipur	1	198535	40	0.201
Maharashtra	27	22727186	8589	0.378
Delhi	1	8419084	4000	0.475
Punjab	10	3209903	1001	0.312
Orissa	7	1766021	646	0.366
Mizoram	1	155240	46	0.296
Tripura	1	157358	33	0.210
Assam	4	878,310	196	0.223
West Bengal	23	13943445	4475	0.321
Andhra Pradesh	32	10,845,907	3943	0.364
Himachal	1	82,054	35	0.427
Pondicherry	1	203065	60	0.295
Madhya Pradesh	23	7225833	2286	0.316
Total	**299**	**128113865**	**48134**	**0.376**

The formation of leachates usually takes place during November to April and they practically do not form during May to October. According to research conducted by Szpadt [8], the water confining ability of wastes and concurrent decline of water capacities of leachates as a consequence of the mineralization of organic materials is responsible for ageing of landfill which is usually followed by elevated amount of leachate. Factors such as waste composition, leachate characteristics and precipitation are responsible for the influence of leachate from each type of landfill taken into account [9]. There are various reasons influencing the composition of leachates and their generation. The composition of the solid wastes, working technique of a landfill, climate and hydro-geological conditions and the conditions in the interior of the landfill (bio-chemical activities, amount of moisture content, pH, temperature, and landfill's age) are some of the important aspects [7]. However, according to other researchers, the physico-chemical composition of the leachates can largely rely upon the variations in the atmospheric surroundings, advanced technology for settling waste materials and the landfill's age [10]. Generation of the type of leachate strictly depends on the waste involved. A typical composition of leachate is shown in Table 3.

III STUDY AREA

In the present study, characteristics of the landfills are to be considered and to analyze the influence of leachate flow on groundwater quality by selecting different landfills sites at Delhi, Bangalore & Chennai from various dumpsites of the cities [11]. The composition of the waste received at landfill usually comprises of compostable organic matter, recyclables, toxic substances and soiled waste [12]. MSW composition at the source generation and accumulation locations, is decided on the grounds of wet weight of the waste, comprising primarily of a large amount of organics (40–60%), ash and fine earth (30–40%), paper (3–6%) and metals, glass and plastic (each one < 1%). Various physico-chemical parameters like BOD, COD, TDS, Nitrates, Mg, Total Iron, Sulphates, Zinc, Lead, pH etc., both leachate and in groundwater samples were analyzed in order to recognize the possible link of groundwater contamination [13]. Various remedial measures were elaborately considered in order to diminish the concentration of pollutants in the groundwater.

Table 3 Composition Of A Typical Leachate From A Landfill (Values In Mg/L Unless Otherwise Stated) [10]

Components	Typical Value	Range
BOD_5	10,000	200 - 40,000
COD	30,000	300 – 90,000
Total Organic Carbon (TOC)	6,000	1,500 – 20,000
Total Suspended Solids (TSS)	500	200 – 1,000
Specific conductivity (μScm^{-1})	6,000	3,000 – 9,000
Nitrate	25	5 - 40
Alkalinity as $CaCO_3$	3,000	1,000 – 10,000
Total Hardness as $CaCO_3$	3,500	300 – 10,000
Total Phosphorus	30	1 – 70
Calcium	1,000	200 – 3,000
Sodium	500	200 – 2,000
Chloride	2,000	100 – 3,000
Potassium	300	200 – 2,000
Sulfate	300	100 – 1500
Magnesium	250	50 – 1,500
Total iron	60	25 – 2,500
Zinc	50	25 - 250
pH	6.0	4.2 – 7.8
Lead	2	0.2 - 10

IV RESULTS AND DISCUSSION

Table 4 Leachate Characteristics: Concentration Of Various Parameters At Chennai, Bengaluru & Delhi Landfill Sites

Parameter	Range (Chennai)		Range (Bengaluru)	Range (Delhi)		
	Kodungaiyur	Perungudi	Mavallipura	Ghazipur	Okhla	Bhalswa
BOD_5	17552	15478	-	2757	2825	3300
COD	25102	22148	-	4400	4560	5840
TDS	25514	22961	9700	9636	11135	11284
Nitrates	361	321	297	-	-	-
Sulphate	-	-	198.4	-	-	-
pH	6.9	6.9	11.5	7.6	7.9	8.1
Ca	-	-	510	-	-	-
Mg	-	-	770	37.8	46.4	37
Zn	2.10	1.29	-	0.4	0.56	1.35
Fe	63.41	58.91	1.7	7.5	10.2	41.6
Pb	1.10	1.20	-	-	-	0.56
EC	2360	2256	18700	14632	16153	31800

A. Leachate Characteristics

Based on various studies and experiments conducted by various researchers, the characteristics of the leachate specimens possessed from the dumpsite in Chennai, Delhi and Bengaluru have been presented in Table 4. There are various parameters such as BOD_5, COD, TDS, EC, nitrates, sulphates, pH, calcium , magnesium, etc for the purpose of

comparison.

B. Physico-Chemical Analysis of Groundwater Samples

The underground water of the areas under study in the present work is utilized for domestic and various other intents. Table 5 shows the comparative study of the groundwater at the landfill sites in three metro cities namely Chennai, Bengaluru and Delhi. The EC is a beneficial signal of the quantity of material dispersed in water while the groundwater salinity is indicated by Total Dissolved Solids (TDS). The high conductivity values achieved for the underground water near the landfill are signs of its effect on the quality of water. Various pollutants present in groundwater due to leaching results in increased TDS, which may in turn diminish the palatability and may lead to gastro-intestinal sensitivity in human beings and also have laxative impact especially upon transits [14]. COD is an index of organic pollution and thus, used as an organic indicator to assess the groundwater quality. From various tests conducted by different researchers, the COD value was found to be ranging between 243 to 436 mg/L with a typical value of 331 mg/L indicating the existence of organic contaminants in water [15].

Similarly, unpleasant taste is imparted due to high alkalinity and can be harmful to health of the humans with presence of high pH, TDS and total hardness. The presence of high accumulations of EC, TDS, SO^{-4}, NO^{-3}, Na^{+}, etc in groundwater nearby landfill site can result into deterioration of the quality for domestic purposes, especially drinking. Also, leachate percolation can be traced by mere presence of Cl^{-}, NO^{-3} and COD. By continuously monitoring the landfill site, it was evident that the groundwater characteristics have been adversely damaged from leachate generation which is located adjacent to the areas due to percolation in the sub-soil. Multivalent cations, especially Mg^{2+} and Ca^{2+} usually exist at a critical concentration in natural waters which easily precipitate and react with soap making it difficult to remove scum [16]. The improvement in the groundwater quality was observed with the raise in depth and distance from the source of pollution. Even though, the existence of hardly any contaminants lies within the drinkable water standards but there are contaminants in the groundwater which is a serious threat to public health. This will go a long way in protecting water which is getting degraded by the solid wastes. Solid waste handling, controlling and monitoring techniques in the mentioned areas must be geared towards achieving quality environmental condition for humans to live in.

Table 5 Groundwater Characteristics: Concentration Of Various Parameters Near Chennai, Bengaluru & Delhi Landfill Sites

S.No	Parameter	Units	Chennai	Bangalore	Delhi
1.	pH	-	7.1-8.2	6.2-9	7.6-8.1
2.	EC	µmhos/ cm	410-3830	610-977	680-4400
3.	B.O.D.	mg/L	-	8.3-9.0	12.07-96.0
4.	C.O.D.	mg/L	-	243-436	46.22-481
5.	T.D.S.	mg/L	267-2345	389-2789	981-3816
6.	Na^{+}	mg/L	0-437	29-49	-
7.	K^{+}	mg/L	4-76	1.2-1.6	39.16-59.00
8.	Mg^{2+}	mg/L	5-209	6-276	37-46.4
9.	NO^{3-}	mg/L	0-47	0-78	0-89
10.	$SO4^{2-}$	mg/L	12-300	94-400	20.3-360

V FACTORS CONTRIBUTING TO GROUNDWATER POLLUTION AND CONTAMINATION EFFECTS ON GROUNDWATER RESOURCES

From the present study, it was observed that the landfill sites are situated near the urbanized area of the city which usually becomes the source of various problems like public health problems, traffic congestion. Since these areas are being utilized as dumpsites, they can cause serious groundwater contamination [17]. It was also perceived that groundwater is usually fresh, except minor areas near the landfills and the presence of landfill sites deteriorates the quality of local aquifers and the water is thus, not safe for drinking or any other domestic purpose and appears brackish in nature. From the data obtained from various researches, it can be contemplated that some of the parameters such as total dissolved solids, total hardness, lead, magnesium are above the acceptable limits for drinking water giving by the Indian Standards which makes them unfit for drinking and other domestic functions [18].

Also, the contribution of leachates to the groundwater can be observed with the presence of heavy metals exceeding the acceptable limits set by the Indian Standards and WHO. It was also seen through various researches that leachate affected groundwater can be detected by the extreme values of electrical conductivity (EC) being obtained [14]. Sometimes, gastro-intestinal irritation in

humans and decreased palatability serves as an indication of higher dissolved solids concentration.

VI STRATEGIES, PRACTICES & TECHNOLOGY

As the leachate contamination poses serious effects on the groundwater, therefore, the government, local bodies and the dwellers nears the landfill sites must take stringent actions to curb the problem.

- Serious threat to subsurface water can be observed if adequate measures to control the leachate from the landfill sites are not taken. Also, the detrimental effect of pollution by heavy metal on the groundwater should be examined on regular basis by experimental investigations. Remedial measures to curb the problem must also be taken into account.
- New technology related to greenhouse gas recycling originating from landfills should be adopted.
- Improvement of municipal solid waste management practices and construction of appropriately engineered landfill sites with the utilization of clay or plastic liner which prevents leachate from getting into the water table should be highly recommended which can curtail the groundwater pollution.
- It is highly recommended that the upgradation of landfills should be done so as to prevent the leachate directly draining into groundwater or surface water which can cause serious contamination of the sources leading to various hazards and health issues in humans.
- Unsegregated waste should be avoided from dumping at the site to avoid further serious consequences.
- Strict monitoring in and around the dumpsite should be done for temporal and spatial variation in quality and quantity of leachate.
- Utilization of non-biodegradable waste should be avoided so as to further increase the chances of contamination of surface and ground water.

VII CONCLUSION

From the study done, we can undertake that since the sites for landfill dumping were located near to city, problems like over crowding due to traffic, contamination of surface and subsurface waters, health problems etc. are experienced. It can be also accomplished that a serious threat to groundwater will be posed until proper measures are undertaken to regulate the leachate contamination due to dumpsite. The prominence should be given to advance the construction of sanitary landfill with clay or plastic liners to curtail the ground water pollution. Experimentation regarding the pollution of surface and subsurface waters should be carried out. Hence, new technologies should be used from time to time and experimented so as to curb the problems arising from the contaminated leachates.

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