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Effects of open dumping site on surrounding air, soil, and water: a case study of Biratnagar metropolitan city

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Abstract

Managing solid waste is one of the emerging challenges in urban areas, and open dumping and burning are common practices, mostly in developing countries like Nepal. Which affects the overall surroundings. The study investigated the effects of open dumping and burning in nearby air, soil, and river water at the dumping site of Biratnagar metropolitan city. Three air samples were taken at the center, 100m upstream and downstream, in the direction of wind flow to study the impact on air. Soil samples were taken at 10m from the dumping site center, at 25m from the first sample, and at 60m from the second sample, and the water samples were taken at leachate and 100 m upstream and downstream to the leachate. Soil and water were subjected to physiochemical, heavy metals, and microbes tests, whereas PM 2.5 and 10 were tested for air quality. The results showed that the air from upstream carries particulate matter from the dumping site to downstream. Similarly, it is found that the quality of water at leachate and downstream is degraded compared to upstream. The soil quality has been degraded due to the harmful and toxic material of the dumping site. Thus, this study shows that open dumping and burning have affected the nearby air, water, and soil.

Keywords
Municipal solid waste, Dumping site, Effects, Soil, Air, Water, Biratnagar Metropolitan City.

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1 Introduction

With the rise in urbanization, the urban population and consumption of materials are increasing, which has increased in waste generation [1]. The urban waste is called municipal solid waste (MSW), which contains waste mostly from households, public spaces, and institutions [2]. The management of such waste is a complex issue for the municipality. Due to proper knowledge and resources, most of the municipalities in Nepal collect, transport, dump, and burn the waste [3]. Most municipalities in Nepal dump the MSW far from the core areas of the cities, either in the forest or near the river, and burn the waste. This open dumping and burning practice has deteriorated the surrounding environment, especially the air, water, and soil, emitting harmful substances and posing severe risks to overall biodiversity, including human health [4].

Investigating the risk associated with such poor practices of SWM management is necessary to understand the consequences and be aware of the related to be aware of the related stakeholders. Several studies in Nepal and other developing countries have assessed the impacts of open dumping on nearby environments. Khanal et al. 2021 [5] analyzed leachate discharge from the Pokhara landfill site and found significant effects on the Seti River's water quality. A study was carried out by Shrestha et al. 2015 [6] and evaluated the water quality of the Kolpu River near the Sisdol landfill area in the district of Nuwakot. Six water samples and leachate were taken from upstream to downstream of the river, and their physical and chemical characteristics were examined. The study showed that leachate was highly contaminated, with the highest physicochemical characteristics. The river's water was unhealthy for aquatic ecosystems and animal drinking.

While several studies have analyzed the impacts of open dumping in Nepal, there remains a gap in Biratnagar metropolitan city's dumping site. No such research has been reported that has investigated the air, soil, and water pollution arising from the dumping and burning of MSW in Biratnagar metropolitan city's dumping site. Given Biratnagar's large population, understanding the effects of such poor practices is vital, and the study's findings could help compel the local government to establish waste management facilities and make the public aware.

2 Research Methodology

2.1 Study area

The study area is Biratnagar Metropolitan City (BMC)'s dumping site (Figure 1). BMC is the capital city of Koshi province and has a population of 243,927, 56,919 households, and a population density of 3,168 per km2. The city transports the MSW to the dumping site and openly burns it, which has degraded the surrounding environment. The dumping site is on the bank of the Keshaliya River and is roughly 0.01 km^2 in area.

2.2 Sampling Method

In this study, nine points are chosen, three for each, for the investigation (Figure 2). The air test (PM 2.5 and PM10) was conducted using equipment named open Seneca, at a height of 1.5m from ground level to indicate the breathing zone. It helps to expose significant human health risks that impact communities near dump sites. The first sampling point was taken as a center point (AT-0) (26°27'5.04" N, 87°14'47.98" E) at the dumpsite based on prevailing wind direction and the remaining two points were taken upstream (AT-1) (26°27'4.79" N, 87°14'51.4" E) and downstream (AT-2) (26°27'5.47" N, 87°14'44.77" E) of the wind direction at 100m each from the reference point to assess particulate transport from the site. Three pieces of equipment were used simultaneously, being held in position for 2 hours to obtain reliable data. The parameters were then evaluated from each testing point and were averaged to pull out the graph of the average value.

For the water sample, we took three sample stations; one is the leachate outgo point (SW-0) (26°27'6.60" N, 87 14'47.70" E), and the other two are 100m upstream (SW-1) (26°27'10.11" N, 87 14'49.35" E) and downstream (SW-2) (26°27'1.7" N, 87 14'43.6" E) from the leachate outgoing point to analyzed the water quality impact on different conditions and determine the effect of surface water bodies. The sampling bottles and mineral water are cleaned properly with distilled water. We had chosen the sample station with a laminar flow and running water area. Then sampling is sent to the Nepal Batawaraniya Sewa Kendra, Biratnagar, for testing. Total Hardness, Sulphate, Nitrate, Nitrite, Ammonia, Magnesium, Calcium, Chromium, Nickel, Lead, Zinc, Copper, Cadmium, Manganese, and Cobalt tests were conducted. Water testing includes physicochemical properties, nutrients, organic matter, and heavy metals that elevate due to the leaching of dump waste, affecting drinkability and ecosystem health.

In this study, we chose the right-hand side of the landfill area because the soil on the left side is siltier and dryer. The surrounding area is cultivated with cash crops like sugarcane, cucumber, etc. We took the center point with the help of Google Earth software; the first sample (SS-0) (26°27'4.3" N, 87 14'49" E) is approximately 10 m distance from the center of the landfill for the analysis of most impacted soil. The second sample (SS-1) (26°27'3.4" N, 87 14'48.2" E) is taken approximately 25m from the first sample. The last sample (SS-2) (26°27'1.5" N, 87 14'46.4" E) is taken approximately 60m from sample second with varying degrees of impact for testing the contamination gradients in the surroundings. We used a helical type of auger as a sampling instrument. It consists of a head, about 1 m long rod, tee pieces, and a handle. With the help of an auger, we bore holes to the desired sampling depth and the core is then withdrawn, and a sample is collected. We took around 1 kg of soil samples from each station in a plastic bag. For testing parameters, such as p^H, Electrical Conductivity, Coliform, Moisture, Total Hardness, Chloride, Sulphate, Nitrate, Ammonia, Magnesium, Calcium, Manganese, Chromium, Nickel, Iron, Lead, Zinc, Cadmium, Total Coliform, E-Coli, TOC, samples were sent to Nepal Batawaraniya Sewa Kendra, Biratnagar. These physicochemical parameters, heavy metals, and microbes are tested in soil samples to analyze nutrients, salinization, toxicity levels, and pathogenic contamination associated with leakage from the accumulated waste.

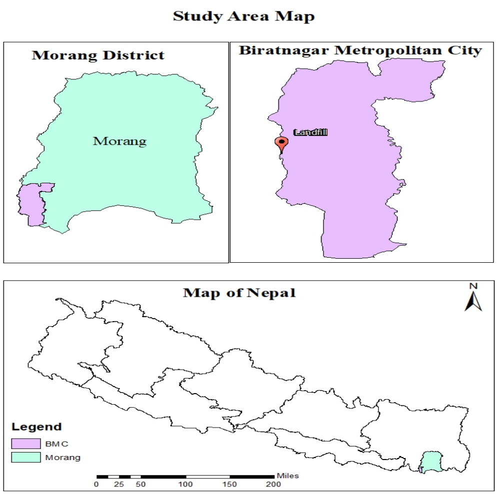

Figure 1: Map of Nepal showing the study area, the dumping site (26°27'5.04" N, 87°14'47.98" E) of Biratnagar metropolitan city, located near the Keshalya river.

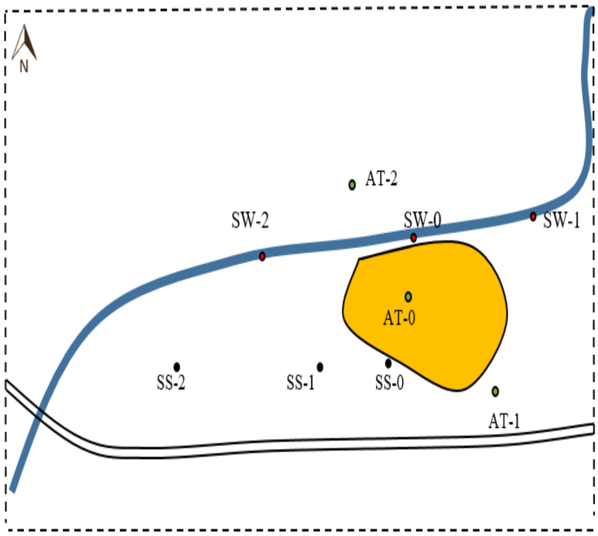

Figure 2: Map showing air, soil, and water sampling points. AT: air test, SW: surface water, and SS: soil sample.

3 Results and Discussion

3.1 Impacts of Open Dumping on Air Quality

Based on the average values of air tests obtained during the study, the center point had the highest concentration of PM2.5 (2,428.443 µg/m^3) and PM10 (2,689.667 µg/m^3) (Figure 3). The downstream particulate matter concentration was higher than the upstream, showing the transport from the dumping site to the downstream. The central point was on the dumping site, where the movement of waste collecting vehicles and dust generated during the unloading of the wastes, and open burning of the wastes, could be the possible reason for higher concentration levels.

The PM2.5 and PM10 at the center and downstream points were far higher than the safe limits. The transfer of these particles can easily enter the human respiratory system and affect our lungs, heart, and liver, and it is even responsible for reducing visibility. Waste collectors and disposal personnel were seen working without using protective equipment, such as masks, gloves, etc., with their bare hands. This directly harms the health of the workers. The nearby settlements also suffer a lot from this pollution. Exposure to higher concentration particulate matter may lead to cardiovascular death and various respiratory symptoms like regular cough and breathlessness. [7].

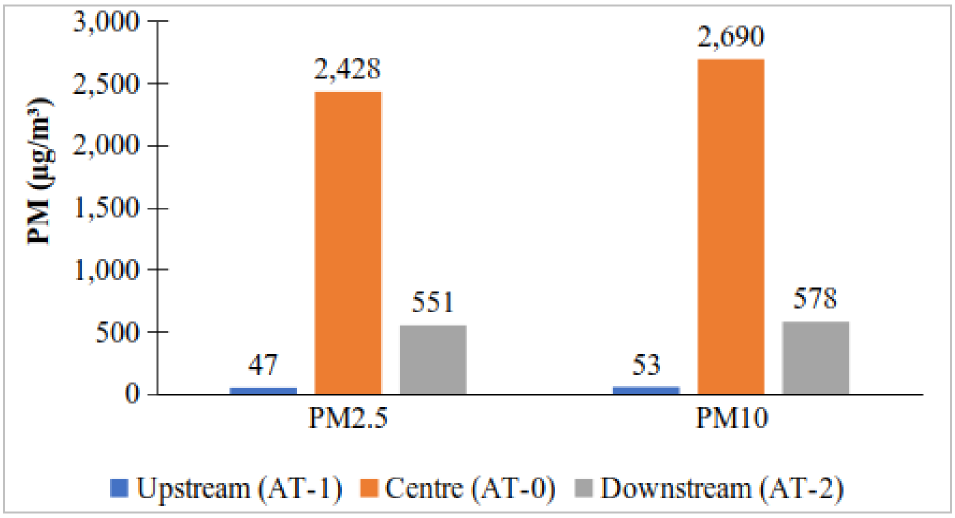

Figure 3: Variation of particulate matter (PM2.5 and PM10) in different air testing points.

The high PM2.5 and PM10 levels measured at the landfill site and downstream locations greatly exceeded WHO guidelines. This suggests significant health risks for site workers and nearby communities from particulate inhalation. Open waste burning produces dangerous fine particulates that can penetrate the lungs.

3.2 Impacts of open dumping on soil quality

3.2.1 Physio-chemical parameters of soil samples

The highest values of moisture (22.76 %), conductivity (1431 µS/cm), total hardness (2 mg/L), chloride (8.2 mg/L), sulphide (10 mg/100gm), calcium (1.69 mg/L), and total organic carbon (0.96 %) were found to be in soil samples taken near the landfill site (SS-0). The highest values of pH (7.76) and Magnesium (0.4 mg/L) were found in the 3rd sample of the soil (SS-2), while nitrate (<0.05 mg/100gm) and temperature (25.1^0 C) were found to be the same for all samples. Reciprocally, SS-0 had the lowest pH value (7.59), 2nd soil sample (SS-1) had the lowest values of conductivity (53.5 S/cm), Sulphide (2.8 mg100gm), Magnesium (0.1 mg/L) and Total organic carbon (0.82 %), SS-2 had the lowest values of chloride (0.65 mg/L), calcium (0.6 mg/L) and moisture (8.03 %), and total hardness (1 mg/L) was lowest on both SS-1 and SS-2. Obtained values of Conductivity (for SS-0), Total Hardness, Chloride, Magnesium, Calcium, and total organic carbon were above the reference limit, whereas conductivity (for SS-1, SS-2), sulfide, and nitrate had values lower than the reference limit, and values of pH and temperature were within the limit.

The pH value was found to be in increasing order (Table 1) from the nearest point towards the farthest sample point, but the values did not vary much with each other and were within the guided limit. The reason behind the highest pH value at SS-2 (at the agricultural land/cropland) may be due to the use of fertilizers like nitrogen and sulfur, soil minerals removal during crop harvesting, or loss of organic matter [8]. If the soil is too alkaline, plant productivity is affected as it causes nutrient imbalances, reduced nutrient uptake, altered soil microbial activity, and plant-specific sensitivity.

Interestingly, the temperature of the soil samples at all the locations was found to be the same, 25 ^{0}C. An electrometric method was deployed to measure it. A 0 to 30 °C temperature range is often needed for seed germination [9]. Temperature ranges are ideal for growth, and maximum yields during the day or night vary depending on the crop. Crop enzyme activity and chemical reaction rates increase with temperature [10]. However, abnormally high temperatures restrict crops' ability to grow and develop.

The electrical conductivity was the highest at SS-0 and lowest at SS-1 (Table 1). The decomposition of organic waste and the addition of minerals and salts from the waste dumping site to the nearest sampling point [11] is supposed to be the reason behind this. In addition, conductivity at SS-0 was found to be above the reference limit, indicating the availability of a high amount of calcium cations.

The moisture content value was found to be in reducing order from SS-0 to SS-2 (Table 1). Leakage from liquid waste and decay of organic waste could have contributed to the highest moisture content in the first sample (SS-0). The total hardness of the soil was found to be the highest at the nearest soil sample SS-0 (Table 1). The study [12] suggests that soil hardness is affected by soil moisture, as he hardness is an indicator of soil compaction. Hard or compacted soil creates suffocation for the plant to survive as the roots cannot take the water and nutrients required. The chloride level is found to be the highest at SS-0 and lowest at SS-2 (Table 1). Cl anion is challenging to be absorbed by soil particles in neutral and alkaline soil [13]. This could be the reason for the lowest chloride measurement at SS-2, implying it is the most alkaline among the three samples. Although Chloride is an essential nutrient for crops, its excessive presence can cause problems like extreme leaf separation, reduced crop growth, curling leaf margins, etc.

The results showed that sulfide was the highest at SS-0 and lowest at SS-1 (Table 1), yet the results are below the limits.

In the case of Nitrate, all the samples were reported to have an amount less than 0.05 mg/100 gm. This low presence of nitrate may be because, like other particles of soil that are negatively charged, it leaches into the underground. This also implies the absence of decomposed plant residues and animal compost.

Furthermore, magnesium is maximum at the farthest soil sample (SS-2) (Table 1). Since all three values of magnesium amount exceed the reference limit it is indicated that there is the possibility of prohibition to plant growth [14] even more calcium does.

The result shows that calcium dropped as we approached SS-2 from SS-0 (Table 1). Municipal solid wastes like phosphate fertilizers, lime, and gypsum are the sources of calcium, and the figure below indicates the transfer of calcium from SS-0 to SS-2. Ca is essential to soil and plant health, but the values are above the considered limit, and too much calcium affects the plants's mineral composition and ionic balance [14].

Table 1: Physiochemical parameters of soil samples.

S.N	Parameters	Units	Results			Method	Reference limit
			SS-0	SS-1	SS-2		
1	pH	-	7.59	7.63	7.76	pH Metric	6-9
2	Temperature	°C	25.1	25.1	25.1	Electrometric	<40
3	Conductivity	μS/cm	1431	53.5	64.9	Electrometric	1000
4	Moisture	%	22.8	9.2	8.03	Oven	Not Stated
5	Total Hardness ($CaCO_3$)	mg/L	2	1	1	Trimetric	0.2
6	Chloride	mg/L	8.24	0.7	0.65	Trimetric	0.25
7	Sulphide	mg/100gm	10	2.8	6.79	Trimetric	250
8	Nitrate (NO_3^-)	mg/100gm	<0.05	<0.05	<0.05	UV-Spectrophotometer	200
9	Magnesium	mg/L	0.3	0.1	0.4	Trimetric	0.05
10	Calcium	mg/L	1.69	0.9	0.6	Trimetric	0.15
11	Total Organic Carbon	%	0.96	0.82	0.91	Walkey-Black	0.2

The total organic carbon was the highest at SS-0 and lowest at SS-1 (Table 1). The highest value at SS-0 might be due to the burning of waste materials on the landfill, as this point is near the landfill [15]. Higher soil organic carbon means greater soil structure and a stable carbon cycle, enhancing crop productivity. Based on Figure 2, SS-2, which lies on agricultural land, shows low possible productivity as compared to other points [16]. Deteriorated soil quality with heavy metal accumulations was observed within 10-60m of the dumping site. Lead, iron and zinc exceeded permissible limits for agricultural soil. This indicates likely contamination of nearby crops, presenting another exposure route to residents. Remediation of affected farm areas should be undertaken to restrict absorption in the food chain.

3.2.2 Heavy Metals Analysis of Soil Samples

For heavy metals analysis of soil samples, it was found that SS-0 possessed the highest values of Pb (34.63 mg/100gm) and Zn (8.08 mg/100gm), SS-1 possessed the highest values of Fe (332.13 mg/100gm) and Ni (0.28 mg/100gm) while Cd value was identical for all soil samples. Similarly, SS-2 had all the lowest values of Fe (296.87 mg/100gm), Pb (21.28 mg/100gm), Zn (2.53 mg/100gm), and Ni (0.25 mg/100gm). Obtained values of Fe and Pb exceeded the reference limit, values of Zn and Cd were below the reference limit, and Ni value was within the limit.

The result showed the iron variations and provided a maximum value of iron at SS-1 and a minimum at SS-2 (Table 2). As suggested by the study [17], the concentration of iron elements is low for alkaline soil solution, and the same might be the reason for the lowest value at SS-2, which has a peak pH among the three samples. However, the iron level exceeds the prescribed limit at all points. Although iron is an essential nutrient contributing to the metabolism process, it can be toxic in an excessive amount by generating Fe-catalyzed reactive oxygen species [18].

Table 2: Heavy Metals Analysis of Soil Samples.

S.N.	Parameters	Units	Results			Method	Reference limit
			SS-0	SS-1	SS-2		
1	Iron (Fe)	mg/100gm	319.8	332.1	296.8	AAS	15
2	Lead (Pb)	mg/100gm	34.63	30.83	21.28	AAS	10
3	Zinc (Zn)	mg/100gm	8.08	3.14	2.53	AAS	60
4	Cadmium (Cd)	mg/100gm	<0.003	<0.003	<0.003	AAS	0.1
5	Nickel (Ni)	mg/100gm	0.26	0.28	0.25	AAS	<10

Table 2 has shown the descending lead level toward SS-2, which is more than the prescribed limit for all samples. The presence of lead-containing municipal solid wastes in dumping sites like batteries, paints, and plastic and their leakage into the soil may have caused a peak value of the lead-heavy metal at the nearest point. Excess lead hinders the photosynthesis process, disturbs the water and mineral uptake, and affects the structure and growth of plants [19]. Zinc levels decreased from SS-0 to SS-2 (Table 2). The highest value of zinc at the point closest to the site might be due to the waste, slag discharge, and the presence of fertilizers and wood preservatives containing zinc on the dumping site. The maximum amount of zinc is toxic and may threaten the environment and ecosystem [20].

The highest quantity of nickel is found at SS-1 and the lowest at SS-2 (Table 2). However, the nickel quantities are not contrasting and are within the limit, indicating the acceptable state of one of the essential elements.

3.2.3 Impacts of open dumping on water quality

3.3 Physio-chemical Parameters of Water Samples

From the results obtained for the physio-chemical parameters test, a sample from leachate point (SS-0) had the highest values of pH (7.9), Conductivity (6640 µS/cm), total suspended solids (TSS) (1270 mg/L), total dissolved solids (TDS) (3340 mg/L),chemical oxygen demand (COD) (1860 ppm), biological oxygen demand (BOD) (228 ppm) and Calcium (61.72 mg/L). The upstream sample (SS-1) had the highest value of Magnesium (15.56 mg/L).downstream sample (SS-2) had the highest values of Total Hardness (450 mg/L), Sulphate (44 mg/L), and Ammonia (3.04 mg/L) while both, Nitrate and Nitrite Nitrogen had values of <0.05 mg/L for all water samples.

On the other hand, SW-0 had the lowest value of Total Hardness (207 mg/L), SW-1 had the lowest values of TSS (104 mg/L), COD (72 ppm), BOD (36.6 ppm), Ammonia (0.17 mg/L) and Sulphate (33 mg/L) and SW-2 had the lowest values of pH (7.5), Conductivity (502 µS/cm), TDS (256 mg/L), Calcium (21.64 mg/L) and Magnesium (8.75 mg/L).

The obtained values of conductivity (for SW-0), TSS (for SW-0, SW-2), TDS (for SW-0), COD, BOD, Total hardness, and Ammonia were recorded above the reference limit. Values of Conductivity (for SW-1, SW-2), TSS (for SW-1), TDS (for SW-1, SW-2), Nitrate, Nitrite Nitrogen, Sulphate, Calcium, and Magnesium were recorded below the reference limit, and pH value was within the limit followed.

Table 3 indicates pH variation in different sampling points. It is maximum at leachate, which might be due to the burning of wood and agricultural waste resulting in ash and slag, which increase the pH value [21]. However, the observed value is slightly alkaline and within the considered limit.

Table 3: Physio-chemical Parameters of Water Samples.

S.N.	Parameters	Unit	Methods	Samples SW-0	SW-1	SW-2	WHO limits
1	pH	-	pH meter	7.9	7.7	7.5	6.5-8.5
2	Conductivity	µS/cm	Electrical Conductivity meter	6640	520	502	1400
3	TSS	mg/L	APHA	1270	104	262	250
4	TDS	mg/L	TDS meter	3340	257	256	500
5	COD	ppm	APHA	1860	72	152	<5
6	BOD	ppm	APHA	228	36.6	40.8	<5
7	Total Hardness (CaCO3)	mg/L	APHA-2340	207	214	450	120-170
8	Ammonia (NH4N)	mg/L	APHA-4500	0.19	0.17	3.04	0.001
9	Nitrate (NO3-)	mg/L	APHA-4500	<0.05	<0.05	<0.05	45

Furthermore, the descending conductivity level is found (Table 3). A high quantity of inorganic dissolved solids like anions of sulphate and cations of iron on leachate could be the reason for the peak conductivity value on the leachate [22]. High conductivity means the existence of unwanted pollutant levels and can cause deterioration and harm to animals, humans, and plants if consumed for a long time.

The amount of TSS is lowest upstream, followed by downstream, and then leachate. This could be due to the accumulation of solid waste and leachate following from the dumping site towards downstream. TSS is the carrier of toxic heavy metals and other pollutants, resulting in water impurity and turbidity, making plants difficult to grow [22].

TDS is proportionally related to the conductivity of the water, which can also be seen in Table 3 at top [21]In conclusion, high TDS is an indicator of toxic minerals that are harmful to animal and plant health. TDS is proportionally related to the conductivity of the water, as shown in Table 3. In conclusion, high TDS is an indicator of toxic minerals that are harmful to animal and plant health [23].

COD is highest at leachate, followed by downstream (Table 3). It is observed that COD has risen with the rise in organic matter content, and leachate water flowing from landfills may have raised the COD level downstream. High COD is an indicator of the high demand for oxygen with low dissolved oxygen [24]. Similarly, in Table 3, BOD is shown to be proportionally related to COD. This shows less oxygen is available for aquatic life at the leachate point [25].

The total hardness variation of water samples is minimum at upstream and highest at leachate. Water's hardness is mainly due to the presence of calcium and magnesium rather than iron and other heavy metals dissolved in water [24]. However, the obtained result does not match the data on calcium and magnesium, which could be due to sampling error.

The amount of ammonia in water samples is in diminishing order form from SS-0 to SS-2 (Table 3). This condition is in constant order with the pH value [22]. A high ammonia level is unsuitable for aquatic life; however, it can lead to eutrophication and heavy plant growth in water. The amount of nitrate was found to be below 0.05 mg/L in all the sample cases. This finding suggests that nitrate is negatively charged, like other soil particles, and is underground. This supports the low availability of decomposed plant residues and animal remains.

The leachate and downstream water samples displayed excess iron, manganese, and other indices above drinking water standards, negatively impacting aquatic habitats. Such leachate discharge could have caused algal blooms and biodiversity loss downstream.

3.4 Heavy Metals Analysis of Water Samples

Heavy metals analysis for water samples showed SW-0 had the highest values of Fe (11.67 mg/L), Mn (0.79 mg/L), Zn (2.18 mg/L), and Pb (0.13 mg/L) (Table 4). T-Cr, Ni,and Co were found to be lower than <0.05 mg/L and Cd <0.003 mg/L for all water samples. On the other hand, SW-2 had the lowest value of Fe (0.45 mg/L) while SW-1 and SW-2 had the lowest value of <0.005 mg/L for Zn, T-Cr, Mn, Ni, and the lowest value of <0.001 mg/L for Pb and Cd. Obtained values of Fe, Mn (for SW-0), Zn (for SW-0), and Pb (for SW-0) were recorded above the reference limit, and values of Mn (for SW-1, SW-2), Zn (for SW-1, SW-2), Pb (for SW-1, SW-2), T-Cr, Cd, Co were recorded to be below reference limit. Leakage of rusted ferrous municipal waste, like construction waste, furniture, automobiles, etc., could be the reason for the leachate's high iron level. An excessive amount of iron may take the place of other essential nutrients and thus may lead to nutrient deficiency [26].

Table 4: Heavy Metals Analysis of Water Samples using APHA-3111B method.

SN	Parameters	Units	Results			WHO limits
			SW-0	SW-1	SW-2	
1	Iron (Fe)	mg/L	11.67	0.7	0.45	0.3
2	Manganese (Mn)	mg/L	0.79	<0.05	<0.05	0.1
3	Zinc (Zn)	mg/L	2.18	<0.05	<0.05	0.05
4	Lead (Pb)	mg/L	0.13	<0.01	<0.01	0.05
5	T-Chromium (T-Cr)	mg/L	<0.05	<0.05	<0.05	0.05
6	Cadmium (Cd)	mg/L	<0.003	<0.003	<0.003	0.003
7	Nickel (Ni)	mg/L	<0.05	<0.05	<0.05	0.02
8	Cobalt (Co)	mg/L	<0.05	<0.05	<0.05	0.11

The positive fact is that the Manganese (Mn) amount is below the WHO limit (i.e.) in all cases. This will support smooth photosynthesis, chlorophyll production, carotene synthesis, ascorbic acid, and riboflavin. The leachate sample contained the highest zinc (above WHO's recommended limit). Furthermore, excessive lead, a toxic heavy metal, should be controlled before it enters the water bodies. The consumption of water containing lead causes toxic effects on humans and livestock. The amounts of T-chromium, Cadmium (Cd), Nickel (Ni), and Cobalt (Co) were found to be much below the WHO's limit (Table 4). This shows that their respective contributions to environmental pollution are very low, which is preferable.

4 Conclusion and Recommendation

The study concludes that open dumping near rivers and burning practices have impacted the surrounding area. Pollution from the dumping site is transported to the nearby air, water, and soil, posing severe risks to overall biodiversity and human health. The surrounding settlements are suffering due to poor waste management practices. Further research is recommended, considering more samples in various seasons, which helps to provide concrete information regarding the impacts of open dumping and burning on the surrounding environment.

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