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Effects of municipal solid waste landfills on soil and groundwater quality

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A B S T R A C T

The percolation of untreated wastewater contaminates the groundwater and alters its physiochemical properties. Leachate is created when solid waste is dumped improperly and haphazardly, and the following percolation of these materials shows a negative effect on groundwater. Population expansion that is out of control, urbanization, industry, and changing living standards give pressure on water sources to satisfy the rate of water use in various areas. As a result, meeting the requirements of more water of higher quality and quantity has become a difficult task for all humans in the modern day. The leachate percolation affects the quality of groundwater and surrounding soil samples in the vicinity of municipal solid waste disposal facility at Pallavaram, Chennai, was examined in the current study. High concentrations of nitrates, chlorides, and sulphates and also total hardness, electrical conductivity and total dissolved solids, were the consequences of dumping activity on groundwater that were most obvious. Groundwater samples taken close to a dumping site showed elevated levels of contaminants as calcium, magnesium, sodium potassium, lead, cadmium, chromium and nickel. A significant amount (range, average±SD) of heavy metals (mg/kg) (Pb: 18.74-82.39, 55.25±21.15; Cd:0.532-2.142, 1.251±0.537; Cr: 12.29-42.19, 29.52±10.89; Ni: 8.527-26.74, 18.71±5.707) present in the soil samples. The study certainly shows that groundwater monitoring should be done regularly at landfills in highly populated places. Furthermore, unless it satisfies certain criteria, groundwater near garbage sites is forbidden to be used for drinking. Wastes should not be dumped randomly in the study areas without effective solid waste management procedures.

Keywords: Municipal solid waste · Landfill · Heavy metal · Soil quality · Groundwater quality

1. Introduction

Due to urbanization, industrialization, economic development and increasing standards of living, there is an exponential increase in the amount of municipal solid garbage generated globally. Production and unskilled management of solid waste release contaminants that have an influence on ecology and public health. In India, the issue of municipal solid waste (MSW) is getting worse and more difficult by the day. India presently produces roughly 70 Mt of MSW annually, and if the current rate of growth continues, by 2030 it is projected to have increased to around 165 Mt, and by 2050 it may have reached about 436 Mt[1]. Human activity inevitably results the generation of solid waste and how that garbage is managed has a strong impact on the local population's and the environmental overall health. Globally, as plastics and electronic goods for consumption spread, people are discarding increasing amounts of debris, and the chemical makeup is more complex than ever. In the present-day concern, our universe is urbanizing and industrializing at an unprecedented rate.

Numerous waste management practises, procedures and technologies offer a range of environmental advantages, including reducing the effects of climate change. The main waste management challenges include integrating the informal waste sector into developing cities, reducing consumption in highly industrialised cities, expanding and standardising solid waste collection and analysis, and effectively managing more complex waste while simultaneously protecting the environment and individuals. In developing countries, solid waste is gravely degrading the environment. Generally in the developing world, incorrect solid waste disposal has a negative influence on the environment.

Wealth, urbanization and population growth are contributing to increase waste output [2,3,4]. Even while distribution of the world's growing population is changing in a more drastic way. The majority of this urbanization is taking place in small to average sized cities within nations of low income [5], which is occurring at an unprecedented rapid rate. Open garbage disposal causes groundwater and/or surrounding soils contaminated with environmental pollutants that are both inorganic and organic. Additionally, it endangers human health by spreading vectors of diseases and exposing nearby residents to the hazardous wastes in the garbage storage [6]. Dioxins and furans [2,7] are the persisting organic pollutants that disperse widely and are causing harm to ecological and human health are among the contaminants released during garbage incineration.

The most major sources of greenhouse gases (GHGs) released by landfills and treatment of disposed waste release methane as breaks down of organic garbage. When a landfill lacks a method for collecting and treating leachate, transmission of the liquid could pose harm to ecosystems and human cultures. Water resources become contaminated when leachate from landfills seeps through the soil and into the groundwater and nearby surface waters. Leachate contains various heavy metals [6, 8], drugs [2] and organic pollutants [9], may get into the water and contaminates severely. They have detrimental effects on public health and penetrate groundwater and the food chains [10]. Municipal solid waste management inefficiencies can have detrimental environmental impacts.

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Emerging contaminants discovered in municipal solid waste leachates in recent years have sparked worries about the contamination of groundwater and surface water [2].The municipal solid waste production increases dramatically through the world by the exponential world population growth of urbanization, socioeconomic development, and rise in living standards [2]. MSW quantities and composition vary depending on socioeconomic, meteorological, and cultural factors. Cities need to enhance their systems for handling waste for different reasons, including health issues, recovery of resources, safeguarding the environment, climate change effects, and the pursuit for modernity. This primary goal of the study is to assess how heavy metal containing municipal waste affects the soil and the groundwater quality, posing a threat to both the ecosystem and human health.

2. Materials and Methods

To evaluate the aim of the study, the current research was designed to analyze the impacts of municipal solid waste materials on the quality of groundwater and soils in the Pallavaram area in Chennai, which is used for a variety of activities, including drinking and cooking. The most urgent issues facing the city at the moment are the collection, transportation, and disposal of generated municipal solid waste. Samples from ground, water were collected from 23 locations, including hand pumps, bore wells, and open wells for evaluation of the groundwater chemistry. Using an electrical conductivity and pH metre, the two parameters were measured on-site. After collection of groundwater and soil samples (n=12) were transferred to the laboratory and initial treatment was provided for the preservation and analysis.

The collected samples were preserved by adding the proper chemicals in the lab to perform the examination of the water quality parameters. Acidification of samples was done with concentrated HNO_3 [11] to achieve pH 2 in preparation for heavy metal analysis. Some physicochemical parameters (pH, EC, TDS, alkalinity, total hardness, Ca^{2+}, Mg^{2+} $SO4^{2-}$, PO_4^{3-} NO_3^-, Cl^-, Na^+, K^+, fluoride F^-, along with Pb, Cd, Cr and Ni) were evaluated for this study. To remove the suspended sediments, water samples were filtered using a 0.45 millipore filter. After digestion, heavy metal solutions were tested by AAS (GBC, Avanta). The groundwater and soil samples were analyzed repeatedly according to the standard methods APHA 2005 [11].

3. Results and Discussion

The quality of groundwater is influenced by the chemical components with various chemical concentrations, which are primarily received from the geological signature of the particular region through groundwater flows and are also impacted by anthropogenic sources. Pollution of groundwater is becoming more likely as a result of both improper waste disposal and the extensive use of potentially hazardous chemicals in both industries and agricultural sectors. Whether from discrete, point sources like the disposal of rubbish, pollution can happen. The issue of managing solid waste has been one of the worst effects of fast urbanisation, especially in aspects of environmental annoyance paired with the health threat and its ramifications.

3.1. Water quality analysis

Leachate from disposal site of waste has been found to contaminate sources of water used for drinking and other household purposes, posing serious concerns to the public health in several studies [12-21]. For instance, Hong *et al*. [21] calculated that between 160 and 180 m^3 of leachates per day were evaporating from waste dumps in Pudong (China) in 2006. An adequately engineered facility for the waste disposal can safeguard public health, protect significant environmental resources, avoid drainage clogs, and stop leachates from migrating to contaminate both surface and groundwater, farmland, animals, and the air from their route of entry in human bodies [22,23]. The values of the groundwater physicochemical parameters are presented in the table 1. pH for the considered samples examined, ranged from 5.73 to 6.95, with mean±SD value of 6.51±0.37. The value of low pH was observed along the study area. The result may be caused by the direct impact of dumping ground of municipal solid waste in the vicinity of the study area. It’s a strong reflection of an acid producing phase during the decomposition of wastes. According to Alloway (1995) [24] the low level of pH is the indicator of leachate undergoing anaerobic or methanogenic phase. The total concentration of water soluble salts is represented by electrical conductivity (EC). There is a significant variation in the electrical conductivity (EC) values among the groundwater samples, of which S7 has the highest value of 2680 (µmhos/cm). An elevated level of EC in the groundwater indicates addition of some pollutants to it. Total Dissolved Solids (TDS) is a measurement of the quantity of dissolved minerals in water that determines whether the water gains suitability for use or not. The values of total dissolved solid (TDS) among the twenty three groundwater samples ranged from 1159 to 1824 mg/l. The quality of groundwater is influenced by the various chemical components.

Leachate causes pollution in the surface soil and groundwater. In this study, the alkalinity of groundwater samples ranged from 172-276 mg/l with a mean±SD value of 218±31.2 mg/l. The hardness is the product of calcium carbonate ($CaCO_3$) and an excess hardness concentration produced by the limestone dissolution deposits that may be present under the research regions. There is a significant variation in the total hardness values (TH) among the groundwater samples, of which S7 has the maximum hardness value of 580 mg/l. The elevated level of calcium (164mg/l) was recorded at the sampling site S7 and the minimum values of calcium 92.6 mg/l and 92.7 mg/l were recorded at sampling site S3 and S20 respectively. The value of magnesium ranged from 52.3-117 mg/l with a mean±SD value of 76.8±19 mg/l. Various disease-carrying vectors, such as flies, rats and mosquitoes are created by the wastes of open dumping sites including organic waste [25-33]. Residents nearby are negatively impacted by the odours from dump sites and their outward look, which

Table 1 Physiochemical parameters of groundwater Samples

	pH	EC	TDS	Alk	TH	Ca^{2+}	Mg^{2+}	Cl^-	NO_3^-	SO_4^{2-}	PO_4^{3-}	Na^+	K^+	F^-	Pb	Cd	Cr	Ni
S1	6.23	2150	1467.6	184	464	98.4	92.5	453	15.3	287	0.124	412	8.652	0.062	0.004	0.005	0.057	0.086
S2	6.54	2010	1259.4	224	432	132	86.4	478	10.3	348	0.085	329	12.34	0.253	0.008	0.007	0.045	0.075
S3	6.47	2440	1476.5	260	276	92.6	58.3	350	12.6	362	0.064	328	10.46	0.464	0.002	0.000	0.008	0.039
S4	5.91	2590	1685.2	266	528	152	112	653	21.9	468	0.031	408	9.356	0.043	0.028	0.014	0.117	0.119
S5	6.72	2430	1683.4	212	432	128	109	574	18.5	358	0.152	326	12.38	0.274	0.000	0.009	0.006	0.048
S6	6.89	1870	1275.8	176	396	152	74.3	619	15.1	275	0.092	338	22.52	0.085	0.005	0.007	0.029	0.031
S7	5.87	2680	1683.4	276	580	164	117	782	23.5	472	0.043	412	15.19	0.143	0.035	0.015	0.122	0.129
S8	6.91	1860	1158.7	248	496	96.1	54.6	542	15.7	253	0.125	298	14.53	0.548	0.000	0.003	0.000	0.008
S9	6.83	2160	1429.1	196	380	120	73.9	256	12.9	326	0.181	386	4.562	0.224	0.004	0.005	0.017	0.054
S10	6.43	1940	1231.5	180	412	96.2	56.7	218	20.4	324	0.074	356	19.28	0.415	0.000	0.007	0.094	0.007
S11	6.52	2130	1625.8	236	296	112	64.8	194	21.2	92.8	0.124	341	14.72	0.129	0.009	0.000	0.000	0.039
S12	6.77	2340	1498.7	240	384	124	81.5	208	15.3	235	0.068	324	15.34	0.265	0.000	0.000	0.000	0.000
S13	6.37	2270	1608.2	216	456	144	53.7	237	20.8	381	0.027	336	16.81	0.526	0.028	0.000	0.003	0.005
S14	6.29	2220	1418.9	208	292	132	74.2	386	14.7	408	0.142	386	8.915	0.362	0.006	0.012	0.075	0.009
S15	6.72	2390	1724.5	184	428	156	69.1	410	18.6	396	0.069	362	17.47	0.426	0.000	0.006	0.085	0.035
S16	6.59	2450	1517.8	248	460	128	68.3	253	16.1	364	0.128	281	20.16	0.072	0.000	0.002	0.026	0.007
S17	5.86	2570	1824.1	252	292	134	58.4	336	9.25	382	0.037	352	12.26	0.164	0.027	0.009	0.007	0.006
S18	6.71	2290	1496.2	192	412	121	76.8	452	12.4	94.6	0.093	312	18.91	0.096	0.003	0.000	0.000	0.000
S19	6.63	2050	1297.4	232	292	132	92.3	415	14.2	392	0.076	359	22.48	0.528	0.001	0.003	0.019	0.114
S20	6.95	1820	1175.8	172	436	92.7	52.3	526	8.45	86.7	0.127	296	8.627	0.149	0.000	0.000	0.000	0.000
S21	5.73	2580	1788.4	220	516	146	64.9	436	17.4	309	0.094	406	16.42	0.084	0.008	0.002	0.019	0.027
S22	6.91	2360	1578.6	204	456	142	91.2	398	9.55	296	0.072	296	10.37	0.524	0.001	0.005	0.094	0.053
S23	6.83	2510	1657.2	188	460	128	84.6	489	10.6	338	0.128	358	12.49	0.146	0.002	0.004	0.037	0.009
Min	5.73	1820	1159	172	276	92.6	52.3	194	8.45	86.7	0.027	281	4.562	0.043	0.000	0.000	0.000	0.000
Max	6.95	2680	1824	276	580	164	117	782	23.5	472	0.181	412	22.5	0.548	0.035	0.015	0.122	0.129
Ave	6.51	2266	1503	218	416	127	76.8	420	15.4	315	0.094	348	14.1	0.260	0.007	0.005	0.037	0.039
SD	0.37	255	197	31.2	82.3	21.2	19.0	154	4.34	106	0.041	39.5	4.74	0.175	0.011	0.005	0.041	0.040

Units: mg/l; except pH and EC (μmhos/cm) endangers their health, threatens their way of life, and lowers the value of their homes [34-39].

Human activities like the use of fertiliser in agricultural practises, the discharge of wastewater from the tannery sector, and seawater intrusion are all leading causes of chloride in water. Beneficial organisms like fish and other invertebrates are affected by some chemical constituents [40] also. The values of chloride content (Cl) among the 23 groundwater samples ranged from 194 to 782 mg/l, with a mean±SD value of 420±154mg/l. The research work showed that the municipal solid waste dumping ground has a significant impact on groundwater chloride concentration. An overabundance of chlorides in a water sample is typically used as a measure of pollution and as a marker for contaminated groundwater [41]. Human activities including the use of agricultural fertilisers and pesticides, and also human and animal wastes, are leading causes of nitrate in water. Nitrate concentration of groundwater samples in the studied area ranged from 8.45 to 23.5mg/l. The maximum value of nitrate was found at site S7 and the minimum value was found at S20. The study revealed that the municipal solid waste dumping ground has a significant impact on groundwater nitrate concentration. The concentration of sulphate in the studied area was in the ranged between 86.7 to 472mg/l. Ammonium sulphate, chrome sulphates and sodium sulphate are among the main chemicals utilised during the tanning process and are a potential source of sulphate (SO_4^{2-}) from tanneries. Contamination of groundwater may have resulted via leaching from the leachate into the ground.

Worldwide, landfills are still highly prevalent. Since it is the easiest technique and the most cost-effective way to store these waste types in different nations, especially the developing countries, it has been the main method of eliminating municipal solid wastes in recent decades [42]. By leaching and infiltrating through the ground, the leachate creates an organic, heavy metal and bacterial contamination of soils, water at the surface, and ground water [43].

The leachate carries an important pollution load that is primarily composed of organic matter, heavy metals and an essential community of pathogenic bacteria. Potential dangers to human health can result from the mixing of hazardous industrial waste with municipal garbage. The concentration of sodium in the study area had the maximum value of 412 mg/l at both S1 and S7 and the minimum value of 281 mg/l at S16. Among the 23 groundwater samples, the value of potassium was in the range of 4.562 to 22.5mg/l with a mean±SD value of 14.1±4.74mg/l. The fluoride concentration in the groundwater samples depict different values, in which S8 had the highest value of 0.548 mg/l , followed by S19 with the value of 0.528 mg/l, while the lowest value of 0.043mg/l was recorded for the S4 groundwater sample.

There is the specific risk of heavy metals concentration magnified from the tolerable range in the food chain. Although it is well known that rodents and insects can transmit a variety of pathogenic agents (such as cholera, yellow fever, plague, typhoid fever, salmonellosis, various parasitic organisms, and amoebic and bacillary dysentery), it is frequently challenging to pinpoint how such transmission affects a particular population. One of the most significant contaminants in landfill leachate is heavy metals [44]. There is significant difference in the concentration of lead (Pb) among the groundwater samples, of which S7 has the highest value of 0.035mg/l. One of the significant pollutants that enter the environment from several sources, such as wastewater and solid waste, is heavy metals. The cadmium concentration of groundwater samples ranged from 0.00-0.015mg/l. The maximum concentration was observed at the site S7. There is significant variation in the chromium (Cr) concentration among the twenty three groundwater samples, of which S7 showed the highest value of 0.122mg/l, followed by S4 0.117 mg/l. As they go up the food chain, these contaminants can affect humans and cause a number of ailments. The values of nickel concentration (Ni) among the 23 groundwater samples ranged from 0.00 to 0.129 mg/l, with a mean±SD value of 0.039±0.04mg/l.

The abundance of heavy metals like Pb, Cd, Cr, and Ni in the groundwater samples will cause contamination of soil and underground water resources. Therefore, there is a chance of soil and groundwater pollution in the study areas affected by municipal solid waste.

3.2. Soil quality analysis

Heavy metal concentrations (mg/kg) in soil samples are presented in the table 2. The human body can absorb lead through food (65%), drink (20%), and air (15%). The concentration of lead (Pb) among the 12 soil samples ranged from 18.74 to 82.39 mg/l, with a mean±SD value of 55.25±21.15mg/l. There is significant variation in the values of cadmium (Cd) among the 12 soil samples, of which S4 had the highest value of 2.142mg/l, followed by S11 (2.119 mg/l). The extremely hazardous element cadmium attacks the body's cardiovascular, gastrointestinal, neurological and respiratory systems. Several Cadmium compounds are thought to be carcinogenic [45] as well. The chromium concentration in the soil samples depict different values, in which S4 had the highest value of 42.19 mg/l , followed by S12 with the value of 39.62 mg/l, while the lowest value of 12.29mg/l was recorded for the S9 soil sample. Nickel has been regarded as a trace element that is crucial for both human and animal health [46]. The concentration of nickel (Ni) among the 12 solid samples ranged from 8.527 to 26.74mg/l, with a mean±SD value of 18.71±5.707mg/l. Nickel has been regarded as a trace element that is essential to both human and animal health. It functions as a regulatory component for different enzyme systems and is connected to DNA and RNA molecules in living systems [47]. Many soils around industry and landfills are contaminated, as per the findings and reports of several research that have gone through different issues [48,49]. Effective solid waste management (SWM) reduces negative effects on the environment and human health, conserves resources, and enhances city livability. However, unsustainable SWM practises have a detrimental effect on the general population and environmental sustainability. Agriculture productivity will decline as heavy metals enter into the food chain. As a result of high metal contamination

Table 2 Heavy metal concentration (mg/kg) in soil samples

	Pb	Cd	Cr	Ni
S1	26.35	1.268	36.58	21.58
S2	34.51	1.493	37.56	18.67
S3	56.43	0.532	29.41	19.72
S4	82.39	2.142	42.19	21.36
S5	49.27	0.815	23.32	26.74
S6	65.47	0.646	38.56	9.66
S7	63.12	1.016	37.42	24.19
S8	42.56	0.927	14.62	15.28
S9	18.74	1.027	12.29	8.527
S10	68.35	1.243	28.12	15.41
S11	81.26	2.119	14.55	24.96
S12	74.58	1.786	39.62	18.39
Min	18.74	0.532	12.29	8.527
Max	82.39	2.142	42.19	26.74
Ave	55.25	1.251	29.52	18.71
SD	21.15	0.537	10.89	5.707

in soil, there will be harmful health effects [50] on plants. Inadequate SWM is one of the main issues impacting environmental quality and cities' sustainable growth, and it is linked to poor public health. A high concentration of heavy metals in the soil samples indicates addition of some pollutants to it from the dumping ground of municipal solid waste. Therefore, the transfer of various pollutants, including heavy metals, to the soil resources near the waste dumping station is a serious environmental concern. These heavy metals have the potential to have a negative impact on the ecology of the soil, the quality of agricultural output or products, the quality of ground water, and ultimately the health of all living organisms along the food chain.

4. Conclusion

There is a huge pool of information regarding the spectrum of heavy metal levels in soil and groundwater across the study area. Groundwater quality around landfills deteriorates due to high concentrations of nitrates, sulphates, chlorides, total hardness, total dissolved solids and electrical conductivity. Practically all of the physicochemical characteristics studied for water quality showed that the drinking water is contaminated. Therefore, it is best to avoid using water from such bore wells. Due to drinking water pollution, those who depend on this water are frequently at risk for health problems. As a result, urgent action is needed to improve the quality of drinking water. Environmental impact studies (EIA) and national and international standards should be used to design, site, and operate landfills. The presence of high level of heavy metals like Pb, Cd, Cr, and Ni in the studied stations is due to the presence of solid residues that are the origin of these metals. The possibility exists that metals could enter the food chain as an outcome of irrigation of agricultural vegetation with water under the effect of groundwater.

Conflict of interest

The author declares that there is no conflict of interest in this manuscript.

Data availability

The author confirms that all data collected or analyzed during this study are included in this published article.

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