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Groundwater and Leachate Quality Assessment in Balaoan Sanitary Landfill in La Union, Northern Philippines

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This study seeks to assess the groundwater and leachate quality in Balaoan sanitary landfill using physico-chemical and biological parameters and to compare the results to quality standards. Groundwater and leachate samples were collected through grab sampling during the months of February and April and sent for laboratory analyses. Except for the Total coliform and E. coli counts, the physico-chemical parameters of the groundwater samples such as pH, turbidity, total dissolved solids, and nitrate were found to conform to the Philippine National Standards for Drinking Water (PNSDW). Leachate samples in terms of pH, chemical oxygen demand were found to conform to the regulatory limit while toxic metals such as cadmium, chromium, copper, lead and mercury showed very low concentration based on DAO 35, series of 1990 Class C waters. Groundwater samples from tube wells near the sanitary landfill are no longer safe for human consumption.

1. Introduction

Sanitary landfills are the most widely utilized method for solid wastes disposal around the world (Qasim and Chiang, 1994). In a landfill, the wastes are dumped, covered with soil and in the decomposition of these wastes, leachate is produced as a harmful side effect. Thus, landfills can pose a serious threat to the quality of environment if incorrectly secured and improperly operated (Longe and Balogun, 2010).

Landfill leachate characterization is a critical factor in establishing a corresponding effective management strategy or treatment process (El Fadel et al., 2002). Landfill leachate can consist of many different organic and inorganic compounds that are either dissolved or suspended in the wastewater. According to Mor et al. (2010), areas near landfills have a greater possibility of groundwater contamination because of the potential pollution source of leachate which also contain heavy metals such as cadmium, chromium, lead, zinc, nickel and xenobiotic substances from nearby dumpsite (Aderimi et al., 2011) which was confirmed by the study of Longe and Balogun (2010).

In the Philippines, there are about 960 sanitary landfills, and of these, 936 are controlled and the rest are open dumps. Republic Act 9003 (2000) known as Ecological Solid Waste Management Act of 2000 mandates the Local Government Units (LGUs) to implement engineering measures to control over significant potential environmental impacts arising from the development and operation of the facility, such as presence of liners, leachate collection and treatment system, gas control recovery system, groundwater monitoring well system, a cover, closure and post closure procedures. However, the LGUs find difficulty in complying and are constrained by several factors, most importantly, the lack of funds and technical assistance (UNDP-EMB, 2009). For this reason, waste disposal management system remained to be the biggest challenge for the LGUs in the country.

In Northern Philippines, particularly in Region I, there are about 125 disposal facilities but only 16 are functional sanitary landfills. The City of San Fernando sanitary landfill which was built in 2005 served as a model to adjacent towns particularly in the implementation of RA 9003. The municipality of Balaoan, which is about 33.5 km north of the city, has established its sanitary landfill in 2008 in compliance with the environmental law. There were many studies conducted related to waste management, however, only a few local studies were conducted on the effects of heavy metals contained in the landfills. In the study conducted by Galarpe and Parilla (2010) on the analysis of heavy metals in Cebu Sanitary Landfill, results revealed that the leachate stations exceeded the standards for lead (0.1968 mg/L) and mercury (0.1438 mg/L). Groundwater stations in the landfill site also exceeded the standard for lead (0.0371 mg/L) and cadmium (0.0042 mg/L). The results could be alarming to

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public health and for the environment because heavy metals such as cadmium, lead and mercury are carcinogenic substances and can adversely affect mental and neurological functions as well as altering metabolic processes in the human body system (Adeyi and Majolagbe, 2014). There has been no data yet on the impact of the landfill since it started operation, thus, this study aimed to assess the groundwater quality characteristics of tube/deep wells adjacent or near the landfill using physical, chemical and biological parameters and to characterize the leachate quality in terms of its pH, chemical oxygen demand, total nitrogen and its metal concentrations. The results of this study could be used in the formulation of policies for local waste management and health prevention in local government units.

2. Methods and Procedures

2.1 Study Area

With a total land area of about 6,870 hectares (17,000 acres), the municipality of Balaoan consists mostly of agricultural lands. With geographical coordinates of 16°19' 30" N latitude and 120°22' 7" E longitude, the municipality generates about 25.5 cubic meters of wastes per day. The bulk of the wastes being collected consist of organics and inorganics, segregated at source and transported to barangay Calumbuyan where the facility is located. The Balaoan sanitary landfill (Figure 1) has a total land area of one hectare with leachate pond situated at 16°48' 42.9" N latitude and 120°23' 21.2" E longitude, with an elevation of 68 m.
The facility was designed following the trench method of landfilling whereby individual trenches are excavated, filled and covered progressively. In here, the landfill leachate is allowed to percolate through the landfill base where the liquid drains into the leachate pond. During the sampling period, the leachate pond was covered with water hyacinth – a water plant potential for wastewater treatment (Kpondjo et al., 2012).

2.2 Ground Water Sampling and Analysis

Two stations were selected within the 500 m radius near the study area during the months of February and April. The first station (GW1) was a tube well from a residence nearby located at 16°48' 45.2" N latitude and 120°23' 21.2" E longitude while the second groundwater station (GW2) was obtained from a constructed shallow well located at 16°48' 44.3" N latitude and 120°23' 35.9" E longitude. Grab method was used in the gathering of water samples and these were placed in plastic and sterilized containers, properly sealed and labelled, preserved with ice at lower temperature inside coolers for storage and transported to the laboratory for analysis. The groundwater samples were analysed in terms of physical, chemical and biological parameters such as pH, temperature, turbidity, conductivity, total dissolved solids (TDS), nitrates, total nitrogen, total phosphorous, total coliforms and fecal coliforms following the APHA-AWWA-WPCF (1994). The pH was measured using a calibrated pH meter and a glass electrode while the conductivity was measured following the gravimetric method. Turbidity was measured using the turbidimeter while nitrate was analysed using the Cadmium Reduction method. Total nitrogen and total phosphorous were measured using the Total Kjeldahl Nitrogen and the colorimetric method, respectively. The test results of the groundwater samples were compared with the standards set by the Department of Health (DOH) Administrative Order No. 2007-0012 or the Philippine National Standards for Drinking Water (PNSDW) and the World Health Organization (WHO) Guidelines for Drinking Water of 1997.

Figure 1: A view of the sanitary landfill showing the groundwater sampling sites.

2.3 Leachate Assessment

The leachate samples were also collected through grab sampling and placed in a plastic container properly sealed and labeled. The parameters such as pH, chemical oxygen demand, total nitrogen, cadmium, chromium, copper, lead and mercury were considered for laboratory analyses. The COD measurement was done using the Open reflux method. The total nitrogen was measured taking the summation of Total Kjeldahl nitrogen (TKN), nitrates and nitrites concentrations. The nitrates and nitrites were measured using the Cadmium Reduction method. Total phosphorous was measured using the colorimetric method. The atomic absorption spectroscopy was used in the measurement of cadmium, chromium, copper and lead. Mercury measurement was done using the cold vapor technique.

3. Results and Discussion

3.1 Groundwater quality

Table 1 shows the results of analyses of the groundwater samples near the landfill. Except for the parameters on pH, total and fecal coliform, the groundwater samples conformed to the quality standards set by PNSDW and the WHO guidelines. This indicates that the water obtained from the two groundwater stations were not fit for human consumption because these contain pathogenic microorganisms which may result to water-borne infections. According to World Health Organization (2006), groundwater contamination occurs more frequently when protective barriers such as overlying soil are breached or may come from sewerage or septic tanks carried by surface water runoff. Groundwater is significantly contaminated due to leachate that percolates from landfills (Jhamnani and Singh, 2009).

As gleaned from the results, pH values which ranged from 5.9 – 6.4 showed slight acidity which deviated from the normal range. Acidic water may have health implications especially water of extreme low and high pH. When water is acidic, the growth and proliferation of microorganisms including coliforms is increased that might affect the safety of the water for drinking purposes. According to researches, an imbalanced pH affects the cellular activity in the body, leading to the progression of most degenerative diseases, including cardiovascular diseases and heart disease, high blood pressure, high cholesterol levels, kidney stones, urinary incontinence, arthritis, osteoporosis, cancer, diabetes, systemic weight gain and obesity. The WHO Guidelines for drinking water quality stipulates that exposure to extreme pH values results in irritation to the eyes, skin and mucous membranes particularly with pH values greater than 11 and low pH values such as pH values below 4. Acidic water could contain metal ions such as iron, manganese, copper, lead and zinc. In other words, acidic water contains elevated levels of toxic metals. Pure water should be neutral with pH values of 7, however, the pH values of groundwater drinking water system is 6.5 – 8.5.

The temperature which ranged from 27.8 ^{0}C to 30.2 ^{0}C were within the normal values since the sampling was done during summer when the relative humidity is low.

Turbidity is the measure for the clarity of water and a parameter for the presence of suspended materials in the water that would decrease the passage of light. As gleaned from the table, the values were within the regulatory limit while electrical conductivity showed appreciable values from 287 – 474 µS/cm. It would be noted, however, that the two samples during the first sampling has exceeded the standard value of 300 cfu/cm set by WHO. This means that the water is affected by the presence of inorganic dissolved solids such as chloride, nitrate, sulfate and phosphate anions (ions that carry a negative charge). The high conductivity values also suggests the potential of the water to be saline which would pose another health risks to water users. Potable waters normally register conductance from 50 to 500 micromhos/cm and values over 500 are of mineralized water (EPA, 2015).

High values of TDS could be an indicator of potential concerns such as high water hardness, unpalatability and mineral deposition. In this study, the TDS values which ranged from 161 – 341 mg/L conformed to the PNSDW and to the WHO Guidelines.

Nitrates may get into the drinking water through runoff from fertilizers, leaks from septic tanks, sewage and erosion of natural deposits. As gleaned from the table, all the water samples conformed to PNSDW and WHO guidelines. The PNSDW limit for nitrate is 50 mg/L. However, EPA maximum contaminated level (MCL) is 10 mg/L. Above this limit, infants below the age of six months who drink water containing nitrate in excess of the MCL could become seriously ill, and if untreated, may die (EPA, 2015).

The water samples measured in terms of total nitrogen and total phosphorous gave minimal values which suggest the presence of these in trace amounts. Phosphorous aside from natural weathering of rocks and industrial products may come from sewage. Phosphorous is not toxic to human and animals unless present in high levels which could give digestive problems.

Table 1: Results of the analysis on groundwater samples in Balaoan sanitary landfill

Parameters/Units	1st Sampling		2nd Sampling		PNSDW 2007	WHO 1997 Guidelines
	GW1	GW2	GW1	GW2		
pH	6.2	6.4	5.9	6.3	6.5-8.5	6.5-9.2
Temperature, °C	30.2	30.2	27.8	28.2	-	-
Turbidity, NTU	0.65	5.0	1.2	5.0	5.0	-
Conductivity, µS/cm	444	474	287	288	-	300
TDS, mg/L	320	341	214	161	500	500
Nitrate, mg/L	3.0	1.80	4.60	3.0	50	-
Total Nitrogen, mg/L	<1.0	<1.0	1.0	<1.0	-	-
Total Phosphorous, mg/L	<0.004	<0.1	<0.004	<0.3	-	-
Total coliform, MPN/100 mL	>23	>23	>23	>23	<1.1	-
Fecal coliform, MPN/100 mL	3.6	3.6	>23	12	<1.	0

In the study conducted by Akinbile and Yusoff (2011), they also noted in their study that borehole water samples near a landfill in Akure, Nigeria showed appreciable presence of pollutants ranging from 30 to 61 mg/L. The researchers recommended that these water supplies should not be consumed by humans let alone given to babies. Likewise, in the study of Ghanem and Sanham (2012), they found out that five wells out of seven domestic wells in the area are polluted by nitrate and the researchers were associating this nitrate pollution to the many anthropogenic activities and agricultural land and the excessive use of fertilizers, pesticides, herbicides, and soil fumigants. The nitrate wells are located within the irrigated complex cultivation and village boundaries of Tulkarm, which explain the source of pollution.

In terms of total and fecal coliforms, the groundwater samples did not pass the PNSDW and WHO guidelines. Total coliforms result is the estimate of the amount or density of rod-shaped coliform bacteria and an indicator of drinking water quality. Coliform bacteria are common inhabitants in soils, plants and animals that may come in contact with water. They are not harmful but their presence may also indicate the presence of pathogens from fecal origins and other disease causing microorganisms. The results suggest that the water taken from these deep wells should not be used for drinking purposes as this may cause health problems which include diarrhea, cramps, nausea and vomiting. The location of the landfill has a significant impact in the process of leaching. Mor (2005) emphasized in his study on the strong relationship between depth and distance from landfills with groundwater wells. Water samples taken from adjacent to the landfills were the most vulnerable to pollution and decrease of contaminants results as the horizontal distance from landfills increase. In the same manner that the leachate concentration increase with depth and decrease with increase water addition. In this study however, the elevation of the leachate pond is 68 meters above sea level while groundwater sample in station 1 was positioned about 62 m above sea level and groundwater sample station2 was located 59 m above sea level. The contamination of the wells could hardly be associated with leachate percolation, but could be attributed to the surface water runoff during precipitation which runs over the groundwater sites and possibly, being aggravated by the improper practices by the local users.

3.2 Leachate quality

Leachates are the liquid that drain from a landfill that is produced from the decomposition of biodegradable wastes. According to Raghab et al. (2013), leachate generation can cause significant threat to surface water and groundwater when not managed well and disposed untreated to the environment. In the study conducted by Abd El-Salam and Abu-Zuid (2015), they compared the impact of two landfill sites in Egypt on the groundwater quality. They found out in their study that the results of the physico-chemical analyses of the leachate were highly variable with severe contamination of organics, salts and heavy metals. Leachate is characterized by high concentration of organic matter (biodegradable and non-biodegradable), ammonia nitrogen, heavy metals and chlorinated organic and inorganic salts (Nagarajan et al., 2012).

As shown in Table 2, the parameters being measured conformed to the regulatory limit set by DENR water quality criteria and applies to industrial and all municipal wastewater effluents. The pH values of the leachate water which ranged from 6.6 -8.8 conformed to the standards set by DAO 35 for Class C waters. The change from slightly acidic to alkaline pH can be attributed to the types of wastes deposited in the landfill which may result to methane fermentation. The results also indicate anaerobic or methanogenic fermentation stage of the leachate which is usually characterized with the production of volatile fatty acids and high partial pressure of carbon dioxide. In this phase, the growth of the methanogens which converts the organic contaminants to gas was in alkaline environment. It would be noted that organics are negatively charged ions, thus, attenuation of organic ions in a clayey soil environment will be mostly through anionic exchange (Qasim and Chiang, 1994).

From the waste data gathered from EMB-DENR in 2013, Balaoan Sanitary Landfill generates 2 t/d of wastes.

Chemical Oxygen Demand (COD) is the measure of oxygen-depleting capacity of a waste water and is equivalent to the amount of oxygen needed to oxidize the pollutants. According to Kamaruddin et al (2015), young leachate (1-2 y) is characterized by high organic fraction of relatively low molecular weight volatile organic acids, high COD and with BOD_5 /COD > 0.6. In contrast, old leachate (>10 y) is characterized by low COD, slightly basic pH (pH >7.5). In this study, COD values were found below the limit of 100 mg/L. The decline in the COD values during the 2nd sampling denotes reduction of organic strength due to anaerobic decomposition to produce methane.

Total Nitrogen values ranged from 6 mg/L to less than 1 mg/L. The most dominant form of nitrogen is nitrate and is a mobile form of nitrogen. Though, there is no limit to this parameter based on DAO 35,Class C water, however, when nitrogen concentration is increased and percolates into the groundwater, this may cause serious illness to both wildlife and humans.

Heavy metals concentration of cadmium, chromium, copper, lead and mercury are way below the regulatory limits which implies that the measured parameters have values below the standards and therefore may not pose a risk contaminating the groundwater. The presence of the water hyacinth in the leachate pond may have contributed to the decrease of concentrations of these toxic substances. According to Kpondjo et al. (2012), water hyacinth has been effective in the removal of carbon and nitrogen for COD 70 %, 52.8 % BOD, TKN 57.3 % and can improve the quality of water by reducing the levels organic and inorganic nutrients and heavy metals (Gupta et al., 2012). In the study conducted by Maharjan and Ming (2012), water hyacinth has the potential to treat waste water. Results of their studies showed reduction of pollutants and nutrients particularly in the concentration reduction in Biochemical Oxygen Demand (BOD), Total Nitrogen, Total Phosphorous, and Fecal Coliform. Further, they claimed that water hyacinth can readily absorb and concentrate heavy metals such as lead, cadmium, mercury and nickel in high quantity without exhibiting visible signs of toxicity. This study showed similar results where the values measured for the concentrations of the toxic metals were below the regulatory limit. Waste reduction and management is being practiced and implemented by the local government unit of Balaoan, La Union, Philippines which at this time is compliant to Republic Act 9003 known as Ecological Solid Waste Management Act of 2000.

Table 2: Results of leachate analysis

Parameters/Units	1st Sampling	2nd Sampling	DAO 35, Class C Water
pH	6.6	8.8	6.5-9.0
Chemical oxygen demand, mg/L	88	39	100
Total nitrogen, mg/L	6.0	<1.0	-
Cadmium, mg/L	<0.006	<0.006	0.05
Chromium, mg/L	<0.02	<0.02	-
Copper, mg/L	<0.01	<0.01	-
Lead, mg/L	<0.05	<0.05	0.5
Mercury, mg/L	<0.0001	<0.0001	0.005

4. Conclusion

Groundwater from tube wells/shallow wells near the Balaoan Sanitary Landfill was found to be slightly acidic and failed to meet the standards set by PNSDW and WHO guidelines on total coliforms and fecal coliforms. Water samples being extracted from these water sources are no longer fit for human consumption. The leachate water consists of trace amounts of cadmium (<0.006 mg/L), chromium (<0.02 mg/L), copper (<0.01 mg/L), lead (<0.05 mg/L) and mercury (0.0001 mg/L) which conformed to DENR Administrative Order 35 for Class C water.

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