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Leachate characteristics generated by Pagalungan landfill Cagayan de Oro City, Philippines

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Key words: Biological oxygen demand (BOD), Chemical oxygen demand (COD), Landfill leachate, Organic matter (or organic material)

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Abstract

This paper discusses the characteristics of leachate generated from municipal solid waste of Pagalungan landfill in Cagayan de Oro City, Philippines. Leachate samples were collected and analyzed for various physicochemical parameters. Leachate characteristics are evaluated by standard tests. The pH of the leachate is considered as acidic as the pH is 6.47 in the Pagalungan landfill. BOD5 and COD of the leachate are 3, 809.27 mg/L and 23, 264 mg/L, respectively. It has been found that leachate contains high concentrations of organic and inorganic constituents beyond the permissible limits. The results showed that the highest metal concentration that exists in the leachate was lead, with less than 0.044 mg/l concentration. In contrast, heavy metals concentration was in trace amounts as the waste is domestic in nature. The BOD5 /COD ratio suggested that the landfill leachate is young-aged leachate.

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Introduction

In most developing countries, solid wastes are being dumped on land without implementing any suitable sanitary landfilling methods. Precipitation that infiltrates the solid wastes disposed on land mixes with the liquids already trapped in the crevices of the waste and leach compounds from the solid waste and thus formed contains dissolved inorganic and organic solutes (Vasanthi *et al.,* 2007). This is the process that forms leachate. Leachate is a liquid that is likely to contain a large number of organic contaminants, the COD(chemical oxygen demand), BOD(biochemical oxygen demand), ammonia, hydrocarbons suspended solids, concentrations of heavy metals, and inorganic salt and it is also rich in phenols, nitrogen, and phosphorus (Yusmartini *et al.,*2013).

The release of leachate into the environment without any treatment may pollute the soil, surface, and ground (Sharpudin *et al.,* 2017). In the course of time, the leachate formed diffuses into the soil and changes the physicochemical characteristics of water (Vasanthi *et al.,* 2007). The landfill leachate discharge may lead to serious environmental problems and may percolate through landfill liners and subsoil, causing pollution of groundwater and surface water resources (Naveen *et al.,* 2014).

Ineffective management and dumping of solid waste are obvious causes of the degradation of the environment in developing countries. Environmental impacts such as land degradation and water and air pollution are linked with improper management of municipal solid waste. Landfills are the most common way of disposing of municipal solid wastes in developing countries due to the higher capacity of landfills at a lower cost than other waste management techniques (Sewwandi *et al.,* n.d.).

Cagayan de Oro City is a first-class city in Southern Philippines which generates about 71,480 tons day-1 (*Cities Development Initiative for Asia, 2012*) of solid wastes from 598,803 households (*National Statistics Office, 2013*). The current practice in Cagayan de Oro is the collection of mixed waste with waste minimization strategies being implemented sporadically and at a minimum. The collected waste is then taken to the existing dumpsite, which is about twenty-five years old, located in Upper Dagong, Brgy. Carmen, which has been filled to capacity for quite a while. With the increase in population, the volume of waste being generated has increased. Cagayan de Oro officials have since then opened a new sanitary landfill in Barangay Pagalungan, 16 kilometers away from the city center (Lagsa, 2017). However, the current landfill has to be properly managed or, if possible, treat the leachate generated from the city's unsegregated waste. At present, the landfill employs leachate re-circulation, in which leachate is collected and re-injected into the waste mass. Landfill leachate characterization is necessary to have a proper treatment facility since the composition of landfill leachate is varied from site to site. This will facilitate the introduction of site-specific technologies, such as *in-situ* permeable reactive barriers for the treatment of landfill leachate. This study aims to characterize the generated leachate from the sanitary landfill of Sitio Burak Brgy. Pagalungan, Cagayan de Oro City, Philippines, in terms of its color, pH, turbidity, total solids (TS), total suspended solids (TSS), total dissolved solids (TDS), biological oxygen demand (BOD), total nitrates, total phosphates and heavy metal content like lead (Pb) and arsenic (As).

Materials and methods

Research setting

The research was conducted in the sanitary landfill of barangay Sitio Burakan, Brgy. Pagalungan, as shown in Fig. 1. Pagalungan is a barangay in the city of Cagayan de Oro. It is one of the city's hinterland barangays and located some 16 kilometers southeast of the city proper. Its population, as determined by the 2015 Census, was 2,290. This represented 0.34% of the total population of Cagayan de Oro. Pagalungan is situated at approximately 8.4114 latitudes and 124.5540 longitudes on the island of Mindanao. Elevation at these coordinates is estimated at 32.0 meters or 105.0 feet above mean sea level. Sitio Burakan, Brgy. Pagulangan was chosen as the site for the city's sanitary landfill through tedious research

and due also to renewed calls from concerned groups. The city government of Cagayan de Oro finally closed its 17-hectare dumpsite on April 15, 2017, and on the same day of the dumpsite's closure, started the opening of a new sanitary landfill in the barangay (Lagsa, 2017). The 45 hectares of land for the sanitary landfill has been in operation for two years and 5 hectares of land have already been filled with waste.

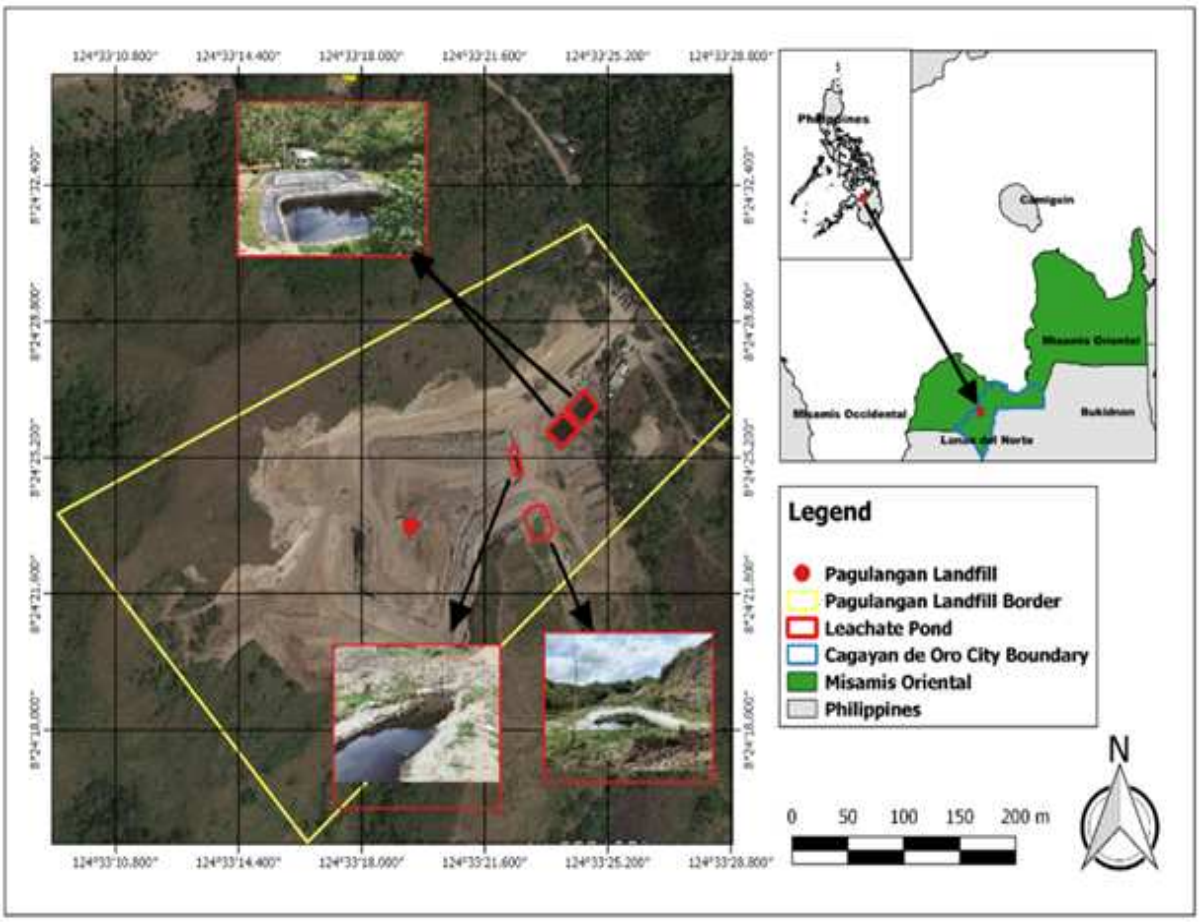

Fig. 1. Sample location points of the study.

Leachate sampling

To characterize the quality of leachate, integrated samples were collected from Pagalungan sanitary landfill. Leachate samples were collected on May 21, 2019, from the leachate pond where the leachate is stored specifically at the very source. Data from a separate analysis done by the City Environment and Natural Resource Office was also taken to complement the study. The collected samples were transported to the laboratory and stored at 40 °C until analysis of the samples.

Leachate characterization

Various physicochemical parameters like pH, turbidity, Total Suspended Solids (TSS), Total Dissolved Solids (TDS), Biological Oxygen Demand (BOD), Total Nitrates, Total Phosphates, and heavy metal content like lead (Pb), and arsenic (As) was analyzed to determine pollution potential of leachate discharge from solid waste landfill sites. Analytical methods according to "Standard methods for the examination of water and wastewater" was done for each parameter and were done in the laboratory. The pH was measured by an electronic pH meter on-site. Total Suspended Solids (TSS) was determined by properly shaken unfiltered sample and estimated by gravimetric method. Total Dissolved Solids (TDS) were determined by filtered sample through Whatman filter paper-44 and was estimated by gravimetry. Turbidity was measured by using a turbidity meter. The Biological Oxygen Demand was determined using a standard 5-Day BOD test.

Standard methods for the examination of water and wastewater were conducted by an external laboratory for other parameters. Fig. 1 shows sample points of the study.

Results and discussion

Table 1 shows the results of the chemical characteristics of the leachate from the Pagalungan landfill. As for metals, low concentrations of cadmium, followed by lead and mercury, were observed.

Leachate pH

The pH value of leachate in the landfill site was 6.47. The leachate is acidic in nature but still well within the pH range of 6.0 to 9.0, which is preferable for freshwater fish and bottom-dwelling invertebrates. It is also well within the effluent standard for Class A water bodies in the Philippines. pH with this value belongs to a landfill with young age (< 5 years) (Bhalla *et al.,* 2012). The pH of young leachate is less than 6.5, while old landfill leachate has a pH higher than 7.5 (Abbas *et al.,* 2009). Initial low pH is due to the high concentration of volatile fatty acids (Bohdziewicz and Kwarciak, 2008).

According to Naveen *et al.* (2014), pH is controlled principally by a series of chemical reactions and the important reaction is the degradation of organic materials to produce carbon dioxide and a small amount of ammonia. These dissolve in the leachate to form ammonium ions and carbonic acid, where the carbonic acid dissociates with ease to produce hydrogen cations and bicarbonate anions, which influences the level of pH of the system. Additionally, leachate pH is also influenced by the partial pressure of the generated carbon dioxide gas that is in contact with the leachate.

Table 1. Leachate characteristic of Pagalungan landfill.

Parameters	Leachate	Desirable Limit for A Class Water Body (DAO 2016-08)
pH	6.47	6.0-9.0
Colour (TCU)	Dark Black	100 (True Color Unit)
Odour	High (Foul)	-----
Temperature	17.1 ^{0}C	3 ^{0}C change
Turbidity (NTU)	105.95	-----
TS, mg/l	4, 716	-----
TDS, mg/l	2,604	-----
TSS, mg/l	2112	70
DO, mg/l	< 0.01	-----
COD, mg/l	23, 264	60
BOD5 , mg/l	3, 809.27	20
Cadmium, mg/l	< 0.002	0.006
Lead, mg/l	< 0.044	0.02
Mercury, mg/l	< 0.0015	0.002
Oil and Grease, mg/l	48	5
Ammonia as NH_3-N, mg/l	472	0.5
Reactive Phosphate,mg/l	23.8	1
Nitrate as NO_3-N, mg/l	0.09	14

Color and Odor

The color of the leachate was determined by observing its apparent color through the human eye since the researcher lacked the instrument to measure its true color unit. It was observed that the color of the leachate samples was dark black. The leachate has a rancid smell, mainly due to the presence of organic acids, which come from the high concentration of organic matter when decomposed. The high concentration of color in landfill leachate is due to the presence of high organic substances (Bhalla *et al.,* 2012). Naveen *et al.* (2014) stated that color in leachate is caused by a metallic substance like salts of iron, manganese, humus materials, tannins, peat, algae, weeds, protozoa, industrial effluents from paper and pulp, textile, tanneries, etc. The color in water is due to dissolved substances and substances present as fine colloids. As leachate first emerges, it

can be black in color, anoxic, and may be effervescent with dissolved and entrained gases.

Temperature and turbidity

The temperature of the leachate in the Pagalungan landfill is well below the standard set by the DENR at 17.1 ^{0}C. But in time, any max increase in temperature should not increase by more than 3 degrees, according to the DAO 1990-35. The temperature of 28.90 ^{0}C and 25.95 ^{0}C is very much favorable for leachate formation (Mishra and Tiwary, 2018). These temperatures are within the range of the standard here in the Philippines of 26-30 ^{0}C.

According to Lee and Hur (2016), leachate temperature in a landfill is affected by climatic temperature due to fluctuation of ambient temperature as temperature poses an impact on bacterial growth and chemical reaction. Bacterial growth is constrained by particular individual bacterial optimum growth temperature and any temperature change will retard growth due to its enzyme deactivation and cell wall rupture. Besides this, temperature also poses an impact on the solubility of many compounds to increase or decrease, which affect the quality of leachate. It is also reported that numerous compounds in leachate, such as $CaCO_3$ and $CaSO_4$, show a decrease in solubility as temperature increases.

The turbidity value of leachate samples of the landfill site is 105.95 NTU. Turbidity is due to the colloidal, extremely fine suspension such as clay, silt, finely divided matter (organic and inorganic), microorganisms like plankton, etc. (Naveen *et al.,* 2014).

Total Solids (TS), Total Suspended Solids (TSS), and Total Dissolved Solids (TDS)

TS and TSS values of leachate samples of the landfilling sites were 4,716 mg/l and 2,112 mg/l, respectively. TSS value is way above the standard value and needs treatment. High concentrations of suspended solids can cause many problems for stream health and aquatic life. High TSS in a water body can often mean higher concentrations of bacteria, nutrients, pesticides, and metals in the water. Studies have shown that typical SS values of 200-2000 and 100-400 mg/l were recorded for the new (less than two years) and mature landfills (more than 10 years), respectively (Tchobanoglous *et al.,* 1993). TDS values of leachate samples of the landfilling sites were 2,604 mg/l which is also way above the standard limit. The more dissolved solids in the water, the higher the hardness. TDS comprises mainly inorganic salts and dissolved organics (Naveen *et al.,* 2014).

Dissolved Oxygen (DO), Chemical Oxygen Demand (COD), and Biochemical Oxygen Demand (BOD)

The dissolved oxygen content of the leachate was less than 0.01. A large concentration of organic compounds in leachate increases the demand for oxygen by bacteria present in it.

BOD is the measure of the biodegradable organic mass of leachate and that indicates the maturity of the landfill, which typically decreases with time (Naveen *et al.,* 2014). In this study, the BOD value for leachate at the landfilling site was 3, 809.27 mg/l. The measured BOD value was considerably higher than the standard limit. BOD value varies according to the age of landfills. For new landfills, BOD values were 2000-30000 mg/l (Bhalla *et al.,* 2012).

COD represents the amount of oxygen required to completely oxidize the organic waste constituents chemically to inorganic end products (Naveen *et al.,* 2014). The COD value for the leachate sample of the landfilling site was 23, 264 mg/l. The measured COD values were considerably higher than the standard limit. The young landfill leachate is commonly characterized by high chemical oxygen demand (COD) of 30,000–60,000 mg/L (Li *et al.,* 2010). In this study, the BOD5/COD ratio for the collected leachate samples of the landfilling site was 0.16. It indicates that the landfill in Pagalungan is at a young age (<5 years). Generally, the BOD5/COD ratio describes the degree of biodegradation and gives information on the age of a landfill. The low

BOD5/COD ratio shows the high concentration of non-biodegradable organic compounds and, thus, the difficulty of being biologically degraded (Bhalla *et al.,* 2012).

Oil and grease

Oil and grease content in the leachate of the sampling site was 48 mg/l. The value is higher than the standard limit. The oil and grease layer reduces the biological activity of the treatment process, where oil film forms around microbes in suspended matter and water. This lead to decrease dissolved oxygen levels in the water (Abd El-Gawad, 2014).

Ammoniacal nitrogen (NH3-N)

Ammoniacal nitrogen (N-NH3) in leachate is higher than the standard limit of 0.5 mg/l at 472 mg/l. Slow leaching of wastes producing nitrogen and no significant mechanism for the transformation of N-NH3 in the landfills causes a high concentration of ammoniacal nitrogen in leachate over a long period of time (Aziz *et al.,* 2004). It has been identified as the major toxicant which causes toxicity to most organisms (Aziz *et al.,* 2004).

Reactive phosphate and nitrate

Reactive phosphate content in the landfilling site exceeds the standard limit of 1 mg/l with 23.8 mg/l. The phosphorus concentration detected by means of molybdenum-blue colorimetry is called, from an environmental aspect, 'dissolved reactive phosphorus (DRP) (Matula, 2011). Phosphorus is one of the key elements necessary for the growth of plants and animals and is a backbone of the Krebs' Cycle and Deoxyribonucleic acid (DNA) (Naveen *et al.,* 2014). The nitrate value for leachate at the landfilling sites was 0.09 mg/l. The measured nitrate value was considerably lower than the standard limit. Bhalla *et al.* (2012) stated that microbial decomposition of organic carbon influences many processes of the nitrogen cycle. With time, nitrogen concentration decreased due to microbial utilization of nitrate compounds and denitrifying as ammonia gas. Nitrates are the primary contaminant that leachesinto groundwater.

Heavy metals

The cadmium, lead and mercury values for leachate at the landfilling sites were < 0.002 mg/l, < 0.044 mg/l, and < 0.0015mg /l, respectively. The measured heavy metal values were considerably lower than the standard limit. The concentration of heavy metals in a landfill is generally higher at earlier stages because of higher metal solubility as a result of low pH caused by the production of organic acids. On the other hand, the metal content comes down during the fermentation and maturation phases, where the pH increases to neutral (Yusmartini *et al.,* 2013). But maybe the heavy metals concentration was in trace amounts as the waste is domestic in nature (Bhalla *et al.,* 2012)

Conclusion

Based on the result of the study, the leachate sample contains a high concentration of organic and inorganic constituents beyond the permissible limits. High ammonia concentrations can lead to the disruption of water bodies such as wells or shallow groundwater. Although the metal content and effluent from the landfill still meet the applicable quality standards, leachate from the landfill is still a major source of environmental pollution from heavy metals. The pH of the leachate in the Pagalungan landfill is considered as acidic as the pH is 6.47. BOD5 and COD of the leachate are 3, 809.27 mg/L and 23, 264 mg/L, respectively. The results showed that the highest metal concentration that exists in the leachate was lead, with less than 0.044 mg/l concentration. In contrast, heavy metals concentration was in trace amounts as the waste is domestic in nature. The BOD_3 / COD ratio suggested that the landfill leachate is young-aged leachate.

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