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CHARACTERIZATION OF LEACHATE FROM MUNCIPAL LANDFILL AND ITS EFFECT ON SURROUNDING WATER BODIES

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ABSTRACT

Percolating water passing through waste becomes contaminated and will have dissolved soluble organic and inorganic compounds as well as suspended particles. Also the pore fluid of the waste is often released and mixes with this water. The entire contaminated fluid is called leachate. There are many factors that affect leachate production like annual precipitation, runoff, infiltration, evaporation, transpiration, and freezing, mean ambient temperature, waste composition, waste density, initial moisture content, and depth of the waste fill. The production of leachate reduces when a landfill is closed. The decomposition of waste in presence of water can be separated into two different phases of degradation viz., initial aerobic and subsequent anaerobic. Generally, the leachate undergoes natural chemical changes over time that reduces its toxicity. Some of the soluble contaminants enrich the water table, or the saturated zone. Some of remaining molecules naturally adsorbed to the clay liner particles. The paper discusses the characteristics of leachate generated from municipal solid waste landfill and its effect on surrounding water bodies near Mavallipura landfill area in Bangalore. Two samples of water from the nearby pond and well were collected from downstream of Mavallipura landfill site. Physico-chemical characterization of leachate has shown that the leachate contains high concentrations of organic and inorganic constituents beyond the permissible limits. While the heavy metals concentration was in traces as the waste is dumped in the landfill is mainly domestic in nature. The pH of the leachate is marginally alkaline as the pH is 7.4. The results also showed that the highest metal concentration that exists in the leachate was Iron which is about of 11.16 ppm. BOD_5 and COD of the leachate are 1500 mg/l and 10400 mg/l, respectively. The leachate characteristics indicate favorable growth of algae in natural water contaminated with leachate with the alkaline condition and with the presence of magnesium as nutrient, which has been confirmed in the nearby surface pond. Knowledge of leachate quality will be useful in planning and providing remedial measures to protect surface and ground water quality in the area.

Keyword: Decomposition, Landfill, Leachate, Municipal Solid Waste

INTRODUCTION

Leachate is a contaminated liquid emanating from the bottom of the solid waste such as landfills and contains soluble organic and inorganic compounds as well as suspended particles. Depending on weather leachate flow can increase (during rainy season) or decrease (during dry/summer season). The landfill leachate discharge may lead to serious environmental problems. Leachate may percolate through landfill liners and subsoil causing pollution of ground water and surface waters resources. A landfill is designed to protect the environment from harmful contamination by minimizing the migration of contaminants in leachates by providing appropriate liner. Sanitary landfill is the scientific dumping of municipal solid waste due to which maturity of the waste material is achieved faster [1]. Generation of leachate from sanitary landfill is a complex combination of physical, chemical and biological processes whereby waste age has effect to performance of landfill that generate leachate [2]. The major potential environmental impacts related to solid waste landfill leachate are pollution of surface water and ground water. The risk of ground water pollution is probably the most severe environmental impact from landfills because historically most landfills were built without engineered liners and leachate collection and treatment systems [3]. Generally, it is accepted that landfills undergo at least four phases of decompositions: (a) an initial aerobic phase, (b) an anaerobic acid phase, (c) an initial methanogenic phase, (d) a stable methanogenic phase [4].

This paper presents the results of leachate composition and characteristics such as pH, BOD_5, COD, heavy metals of a municipal solid waste (MSW). Three samples of leachate/water were collected from the landfill and surrounding water bodies and analyzed for various physico-chemical parameters to estimate its characteristics or composition. The two different water samples from the nearby pond and well were collected from downstream of Mavallipura landfill site. Another leachate sample has been collected directly from Mavallipura landfill itself. The concentration of magnesium is also measured as it is one nutrient for the growth of algae.

SAMPLING LOCATIONS

The Landfill is situated at survey no.108, at Mavallipura village, Hesaragatta zone, Bangalore North, Karnataka state. This site has been used as processing for the municipal solid waste generated from the Bangalore city. Fig.1. shows sample location points in landfill. Fig.2, 3 and 4 show the location of collection of leachate, Pond and Open well from Mavallipura landfill.

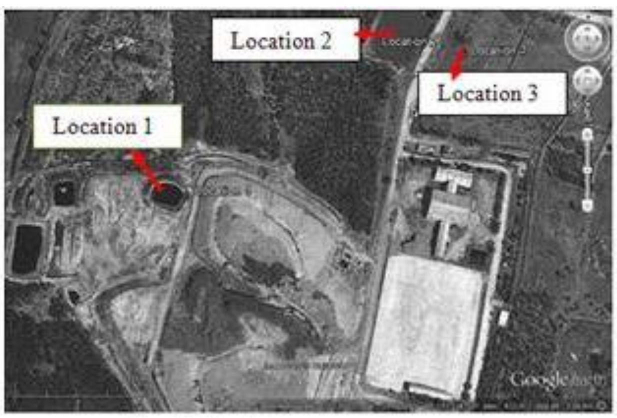

Fig.1. Sample locations points

Fig.2. Leachate collected from landfill

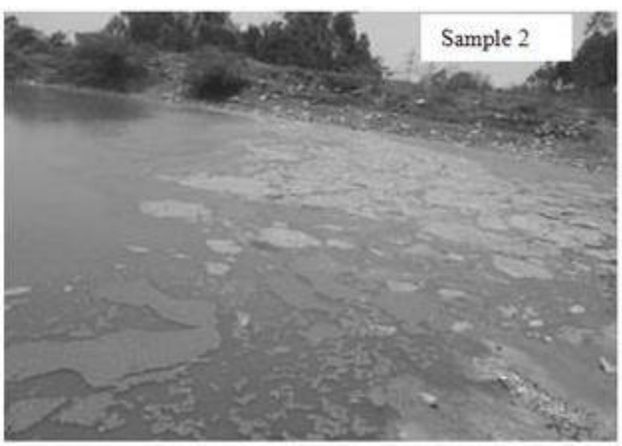

Fig.3. Pond near landfill

Fig.4. Open well near landfill

Sample collection and Preservation

A municipal solid waste leachate sample was collected in the month of April from the Mavallipura landfill area in Bangalore. Glass bottles were used to collect leachate samples for chemical analyses, whereas, samples preserved for BOD and COD tests were collected in polyethylene bottles covered with aluminium foils. A few drops of concentrated nitric acid were added to the leachate sample collected for heavy metals analysis to preserve the samples. The samples were then transported in cooler boxes at temperature below 5°C, and transported immediately to the laboratory. Sample of leachate were stored in refrigerator at 4°C before proceeding for the analysis. The analysis is carried out according to standard methods for examination of water and wastewater unless otherwise stated, APHA [5]. Table 1 shows the methods of analysis of different parameters of leachate.

Table 1. The methods of analysis of different parameters of leachate

Parameters	**Instrument used to identify the parameters**
pH	pH meter
Conductivity, µS/cm	Conductivity meter
TDS, mg/l	TDS meter
COD, mg/l	Open reflux method
BOD_3 , mg/l	Winkler's method
Sulphate, mg/l	Titration
Chloride, mg/l	Titration
Calcium, mg/l	EDT titration
Alkalinity, mg/l	EDT titration
Sodium, mg/l	flame photometer method
Potassium , mg/l	flame photometer method
Nitrate,mg/l	Spectrophotometer method
Heavy metal	Absorption Spectrophotometer

RESULTS AND DISCUSSION

Table 2 shows the results the chemical characteristics of the leachate from Mavallipura landfill. As for metals, high concentrations of iron in the leachate, followed by zinc, nickel were observed. The concentrations of chromium, copper, cadmium and lead were low.

Table 2. Leachate characteristic of Mavallipura landfill

Details	**Leachate (Sample 1)**	**Pond (Sample 2)**	**Well (Sample 3)**	**Desirable Limit IS10500-2012**
pH	7.4	8.4	7.5	6.5 to 8.5
Conductivity, µS/cm	4120	2500	1362	500
TDS, mg/l	2027	1447	703	500
COD, mg/l	10400	1080	440	-
BOD_3 , mg/l	1500	105	3	-
Sulphate, mg/l	40	10	7	200
Chloride, mg/l	660	250	230	250
Calcium, mg/l	400	0	320	75
Alkalinity, mg/l	11200	2000	300	200
Iron, mg/l	11.16	0.16	0.62	0.3
Copper, mg/l	0.151	BDL	BDL	0.05
Silver, mg/l	0.035	0.026	0.051	0.1
Chromium, mg/l	0.021	BDL	BDL	0.05
Cadmium, mg/l	0.035	BDL	BDL	0.003
Lead, mg/l	0.3	BDL	BDL	0.01
Zinc, mg/l	3	1	0.4	5
Nickel, mg/l	1.339	BDL	BDL	0.02
Sodium, mg/l	3710	1676	88	200
Potassium , mg/l	1675	1078	46	200
Nitrate, mg/l	22.36	0.18	1.09	45
Total Phosphorus, mg/l	26.29	5.87	1.5	-

pH

pH value of leachate(sample 1) of the landfill site was 7.4. pH is controlled principally by a series of chemical reactions. The important reaction is the degradation of organic materials to produce carbon dioxide and small amount of ammonia. These dissolve in the leachate to form ammonium ions and carbonic acid. The carbonic acid dissociates with ease to produce hydrogen cations and bicarbonate anions. Which influence the level of pH of the system. Additionally, leachate pH is also influenced by the partial pressure of the generated carbon dioxide gas that is contact with the leachate. pH range of 6.0 to 9.0 appears to provide protection for the life of fresh water fish and bottom dwelling invertebrates.

The pH values of the pond and well water samples found to be 8.4 and 7.5. These variations were likely caused by number of factors such as rain water infiltration and dilution effects. Additionally, the influx of contaminants from natural and anthropogenic activities like percolation of solid waste leachates and other land uses can also affect the pH values. However, these pH values were within what would be considered a relatively normal band [6]. When compared with the IS10500 recommended range for pH in drinking water (6.5-8.5) are within the acceptable range.

Alkalinity

Alkalinity caused by bicarbonate, Carbonate and Hydroxyl ions. It is important in treatment of waste water: coagulation, softening, evaluating buffering capacity of water. However, for landfill leachate total alkalinity values are often found to be significantly higher than natural waters. This is because of the biochemical decomposition and dissolution process occurs within a landfill and disposal sites. The biodegradation processes of organic matter within the waste mass produce a significant amount of bicarbonate, which represents dissolved carbon dioxide and is also the major components of alkalinity. In this investigation, the Mavallipura leachate sample was found to have significantly high alkalinity values. The high alkalinity observed in this study reflects the level of biodegradation process taking place within the disposal sites. The presence of significant amounts of ash and slag is from the combustion of wood, agricultural residues and peat in Mavallipura landfill sites. These components are known to increase alkalinity in leachtes greatly. Water Sample 2 found to be having high concentration could have effect on health due to the reduced solubility of many heavy metals [7]. It might produce unpleasant odour in the water sample that is be unacceptable for many users [8]. The high alkalinity values observed in this study, therefore, imply that the groundwater is contaminated.

Conductivity and Total dissolved solids

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 contents of leachate. Total mineral content further reflects the strength and overall pollutant load of the leachate. The salt content in the leachate is due to presence of potassium, sodium, chloride, nitrate, sulphate and ammonia salts. The leachate sample seems to be having high values (EC=4210µS/cm) as a consequence of degradation of organic matter. When sample 2 and sample 3 are compared with the IS10500, recommended range for conductivity and TDS in drinking water found to be in unacceptable range.

Major anions

The level of inorganic elements present in leachate is dependent principally on the ease of leaching the inorganic constituents present in the municipal solid waste materials and the stabilization process in the landfill. In this investigation, Mavallipura landfill leachate sample was found to have considerably high concentrations of all the major anions like chlorides, nitrates, sulphate as reflected in concentration of chloride is highest, while sulphate concentration is the lowest. The high chloride content in the leachate sample reflects the significant presence of soluble salts in the municipal solid waste materials of the study area. The high chloride content in Mavallipura landfill leachate sample is attributed to the large amount of sewage, agricultural and other animal waste deposited in the site. Prior to anaerobic activity sulphate is converted to sulphide and metal sulphide precipitates in leachate sample.

Sulphate in landfill leachate is sourced primilarly from the decomposition of organic matter, soluble waste, such as construction wastes or ash, synthetic detergents and inert waste, such dredged river sediments.

Nitrates represent the most oxidized form of nitrogen found in natural system. It is often regarded as an unambiguous indicator of domestic and agricultural pollution. In leachate sample it is formed primarily as a result of oxidation of ammonium to nitrite and subsequently, to nitrates by nitrification process.

Sample 2 and Sample 3 are within the acceptable range when compare with the IS10500 recommended in drinking water.

Major Cations

The constituents Calcium, Magnesium, Sodium and Potassium are considered generally to be major cations typically present in leachate. Derived from the waste material through mass transfer processes, concentration of these cations in leachate is specific to the composition of the waste mass and the prevailing phase of stabilization in the landfill [9].

In leachates, these are sourced usually from the degradation of organic materials and the dissolution of inorganic wastes such as concrete, plaster and tiles. Sodium and potassium are both present at considerably high concentrations in the entire samples of this investigation. The sodium and potassium are not affected significant by microbiological activities within the landfill site. These ions play an important role in plant physiology and are most likely derived from vegetable residues and domestic wastes. Increased concentration of potassium in ground water is often considered as an indicator of leachate pollution [9]. Main source of potassium is due to weathering and erosion of potassium bearing minerals such as feldspar and leaching of fertilizer. It can have adverse health effects from exposure to increased potassium in drinking water .It can cause diseases like kidney failure, heart disease, coronary artery disease, hypertensions, diabetes.

Sodium is an essential nutrient and adequate levels of sodium are required for good health. The sodium and potassium are not affected significantly by microbiological activities within the landfill site.

Calcium is one of the most common cations found in ground water aquifers, as it dissolves from rocks, such as limestone, marble, calcite, dolomite, gypsum, fluorite and apatite. In addition with magnesium, it is one of the principal cations associated with water hardness [10]. Calcium concentrations were noticeably high in sample 3. When sample 2 was compared with the IS10500 recommended range for sodium and potassium in drinking water are found to be in unacceptable range.

Indications from BOD and COD values

The BOD/COD ratio indicates the age of the waste fill [11]. Also the changes in the amount of biodegrable compounds in the leachate. Any waste water, having its BOD_5/COD ratio more than 0.63, can hence, be considered to be quite controlled to biological treatment, since it does not contain non-biodegrable organics [12].

Table 3 Age of waste based on BOD & COD values of leachate [11].

BOD_5/COD	Age of fill	COD
≥ 0.5	Young (< 5yr.)	>10,000
0.1-0.5	Medium (5 yr -10yr)	500-10,000
<0.1	Old(>10 yr)	<500

From Table 2, it shows that BOD_5 was 1500 mg/l and the value of COD was 10400 mg/l . The ratio of BOD_5/COD is 0.144 for Mavallipura landfill. For surface sample BOD_5/COD ratio is 0.097(BOD=105mg/L, COD=1080mg/L) and for well sample BOD_5/COD ratio is 0.0067 (BOD=3mg/l, COD=440mg/l) respectively. The value of COD and BOD_5/COD can characterize the age of the landfill according to the leachate consitutents see (Table 3). Thus, the value of COD and BOD_5/COD from Table 3 was compared with Table 2. It shows that the leachate sample in this study was collected from the landfill with the age more than 5 years. It is thus clearly seen that both COD and BOD values of the surface water pond and well sample have considerably reduced. The reduction in the BOD/COD value in the case of surface water pond is much higher indicating that the reduction is mainly due to reduction in the BOD value. Even assuming that the surface water pond is only contaminated with the leachate partially to dilution the reduction BOD/COD value shows that it is due to by plant such as algae. As such the surface water pond is characterized not only by smaller BOD and COD values but also by lower BOD/COD ratio.

Algae are the population of microscopic single and multiple-celled aquatic plants that live in water. When populations of algal cells multiply, thereby clouding or giving color to a pond, it is called an algal bloom. Algae produce oxygen through photosynthetic action and are the primary source of oxygen in a body of water. Other sources of oxygen include other aquatic plants and oxygen interchange at the air-water interface, especially caused by wind driven wave action. Oxygen is also continuously being removed from the pond. It is removed by respiration of aquatic animals, by the biological oxygen demand (BOD) of organisms such as bacteria that break down non-living organic material, and even by a chemical oxygen demand (COD) caused by chemical processes such as decay of dead plants and animals. The presence of algae for the production of oxygen and as a base resource is essential for any healthy body of water [13]. The growth of algae was observed in water pond in downstream of landfill area which is shown in Fig.5. Fig.6. shows the water sample from the well.

Total Phosphorus

Total phosphorus value for leachate was found to be 26.29mg/l. Phosphorus is one of the key elements necessary for growth of plants and animals and is a backbone of the kerb's cycle and Deoxyribonucleic acid (DNA). Phosphorous transported from agricultural lands to surface water can promote eutrophication, which is one of the leading water quality issues in lakes and reservoirs [14]. The IS10500 has not set any guideline value for total phosphorus in drinking water.

Heavy Metals

Heavy metals appear in the municipal solid waste like Batteries, consumer electronics, ceramics, light bulbs, house dust and paint chips, lead foils such as wine bottle closures, used motor oils, plastics, and some inks and glass can all introduce metal contaminants into the solid waste stream. Concentration of heavy metals in a landfill is generally higher at earlier stages because of higher metal solubility as a result of low pH caused by production of organic acids. It is now recognized that most trace elements are readily fixed and accumulate in soils, and because this process is largely irreversible, repeated applications of amounts in excess of plant needs eventually contaminate a soil and may either render it non-productive or the product unusable. Although plants do take up the trace elements, the uptake is normally so small that this alone cannot be expected to reduce appreciably the trace element [15].

CONCLUSIONS

- Leachate sample of Mavallipura landfill has shown high concentration of organic and inorganic constituents. Heavy metals concentration was in trace only indicating that the waste dumped is predominantly municipal waste.
- The leachate is found to have significantly high salinity and alkalinity as reflected in their values for conductivity, TDS, alkalinity and pH. Hence the leachates were considered to contain significant loads of contaminants to pose threat to the underlying ground water aquifer.
- The BOD_5/COD ratio suggested that the landfill leachate is medium aged leachate.
- Based on the different chemical parameters in landfill and surrounding water bodies shows that the effect of leachate is seen in the nearby water bodies.
- There is a tendency of leachate migration to the soil and water resources. This can result in contamination of the soil, surface water and subsurface water resources. The growth of algae in the water bodies is the confirmation of the leachate effect on the water bodies.

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