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Analysis of leachate from municipal landfill and studying it's impacts on the surrounding environment

Priyadarshini N. R*. and Harsha T. S.

[1]*Assistant Professor Department of Studies in Environmental Science Karnataka State Open University Mukthagangotri, Mysuru – 570 006*

Abstract—The disposal of solid waste presents a significant challenge for communities worldwide, whether in developed or developing countries, due to the inherent risks to human health and the environment. The physicochemical attributes and heavy metal contamination found in leachate samples are closely tied to the composition of Municipal Solid Waste and its water content. However, the current solid waste treatment system in many cities proves inadequate, leading to extensive waste disposal in open dump sites and a substantial influx of unsegregated waste to landfill areas. This unsegregated mixed waste poses a threat to nearby water bodies through the generation of leachate, as evidenced by high concentrations of both organic and inorganic constituents in the analysis. The BOD/COD ratio indicates a medium-aged leachate, surpassing standard discharge levels significantly and posing a potential risk of environmental contamination if left untreated. The presence of algae growth in adjacent water bodies further confirms the impact of leachate. Moreover, soil samples collected near dumpsites indicate contamination with heavy metals. Thus, it is imperative to treat leachate before its discharge into water bodies. Various biological aerobic and anaerobic treatment methods such as sequencing batch reactors, up-flow anaerobic sludge blankets, and membrane bioreactors can be considered. Effective solid waste management, particularly in countries like India, necessitates robust enforcement of proactive environmental policies and widespread community engagement in sustainable waste management practices.

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1. Introduction

Disposal of solid wastes is a challenge for many communities in developed and developing countries because of the risks to humans, health, and the general environment [1]. Municipal solid waste (MSW) generation, in terms of kg/capita/day, has shown a positive correlation with economic development on a global scale. On the other hand, landfilling is one of the dominant options for solid waste disposal all over the world. Because of Leachate formation is one of the many environmental hazards associated with landfilling [2].This leachate occurs in liquid form, which accumulates at the bottom of the landfill and is subsequently percolated slowly into the soil to contaminate the aquifer beneath it and adjacent surface water bodies [3].Bangalore city generates about 4,500 metric tonnes of municipal solid waste every day, of which 75% is disposed of in landfills; however, the Mavallipuravillage site has been used as a processing site for the municipal solid waste generated from Bangalore city.

*Corresponding author.

E-mail address: pridanr49@gmail.com (Dr. Priyadarshini N. R.)

The physicochemical characteristics and heavy metal levels of leachates at the Rumuodumaya dumpsites surface water of the river indicate that the heavy metal concentration (mg/L) obtained in the three sites, only Nickel values are above USEPA maximum level of 0.05 mg/L [4]. Leachate analysis of the Mavallipura landfill showed a high concentration of organic and inorganic constituents. Heavy metal concentration was in traces, indicating that the waste dumped is predominantly municipal waste [5]. According to K. S. Khoo et al., metal ions present in leachate represent a threat to river ecosystems if they are not properly treated before discharge[6]. This study reveals that the COD/BOD5 ratio is a good indicator of the biodegradability of an effluent. A value of this ratio close to 1.0 corresponds to very good biodegradability, while a value greater than 4.0 indicates that the effluent is very difficult to biodegrade [3]. Leachate contains hundreds of different chemicals, and the characteristics of municipal leachate vary greatly within an individual landfill over space and time [7].

The aim of this study was to monitor the leachate characteristics of both the active and closed dumping grounds of the uncontrolled landfill site in Bangalore, India, as knowledge of leachate composition is crucial for evaluating the leachate pollution potential of a landfill site. There is a scarcity of published data on the leachate pollution potential of this specific landfill site. Therefore, this study is valuable in identifying the dominant pollutants present in the Mavallipuram landfill site and assessing the likelihood of leachate-induced groundwater and surface water pollution. Additionally, it aims to develop proper leachate management and treatment programs for this identified landfill site.

2. MATERIALS AND METHODS

2.1 Study area

Bangalore is located at 12.97 N latitude and 77.56 E longitude and covers an area of 800 km2. It is located on the ridge, and the natural watercourse along the three directions is the Vrishabhavathi, Koramangala-Challghatta (KAC), and Hebbala-Nagavara valley systems. The city generates roughly around 4000 metric tonnes of municipal solid waste (MSW) per day, which is disposed of at various selected locations on the outskirts of the city. Mavallipura is one such site used to process and dispose of MSW by Brhath Bangalore Mahanagara Palike (BBMP). The present study of leachate analysis has been carried out at the said site.

2.2 Sampling location

The landfill is situated at survey no. 108, at Mavallipura village, Hesaraghatta zone, Bangalore North, Karnataka State. This site has been used to process municipal solid waste collected from Bangalore city. The samples collected were leachate, surface water (Pond), ground water, and soil. These samples were analysed for physical and chemical parameters. Leachate contains hundreds of different chemicals. The characteristics of municipal leachate vary greatly within an individual landfill over space and time.

2.3 Sampling method

In the present study, 2 litres of each representative sample of municipal solid waste leachate, surface water from a nearby pond, and ground water from a nearby well were collected, and soil samples were also collected. These samples were stored in the refrigerator before proceeding with analysis. The analysis is carried out according to the standard methods of examination of water and waste water prescribed by [8], [9].

2.4 Analytical work

Analytical methods were according to "Standard methods for examination of water and wastewater" specified by the American Public Health Association. The pH was measured by an electronic pH metre (4500-H+.B of Standard Methods). Total solids (TS) were determined by a properly shaken, unfiltered sample and estimated by the gravimetric method (2540.B of Standard Methods). Total Dissolved Solids (TDS) was determined by a filtered sample through What Man Filter Paper 44 and estimated by gravimetry (2540.C: Standard Methods). Turbidity was measured by a nephelometer using the optical properties of light (2130.B of Standard Methods). Chemical oxygen demand (COD) was determined by refluxion of the sample, followed by titration with ferrous ammonium sulphate (FAS) (5220.C: Standard Methods). Biological Oxygen Demand (BOD): Winkler's method was used for estimating initial and final DO in the sample, and BOD was determined (5210-B of Standard Methods). The Argento metric volumetric titration method in the presence of potassium chromate provides reliable results for chloride (4500-Cl-.B of Standard Methods). Nitrate was analyzed by HACH Portable.

3. RESULT AND DISCUSSION

The physicochemical characteristics and the heavy metal contamination in the collected leachate sample depend primarily upon the waste composition and water content of the Municipal Solid Waste (MSW) [10]. The physicochemical characteristics and heavy metal concentrations were analysed for the collected leachate sample from the Mavallipura dumping site and are presented in Tables 1-4.

Landfill leachate samples were characterised to assess the leachate quality, including the effects of rainfall events on each measured parameter. The summary statistics of all the measured physicochemical and biological parameters are given in Tables 1–4. Leachate samples were collected during the dry period and six days after a rainfall event.

The colour should be transparent in the sample. No organic or suspended particles should be present. The sample should be odorless. After the colour and odour tests, the sample should be acceptable [11], [12].

3.1 Color

Colour should be black in leachate, light brown in surface water, and also colourless in ground water. An unpleasant odour is present in leachate and surface water but is odourless in ground water [13], [14], [15].

3.2 pH

The pH value of the leachate from the landfill site was 7.1. pH is controlled by a series of chemical actions. Organic matter is degraded to produce carbon dioxide and a small amount of ammonia. These dissolve in leachate to produce ammonium ions and carbonic acid. The carbonic acid dissociates to produce hydrogen cations (1) and bicarbonate anions (ICO), and this influences the pH level. The pH value of well water is found to be 6.1, which is slightly acidic, and that of surface water is 7.4. These variations may be due to various factors, such as rainwater infiltration and the percolation of leachate. Additionally, the influx of contaminants from natural and anthropogenic activities like the percolation of solid waste leachates and other land use can also affect the pH values. pH is an important parameter to be tested in waste water treatment, as pH adjustment by the addition of acidic or basic chemicals allows the waste to get dissolved and can be separated from water [16], [17].

3.3 Alkalinity

Alkalinity is caused by bicarbonate, carbonate, and hydroxyl ions. It is important in the treatment of waste water for coagulation, softening, etc. The alkalinity of the leachate is 13600 mg/l, followed by surface water and ground water, whose alkalinities are 4760mg/l and 230 mg/l, respectively. The landfill leachate has total alkalinity values significantly higher than natural water (2410 mg/l) because of the biochemical decomposition and dissolution processes that occur at the landfill site. The biodegradation process of organic matter within waste mass produces bicarbonate. Mavallipura leachate has a high value of alkalinity [13600 mg/l], and this represents the level of biodegradation taking place. The high alkalinity values of well water show that the water is contaminated [18], [19], [20].

3.4 Conductivity and TDS

These parameters are generally influenced by the total amount of dissolved organic and inorganic materials present in the solution and are used to demonstrate the degree of salinity and mineral content of the leachate. The salt content in the leachate is due to the presence of sodium, potassium, chloride, nitrate, sulphate, and ammonia salts. The conductivity and TDS values of leachate are 3910 S/cm and 2737 mg/l, respectively. Surface water conductivity is 2410µS/cm as well as TDS 1018 mg/l, and the ground water conductivity value is 1561µS/cm and the value of TDS is 1212 mg/l. The leachate had higher conductivity values as a consequence of the degradation of organic matter. The ground and surface water conductivity values are unacceptable too [16], [17].

3.5 Chloride, Sulfate, Nitrate (Anions)

The level of inorganic elements present in leachate is dependent on the leaching of inorganic components present in municipal solid waste (MSW) and the stabilisation process. The chloride sulphate and nitrate present in a leachate are 1602 mg/l, 1 mg/l, and 8.02 mg/l, respectively. In surface water, chloride is 168 mg/l, sulphate s 13 mg/l, and nitrate is 23.2 mg/l. As in ground water, it contains 380 mg/l, 36 mg/l, and 6.4 mg/l of chloride, sulphate, and nitrate. The Mavallipura landfill leachate was found to have high concentrations of anions like nitrate, chloride, and sulphate, which may be due to sewage. Rural and other animal waste deposited at the site Sulphate in leachate may be due to construction waste or synthetic etergents. Nitrates represent the most oxidised form of nitrogen. In leachate, it is found as a result of the oxidation of ammonium to nitrite and subsequently to nitrates by purification. Surface and well water are within acceptable range when compared to the ISI0500 recommended for drinking water. But the chloride value is found to be higher in groundwater [8], [18].

3.6 Calcium, Sodium, Potassium (Cations)

The presence of calcium, sodium, and potassium ions in the leachate depends on various constituents of municipal solid waste, degradation of organic matter, dissolution of inorganic waste such as concrete, plaster, tiles, etc., and the prevailing phase of stabilisation of the leachate. Sodium and potassium are present in high concentrations in leachate and surface water; their values are 1828 1828mg/l potassium, 3960 mg/l in leachate, 1093 mg/l potassium, and 1523 mg/l sodium in surface water, respectively. The concentrations of potassium and sodium in ground water are 9 mg/l and 151 mg/l, respectively. These residues are likely to be derived from vegetable residues and domestic waste. Calcium concentration in leachate is 1412 mg/l, in surface water 27 mg/l, and in ground water 94 mg/l.

3.7 Indications from BOD and COD values

Biochemical oxygen demand is the amount of dissolved oxygen needed by the aerobic microorganisms to breakdown the organic matter in a given sample at a certain temperature over a specific period of time. Chemical oxygen demand is a test to measure the amount of organic compound (i.e., oxygen required to oxidise the organic matter) in water or waste water. The BOD/COD ratio is useful to assess the amenability of waste to biological treatment. The BOD/COD ratio indicates the age of the landfill. Any waste water with a BOD/COD ratio greater than 0.5 can be considered quite controlled for biological treatment (young), while the 0.1–0.5 range is medium and less than 0.1 is old leachate. This investigation revealed that the BOD/COD ratio is 0.132 and the sample collected is more than 5 years old.

Algae are the microscopic aquatic plants that live in water and rapidly multiply due to an excess of nutrients, causing algal blooms.

3.8 Heavy Metals

Heavy metal is a relatively dense metal or metalloid that is noted for its potential toxicity. Examples include lead, mercury, chromium, cadmium, arsenic, nickel, copper, iron, etc. They are non-degradable and get bioaccumulated or biomagnified well beyond the permissible body burden. This will have an adverse effect on health.

Heavy metals that appear in municipal solid waste, like

Table 1: The results obtained from the analysis of physico-chemical parameters of collected samples from the Mavallipura landfill site.

Parameter	**Leachate**	**Surface Water**	**Ground Water**	**Soil**
Color	Black	Light brown	Colorless	–
Odor	Unpleasant	Unpleasant	Odorless	–
pH	7.1	7.4	6.1	–
Conductivity (μS/cm)	3910	2410	1561	–
TDS (mg/L)	2737	1018	1212	–
COD (mg/L)	12116	986	453	–
BOD (mg/L)	1600	96	9	–
Alkalinity (mg/L)	13600	4760	230	–
Calcium (mg/L)	1412	27	94	–
Chloride (mg/L)	1602	168	380	–
Sulfate (mg/L)	61	13	36	–
Nitrate (mg/L)	28.02	23.2	6.4	–
Potassium (mg/L)	1828	1093	9	–
Sodium (mg/L)	3960	1523	151	–
Copper (mg/L)	0.861	BDL	BDL	9.6 mg/kg
Zinc (mg/L)	3.096	0.105	0.124	64 mg/kg
Iron (mg/L)	35.845	0.365	BDL	1017 mg/kg
Lead (mg/L)	0.536	BDL	BDL	BDL

Table 2: Comparison of lake water quality standards with pond water

Parameters	**Desirable Limit (CPCB)**					**Surface Water (Pond Water)**
	A	**B**	**C**	**D**	**E**	
pH	6.5–8.5	6.5–8.5	6.0–9.0	6.5–8.5	6.0–8.5	7.4
Conductivity (μS/cm)	–	–	–	1000	2250	2410
TDS (mg/L)	–	–	–	–	–	1018
COD (mg/L)	–	–	–	–	–	986
BOD (mg/L)	2	3	3	–	–	96
Alkalinity (mg/L)	–	–	–	–	–	4760
Calcium (mg/L)	–	–	–	–	–	27
Chloride (mg/L)	–	–	–	–	–	168
Sulfate (mg/L)	400	–	400	–	1000	13
Nitrate (mg/L)	20	–	50	–	–	23.2
Potassium (mg/L)	–	–	–	–	–	1093
Sodium (mg/L)	–	–	–	–	–	1523
Copper (mg/L)	1.5	–	1.5	–	–	BDL
Zinc (mg/L)	15	–	15	–	–	0.105
Iron (mg/L)	0.3	–	0.5	–	–	0.365
Lead (mg/L)	0.1	–	0.1	–	–	BDL

Table 3: CPCB prescribed limits for pond water

Class of Water	**Designated Best Use**
A	Drinking water source without conventional treatment but after disinfection.
B	Outdoor bathing (Organized).
C	Drinking water source after conventional treatment and disinfection.
D	Propagation of wildlife and fisheries.
E	Irrigation, industrial cooling, controlled waste disposal.
Below E	Not meeting A, B, C, D and E criteria.

Table 4: BOD/COD ratio of leachate indicating the stage of landfill stabilization.

BOD/COD	**Leachate**
0.1–0.5 (Medium, 5 years)	0.132

batteries, light bulbs, lead foils, plastics, and glass, can introduce metal contaminants into the solid waste stream. Leachate has copper (0.861 mg/l), zinc (13.096 mg/l), iron (35.845 mg/l), and lead (0.536 mg/l), which can contaminate nearby water sources. The soil beneath the dump has iron [10173 mg/kg]. Zinc [64 mg/kg] and copper [9.6 mg/kg]. In surface water, traces of zinc [0.105 mg/l] and iron (0.365 mg/l] were found; however, the ground water had a bad zinc concentration [0.124 mg/l]. Leachate is contaminated with heavy metals and has the potential to contaminate the surrounding environment if left untreated [17].

4. CONCLUSION

BBMP is facing various challenges in managing solid waste. The existing solid waste treatment system in the city is not very effective, resulting in large-scale disposal of waste at open dump sites. There is a huge inflow of unsegregated waste to landfill sites. The unsegregated mixed waste has the potential to pollute surrounding water bodies due to leachate generation. Analysis of leachate showed a high concentration of organic and inorganic constituents. The BOD/COD ratio reveals that the leachate is medium-aged. As compared to discharge standards for leachate, it has much higher values and has the potential to contaminate the surrounding environment if left untreated. The growth of algae in nearby water bodies is a confirmation of leachate effects on water bodies. The soil collected in the vicinity of the dumpsite also reveals that it is contaminated with heavy metals. Hence, leachate has to be treated before discharging into the water bodies. Various biological aerobic and anaerobic treatment methods (sequencing batch reactors, up-flow anaerobic sludge blankets, membrane bioreactors) can be adopted. In a developing country like India, solid waste management could be achieved only when there is strong, fair, and effective enforcement of proactive environmental policies and a willingness to involve all sectors of society in the best solid waste management practices.

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