EVALUATION OF SURFACE WATER CONTAMINATION BY LEACHATE FROM UNCONTROLLED LANDFILLS: A CASE STUDY OF YENAGOA CENTRAL WASTE DUMP, NIGERIA.

ABSTRACT

Recently, surface water pollution has generated grave concerns because of anthropogenic activities including inadequate management of waste. Therefore, this study is concerned with the evaluation of surface water contamination by leachate from uncontrolled landfill in Yenagoa Bayelsa State, Nigeria. Three surface water samples were taken from a stream adjacent to an uncontrolled landfill and analyzed. The Downstream point (SW 1) and Upstream points (SW 3) were taken 50 meters from the southernmost and northernmost ends of the landfill, while the Central point (SW 2) was also taken 50 meters from the central edge of the landfill. The parameters analyzed were, pH, EC, TDS, COD, BOD, TH,NH_4^+, SO_4^{2-}, NO_3^-, Phosphate, Cd, Cr, Cu^{2+}, Pb, Zn, Ca^{2+}, Mg^{2+}, Na^+, Fe^{2+}, K^+, as well as Total coliform count using standard methods. The concentration of these parameters were compared with NSDWQ and WHO to ascertain their levels within the surface water. The surface water analysis across the Downstream point (SW 1) showed that parameters like pH, EC, TDS, TA, TH, Na, K, Fe, BOD, COD, Phosphate and Total Coliform Count, recorded 7.18, 2,450 µS/cm, 1,225 mg/l, 534.9 mg/l, 270 mg/l, 122.92 mg/l, 69.42 mg/l, 9.48 mg/l, 25 mg/l, 16 mg/l, 7.5 mg/l and 2.80 X 10^6 cfu/ml respectively. All these values except pH were above NSDWQ and WHO recommended values for potable water. When compared to samples from SW 2 and SW 3, SW 1 samples had higher concentration of parameters. However, some metals and heavy metals like Pb, Cu, Zn, Cd and Cr were below equipment detectable limits for all sampled locations. It was confirmed therefore that the Downstream point (SW 1), was the most contaminated among the three sampled surface water points, in this study. Pearson's correlational analysis also confirmed that some parameters indicated unity. It was recommended that surface water sources around landfills should be properly monitored to curb water pollution.

Keywords: Contamination, Downstream, Surface water, Pollution, Leachate, Uncontrolled Landfill

1.0 INTRODUCTION

Uncontrolled waste dumps in municipalities of developing nations/cities have in recent times given rise to various forms of nuisance such as rodents' proliferation, air pollution (odor), soil pollution (percolation/infiltration) as well as water pollution (overland flow) [1]. When waste is not properly managed, it interferes with the environment, which reduces the aesthetic value of the particular area used for waste disposal (waste littering). When waste is not adequately disposed, its byproducts also poses a threat to those who come in contact with the environmental resources within the dumpsite. The inadequate handling of waste has resulted in serious ecological, environmental and health concerns [1]. The open dumping of municipal solid waste in landfills is one of the oldest and most common disposal methods adopted in most of the countries, particularly developing ones [2]. Landfill leachate is generated when rainwater percolates through the waste layers in a landfill, in which process organic and inorganic constituents of the waste get dissolved, transported and deposited at the bottom of the landfill by gravity [3]. Some of the components of landfill leachate may be categorized as a water-based solution of four groups of contaminants dissolved organic matter, inorganic macro-components, heavy metals, and xenobiotic organic compounds [4]. The most important potential environmental concern associated with landfill is the formation of leachate and the subsequent contamination of soil and water resources [5, 6].

Water is life, it is a globally significant and valuable renewable resource for human life and economic growth. Water has remained the most abundant and most important resource of man, every life depends on it for various reasons. It has prided itself over the years as the source of life on planet earth without which nothing survives. Water exist in the atmosphere as vapor, on the earth surface as surface water and below the earth surface as ground water. Majority of the surface water available on the earth is saline in nature, only a small quantity is fresh water and therefore requires adequate conservation for human accessibility. Freshwater has become a scare commodity due to anthropogenic activities of over exploitation and pollution. Pollution is caused when a change in the physical, chemical or biological condition in the environment harmfully affect quality of human life, as well as plants and animals [7].

When foreign elements enter the water column, or when the minerals found in water exceed the acceptable amount, the water is said to be contaminated; water pollution describes the presence of materials in water that interfere unreasonably with one or more beneficial uses of water [8]. When this happens, some health concerns are raised. Health hazards arising from waste management and disposal associated activities and their ability to pollute surface water consequently need to be analyzed specifically for the conditions in a given setting. Surface water pollution is caused mainly due to several processes of inadequate waste management from various sources including industrial waste, agricultural waste, institutional waste and municipal waste etc. The impact of leachate on surface water and other water resources has attracted a lot of attention because of its devastating environmental and health significance. Leachate migration from landfills poses a high risk to water resource if not satisfactorily managed [9]. Most lakes, rivers and streams in the world are seriously polluted nowadays due to human interference with the ecological balance. The growing population which has increased waste generation potentials has brought about severe environmental, economic, and social difficulties in both developed and developing countries [10]. This has therefore caused an existential concern to residents within regions assigned for waste disposal.

2.0 Description of the study area

The study area was situated within the lower floodplain of the Niger Delta. The terrain is poorly drained with a gentle syncline to the Gulf of Guinea in a southwestern direction [11]. It is characterized by sedimentary formations with a thickness of about 8000m. It includes Akata Formation, Agbada Formation, Benin Formation, from bottom to top, which is Oligocene to Pleistocene in age. It consists predominantly of freshwater continental friable sands and gravel that are excellent aquifer properties, with occasional intercalation of shales [12]. The Niger delta has two basic hydrological regimes which are Coastal and Inland [2].

The landfill is specifically located off Edepie-Amassoma road, Etelebu in Yenagoa Local Government Area of Bayelsa State, and operated by Bayelsa State Environmental Sanitation Authority. As at the time of this study, the site which began operations from around 2008 had an average life span of about 11 years. The landfill also had a height of about 2m and covers a total area of about thirty-six kilometers square ($36km^2$). The hydrogeological condition of the landfill site was consistent with the regional hydrogeological setting of Port-Harcourt area as depicted by [13]. A pictorial view of the landfill is presented in Figure 1 below.

Figure 1: An Image Showing a Pictorial View of the Waste Dump

The waste dump was unlined and serviced wastes generated from the Yenagoa municipality which include industrial, agricultural, institutional, commercial and domestic wastes, as well as sewage.

2. 1 STUDY OBJECTIVES

The aim of the study was to access the impact of a waste dump site on the quality of surface water in a nearby stream within the study area. The specific objectives were to;

- Evaluate the characteristics of surface water from a nearby stream consequent upon waste disposal.
- Determine the variation in the physio-chemical and biological properties of the surface water sampled at Downstream point (SW 1), Central point (SW 2) and Upstream point (SW 3) of the stream.
- Compare the levels of contaminants from collected samples with standard acceptable limits, ie Nigerian Standard of Drinking Water Quality (NSDWQ) and World Health Organization (WHO).
- Ascertain the possible source of surface water pollution using correlational analysis.
- Discuss the potential adverse effects of ingesting or coming into daily contact with water from the stream

Having regular contact with surface water from sources near municipal waste dump sites and possible ingestion of same, could result in endangering the individual as it has the potential to contain contaminants washed into it from the dumpsite.

3.0 MATERIALS AND METHODS

3.1 Sample collection

The study area was described using Geographic Information System (GIS). Every sampling point was picked with the help of a standard Global Positioning System (GPS). To determine the degree of surface water pollution, three surface water samples were taken around the dumpsite and labeled Downstream Point (SW 1), Central Point (SW 2) and Upstream Point (SW 3) respectively. Two samples were taken at the landfill's Northernmost and Southernmost ends, while the third sample was taken at the center of the nearby stream, which provided inhabitants with protein (fish) and other forms of livelihood.

Table 1: Details of Sampling Sites

S/N	SAMPLING LOCATIONS	COORDINATES		DESCRIPTION
		LATITUDE (N)	LONGITUDE (E)	
1.	Surface Water (SW1)	4° 59' 58.78788"	6° 20' 11.51412"	Downstream Point
2.	Surface Water (SW2)	4° 59' 40.14"	6° 19' 57.91"	Central Point
3.	Surface Water (SW3)	4° 59' 27.68064"	6^{0}19’43.92804”	Upstream Point

At each sampling location, surface water samples were taken with the help of clean 1.5L plastic bottles after initially rinsing the bottles with same water to be taken. Non-conservable parameters such as pH, temperature and electrical conductivity were determined in-situ. The pH of water samples was measured with a pH meter previously calibrated with buffer solutions. Conductivity was measured with a conductivity meter calibrated with potassium chloride solution. Temperature was measured with a thermometer [14.

After collection, the samples were immediately placed in iced coolers for transportation to the laboratory and stored in refrigerator. The water quality parameters dealt with were physical, chemical and biological characteristics [15], and were analyzed in accordance with standard laboratory methods [14]. The parameters were; pH, Electrical Conductivity (EC), Total Dissolved Solids (TDS), Chemical Oxygen Demand (COD), Biological Oxygen Demand (BOD), Total Hardness (TH), Ammonium (NH_4^+), Sulphate (SO_4^{2-}), Nitrate (NO_3^-), Phosphate and Heavy Metals such as Cadmium (Cd), Chromium (Cr), Copper (Cu^{2+}), Lead (Pb), Zinc (Zn), Calcium (Ca^{2+}), Magnesium (Mg^{2+}), Sodium (Na^+), Iron (Fe^{2+}) and Potassium (K^+) ions, as well as Total coliform count.

In this study, a total of three surface water samples were taken for laboratory analysis. The three samples were analyzed for, Physico-chemical and microbiological characteristics. The variations of parameters from sampling points SW 1, SW 2 and SW 3 as compared with Nigerian Standard of Drinking Water Quality (NSDWQ) and World Health Organization (WHO) [16, 17] are shown in Table 2 below. The table also presents some descriptive statistics of the surface water parameters analyzed.

4.0 RESULT AND DISCUSSIONS

Table 2: Summary of Spacial Variation and Descriptive Statistics of Surface Water Parameters

Sample ID (Borehole Sampling points)	UNITS	NSDWQ (2015)	WHO GUIDELINES (2011)	SW 1	SW 2	SW 3	MIN	MAX	AVERAGE	Standard Deviation
pH		6.5-8.5	6.5-8.5	7.18	6.91	6.96	6.91	7.18	7.02	0.14
Temp.	^0C		25	22.3	21.3	21.6	21.3	22.3	21.73	0.51
EC	µS/cm	1000	1000	2,450	1,298	852	852	2450	1533.33	824.58
TDS	mg/l	NS	500	**1,225**	649	426	426	1225	766.67	412.29
SO^{2-}_4	mg/l	100	500	20	24	24	20	24	22.67	2.31
NO_3	mg/l	50	50	0.4	0.1	0.1	0.1	0.4	0.2	0.17
PO^{3-}_4	mg/l	NS	0.1	7.5	0.67	0.67	0.67	7.5	2.95	3.94
NH_4	mg/l		NA	0.09	0.022	0.022	0.022	0.09	0.05	0.04
TA	mg/l	NS	200	534.9	290.2	193.5	193.5	534.9	339.53	175.97
BOD	mg/l		5	16	16	14	14	16	15.33	1.15
COD	mg/l		10	25	17	12	12	25	18	6.56
TH	mg/l	250	200	270	250	260	250	270	260	10
Pb	mg/l	0.01	0.01	<0.001	<0.001	<0.001	0	0	#DIV/0!	NA
Cu	mg/l	1	2	<0.001	<0.001	<0.001	0	0	#DIV/0!	NA
Zn	mg/l	3	3	<0.001	<0.001	<0.001	0	0	#DIV/0!	NA
Fe	mg/l	0.3	0.3	9.48	3.67	1.03	1.03	9.48	4.73	4.33
Ca	mg/l	NS	75	14.06	8.15	11.8	8.15	14.06	11.34	2.98
Mg	mg/l	20	20	19.67	9.77	6.59	6.59	19.67	12.01	6.82
K	mg/l		20	69.42	31.72	8.32	8.32	69.42	36.49	30.83

Na	mg/l	200	200	122.92	59.93	23.47	23.47	122.92	68.77	50.31
Cd	mg/l	0.003	0.003	<0.001	<0.001	<0.001	0	0	#DIV/0!	NA
Cr	mg/l	0.05	0.05	<0.001	<0.001	<0.001	0	0	#DIV/0!	NA
Total Plate Count	cfu/ml	10	0	2800000	2440000	2780000	2440000	2800000	2673333.33	202319.88

The average concentration of parameters and their standard deviations as presented in Table 2 above of the three samples analyzed showed that EC, TDS, TA, TH and Phosphate had higher average concentrations as compared to the NSDWQ and WHO standards. The average concentrations were 1533.33µS/cm, 766.67mg/l, 339.53mg/l, 260mg/l and 2.95mg/l respectively. Standard Deviation of these parameters were 824.58, 412.29, 175.97, 10 and 3.94. Similarly, parameters such as DOD, COD, Fe, K and Total plate count also indicated higher average concentrations as compared to the standard acceptable values. The average concentrations were 15.33mg/l, 18mg/l, 4.73mg/l, 36.49mg/l and 2673333.33mg/l. While the Standard Deviations were 1.15, 6.56, 4.32, 30.83 and 202319.88 respectively.

Figures 2 and 3 showed the percentages of the Physico-chemical and microbial characteristics of the surface water samples analyzed during the sampling period.

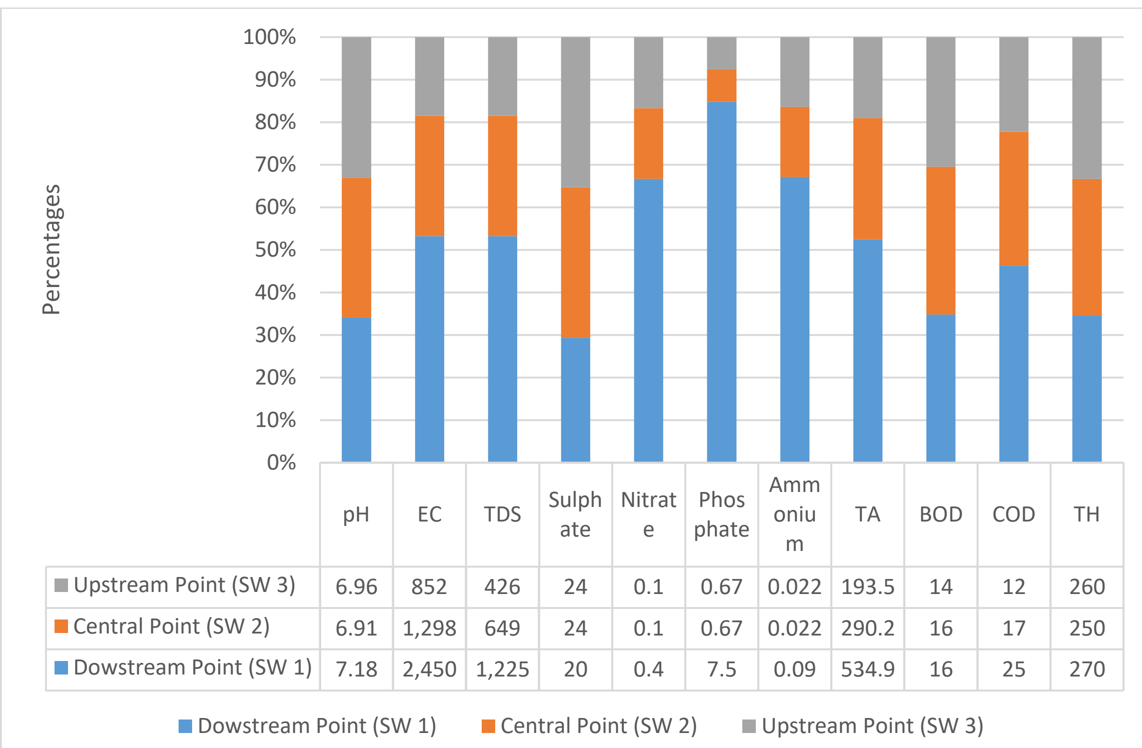
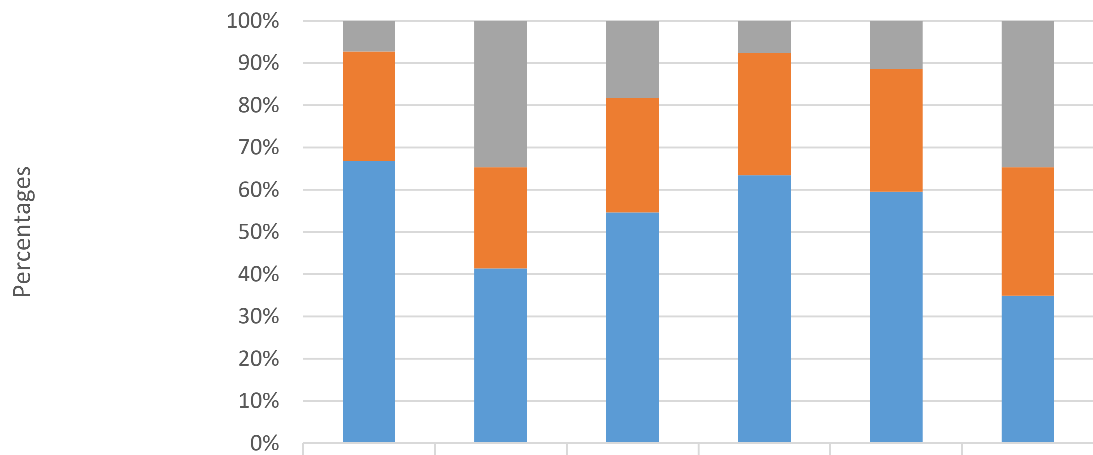


Figure 2: Percentage composition of surface water parameters within the sampling points

All the sampled parameters showed variations across the sampling points. It was observed from the chart above that the values for pH of the surface water samples ranged from 6.96 - 7.18, but were within the WHO recommended range. The EC which ranged from 852 - 2450 µS/cm and Total Dissolved Solid (TDS) with range from 426 – 125mg/l showed similar trends. They both had higher percentages of values that were greater than the regulatory standards at the Downstream (SW 1) and the Central point (SW 2). Concentration of Sulphate (SO_4^{2-}), Nitrate (NO_3), Phosphate (PO_4^{3-}) and Ammonium (NH_4) also showed similar patterns. They all had the same concentrations at the Upstream point (SW 3) and Central point (SW 2), however, the values at the Downstream point (SW 1) were higher. When compared with NSDWQ and WHO standards, they fell within permissible limits except phosphate. Total Alkalinity, BOD, COD and Total Hardness values ranged between 193.5 – 534.9mg/l, 14 – 16mg/l, 12 – 25mg/l and 250 – 270mg/l respectively. When compared with the regulatory standards, it was observed that they were all above WHO standards except for the TA value at the Upstream point (SW 3). The higher BOD_5 and COD values indicate the presence of organic matter in water [4].



	Fe	Ca	Mg	K	Na	Total Coliform Count
Upstream Point (SW 3)	1.03	11.8	6.59	8.32	23.47	2780000
Central Point (SW 2)	3.67	8.15	9.77	31.72	59.93	2440000
Downstream Point (SW 1)	9.48	14.06	19.67	69.42	122.92	2800000

Figure 3: Percentage composition of some metals and microbial load of surface water within the sampling points

Summarily, the surface water analysis across the Downstream point (SW 1) showed that parameters such as pH, EC, TDS, TA, TH, Na, K, Fe, BOD, COD, Phosphate and Total

Coliform Count, recorded 7.18, 2,450 µS/cm, 1,225 mg/l, 534.9 mg/l, 270 mg/l, 122.92 mg/l, 69.42 mg/l, 9.48 mg/l, 25 mg/l, 16 mg/l, 7.5 mg/l and 2.80 X 10^6 cfu/ml respectively. All these values were above NSDWQ and WHO recommended values for drinking water except pH. All the heavy metals in the surface water analyzed (Pb, Cu, Zn, Cd, and Cr) in this study were below instrument detectable limits (BDL) [4]. However, the microbial load within the surface water sampled at all points indicated a huge population much more than the acceptable NSDWQ and WHO standards for potability. The high concentration of parameters in the three surface water samples showed that the surface water was contaminated and poses a threat to those who access it for their needs.

Pearson's correlation was also used to obtain the common sources of contaminants within the samples of surface water analyzed. This was done to identify if the waste dump was indeed responsible for the presence of these contaminants within the stream. The correlation matrices for 18 measured variables during sampling analysis are illustrated in Tables 3 below.

Table 3: Pearson's Correlation for Surface Water Analysis Using Microsoft Excel

	pH	*Temp.*	*EC*	*TDS*	*SO2-4*	*NO3*	*PO3-4*	*NH4*	*Alkalinity*	*BOD*	*COD*	*Hardness*	*Fe*	*Ca*	*Mg*	*K*	*Na*	*Total Plate Count*
pH	1																	
Temp.	0.992603	1																
EC	0.900976	0.841638	1															
TDS	0.900976	0.841638	1	1														
SO2-4	-0.98474	-0.95632	-0.96274	-0.96274	1													
NO3	0.984738	0.956325	0.962737	0.962737	-1	1												
PO3-4	0.984738	0.956325	0.962737	0.962737	-1	1	1											
NH4	0.984738	0.956325	0.962737	0.962737	-1	1	1	1										
Alkalinity	0.899014	0.839199	0.99999	0.99999	-0.96151	0.96151	0.96151	0.96151	1									
BOD	0.341644	0.225018	0.715576	0.715576	-0.5	0.5	0.5	0.5	0.718713	1								
COD	0.844011	0.772656	0.993129	0.993129	-0.92447	0.924473	0.924473	0.924473	0.993646	0.792406	1							
Hardness	0.939829	0.974355	0.698535	0.698535	-0.86603	0.866025	0.866025	0.866025	0.695307	0	0.609994	1						
Fe	0.884565	0.821398	0.999336	0.999336	-0.92447	0.952241	0.952241	0.952241	0.99949	0.740558	0.996734	0.671992	1					
Ca	0.885313	0.935217	0.595898	0.595898	-0.79087	0.790872	0.790872	0.790872	0.592278	-0.13455	0.497825	0.990906	0.566236	1				
Mg	0.91705	0.861854	0.999255	0.999255	-0.97246	0.972457	0.972457	0.972457	0.999071	0.688083	0.987872	0.725632	0.997185	0.626448	1			
K	0.845005	0.773833	0.993344	0.993344	-0.92518	0.92518	0.92518	0.92518	0.993853	0.791272	0.999998	0.611464	0.996882	0.499434	0.988159	1		
Na	0.854757	0.785422	0.995306	0.995306	-0.93204	0.932044	0.932044	0.932044	0.995731	0.779821	0.999793	0.626002	0.998172	0.515381	0.990829	0.999829	1	
Total Plate Count	0.680159	0.764125	0.294752	0.294752	-0.54219	0.542194	0.542194	0.542194	0.290448	-0.45658	0.1809	0.88968	0.259731	0.943025	0.331412	0.182725	0.200888	1

A perfect positive correlation between TDS and EC (r = 1, $p \leq 0.01$), NH_4 and NO_3 (r = 1, $p \leq 0.001$) and PO_4^{3-} and NO_3 (r = 1, $p \leq 0.001$) was observed and this meant that they had exactly the same contributor which could be mud and putrescible wastes brought in by the infiltrating rain water and organics [4].

The strong positive correlation between EC and pH, TDS and pH, TA and EC, TA and TDS, COD and EC ($r = 0.98$, $p \leq 0.01$) signified that they had nearly the same contributors (the dissolved ions). A significant negative correlation was also observed between TA, COD, Fe, Mg, K, Na and SO_4 ($r = -0.9615, -0.92447, -0.92447, -0.97246, -0.92518, -0.93204$) respectively, indicating the opposing distribution of these pair variables.

5.0 CONCLUSION

When compared to samples from the Central point (SW 2) and Upstream point (SW 3) sampling locations, the Downstream Point (SW 1) samples had higher concentration of parameters. However, some metals and heavy metals were below equipment detectable limits for all sampled locations. It was confirmed therefore that SW 1, was the most contaminated among the three sampled surface water points, in this study. The microbial load within all the samples greatly exceeded the recommended WHO and NSDWQ standards for drinking water. The Pearson's correlation results also showed that some pollutants analyzed came from the same source.

Since the stream was the main resource that provided protein (fish) to nearby residents and other local farmers who came in contact with the water daily, its contamination may lead to a serious dislocation of the ecological balance. This may also result to a potential threat of bioaccumulation of pollutants as a result of fishers ingesting their catch and having dermal contact with the microbes infested water daily.

Therefore it was recommended that siting of landfills should be done after a proper study of the environment by policy makers since landfills had been confirmed to contribute contaminants into the environment. The surface water sources within landfills should also be properly monitored to avoid ingestion of contaminated water.

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