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Environmental impact of sanitary landfill to the groundwater and surface water quality

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ABSTRACT

A sanitary landfill is an engineered waste management strategy wherein dumped wastes have been completely degraded biologically, chemically, and physically. However, issues on the production of leachate and gases are still observed that posed potential threats to human health and environmental quality. This study assessed the environmental impact of sanitary landfills on groundwater and surface water quality of deep wells, springs, and rivers. Grab water sampling technique was used to get the water samples from the selected water bodies within one (1) kilometer radius of the sanitary landfill. Then, water samples were analyzed in the accredited laboratory. The quality of water parameters during dry and wet seasons was compared to the PNSDW, WHO, DENR DAO 2016-08 standards. The study's findings revealed that most of the physicochemical parameters of the surface and groundwater are still in good quality. However, TDS of DW2, the turbidity of DW3 taken from groundwater samples, and TDS of the spring water samples have failed from its permissible limits during the wet season. The water quality of both surface and groundwater are still good and free from leachate contaminations. The study may conclude that sanitary landfill at present has a less damaging impact on the water quality of the water bodies within the area. Lastly, the study strongly recommends the continuously implement their effective and efficient management of the sanitary landfill and observance of the RA 9003 and policies be consciously observed to avoid tragic public health risk and adverse environmental impacts.

Key words*: Sanitary landfill, Water quality, Groundwater, Surface water, Environmental impact*

Introduction

It is undeniable that population growth, urbanization, and industrialization contribute to the increasing generation of waste per capita, and this has become one of the major problems of a city, country, or even worldwide (Nabavi-Pelesaraei *et al.*, 2017; Pandey and Tiwari, 2013; Mohan and Gandhimathi, 2009). The rapid population growth contributing to a large quantity and variety of municipal solid wastes had significantly led to social and environmental problems.

According to Umutesi *et al.* (2018), solid waste management is one of the government's big concerns. It involves both the logical planning and scientific knowledge with the cost-effective process yet cannot balance the impact on the environment. The different countries of both developed and developing have several various waste management practices that may differ from one another, especially in their urban and rural areas (Umutesi *et al.*, 2018; Musbah Swesi *et al.*, 2019 and Abdel-Shafy and Mansour, 2018). Iqbal *et al.* (2020) stressed that the MSW is directly burned or dumped openly or into the landfill, most specifically in developing countries where these MSW practices are observed, and MSW disposal is considered a problem due to several reasons (Kahirun *et al.,* 2019; Al-Khatib *et al*., 2007).

On the other hand, Borden *et al.* (1990), sanitary landfilling was believed as a safe, efficient, and environmentally sound method of solid waste management. Similarly, based on the study of Ireaja *et al.* (2018), sanitary landfill, among other waste disposal methods, has been proven to be the most effective method to manage waste. It reduces the threat to human health and the entire ecosystem because it is designed, constructed, and operated so that the contained solid wastes will not cause potential hazards to public health or the environment. However, although sanitary landfills are designed and constructed to prevent leakage of leachate and other harmful substances still leachate leakage may happen due to damage to its geomembrane during the construction and operation (Xiang *et al.,* 2019). According to Dan *et al.* (2017) and Xiang *et al.* (2019), landfill leachate contains many toxic and harmful substances like heavy metals, POPs, and bacteria that may cause groundwater pollution. The primary risk of leachate from the landfill is its infiltration into the groundwater and surface water, leading to water and soil pollution (Alizadeh *et al.*, 2018). Groundwater is a valuable resource primarily used for domestic, agricultural, and industrial purposes, and it is an important natural resource that should be accessible and protected from pollution (Akinbile, 2012 and Umutesi *et al.*, 2018).

In the Philippines, the sanitary landfill establishment is mandated under the Republic Act 9003, known as the Ecological Solid Waste Management Act of 2000. According to Mendoza *et al.* (2017), there are about 960 sanitary landfills in the country, 936 are controlled, and others are open dumps. However, the local government units find difficulty complying with the landfills' required standard operation due to lack of funds and technical assistance (UNDP-EMB, 2009 as cited by Mendoza *et al.,* 2017). It is still a big pressing problem in implementing solid waste management (SWM) of the Philippines due to the high cost of management and lack of enabling agencies. Undeniably, municipal solid waste management (SWM) mismanagement may cause severe environmental and social impacts that may hinder the attainment of healthy and sustainable living of community people (Ferronato and Torretta, 2019).

In a local context, the Calbayog City Sanitary Landfill is one of the three sanitary landfills in the entire region of Eastern Visayas, Philippines. This landfill was built in 2007 and fully operationalized in 2010 that initially catered to 22 villages only. After ten years of operations in 2017, the landfill expanded its service area to almost 90 out of the city's 157 villages, which collected an average waste volume of 80 to 90 tons per day. According to the City Solid Wastes Management Office records, the waste generated of Calbayog City is 7, 115.40 tons in 2019. Conversely, the city's sanitary landfill has been operating for more than a decade; no studies have been conducted on the landfill's environmental and social impact since it started operation. Thus, this study aimed to assess the sanitary landfill's environmental impact on groundwater and surface water quality. Furthermore, the researchers believe that the study's findings could help local officials and urban planners formulate policies for more effective waste management and health risks prevention plans of the city.

Materials and Methods

Study Site

The study was primarily conducted in Calbayog City sanitary landfill and its water bodies within a one-kilometer radius. This sanitary landfill is managed by the local government unit of Calbayog City and specifically under the solid waste management office. The sanitary landfill has a total land area of 5.928 hectares, 11.345 km away from Calbayog proper. It is situated approximately 12º04'46 N latitude and 124º31'42 E longitude on Samar, Philippines. The elevation is measured 3.20 m above the mean sea level at these coordinates. The sanitary landfill is located in Brgy. Dinagan is about twelve kilometers north away from the city proper. It is about 500 meters away from the Jibatang River, and it is an agricultural area within a hilly portion that forms a depression on which ideal for landfilling.

The sampling sites of the study were conducted in the four (4) adjacent communities along with Calbayog Sanitary Landfill: the Barangay Dinagan with 12.1220 N latitude and 124.5245 E longitude; Barangay Amampacang with 12.1004 N latitude and 124.5225 E longitude; Barangay Anislag with 12.1062 N latitude and 124.5327 E longitude; and

Barangay Begah o with 12.1192 N latitude and 124.5377 E longitude. The map of the study site is shown in Figure 1.

Water Samples Collection

The Philippines has two major seasons: (1) the rainy/wet season, from June to November, and (2) dry season, from December to May. Thus, the researchers conducted the water sampling twice, which was in November 2019 for the rainy/wet season and last January 2020 for the dry season. Moreover, the researchers adopted the DENR-EMB Water Quality Monitoring Manual in water sampling and the protocol used by Lagbas and Habito (2016). Water samples in deep wells were collected between 4:00 AM to 6:30 AM. Six (6) 1,500 mL water samples were collected using a disinfected plastic bucket. Polyethylene bottles were rinsed with water samples three times before they were filled. The emptied PET distilled water bottles with caps were used to collect water samples sterilized for 30 minutes before usage. These water samples were used for the analysis of the physicochemical characteristics of the deep well waters. Then, the grab sampling technique was used in getting water samples from the Jibatang River and springs following the protocol of the DENR-EMB in a water quality monitoring manual for freshwater bodies. Table 1 presents the location of the sampling sites of the study for water quality assessment.

Laboratory Analysis for Physicochemical Parameters of Water Samples

The water samples were analyzed with the physicochemical parameters such as chloride (Cl-), sodium (Na+), nitrate (NO^-_3), pH, total dissolved solids (TDS), and turbidity. All the water samples were subjected to laboratory analysis at the Ostrea Mineral Laboratory, Mandaue City, Cebu, Philippines. Following the protocol in handling the water samples, it was kept in an ice-chilled box delivered to the accredited laboratory within 24 hours after the water samples were collected.

The groundwater samples' test results were compared with the standards set by the Department of Health (DOH) Administrative Order No. 2007-0012 and World Health Organization (WHO) Guidelines for Drinking Water of 1997. While the surface water samples were compared with the Department's standards to Environment and Natural Resources (DENR) through DENR AO No. 2016-08 for freshwater parameters.

Results and Discussion

Groundwater Quality

The analysis of the groundwater samples is shown in Table 2. All the groundwater samples' measured parameters have are within the permissible limit or standards of the PNSDW and WHO, except for TDS of DW2 and DW3's turbidity during the wet season

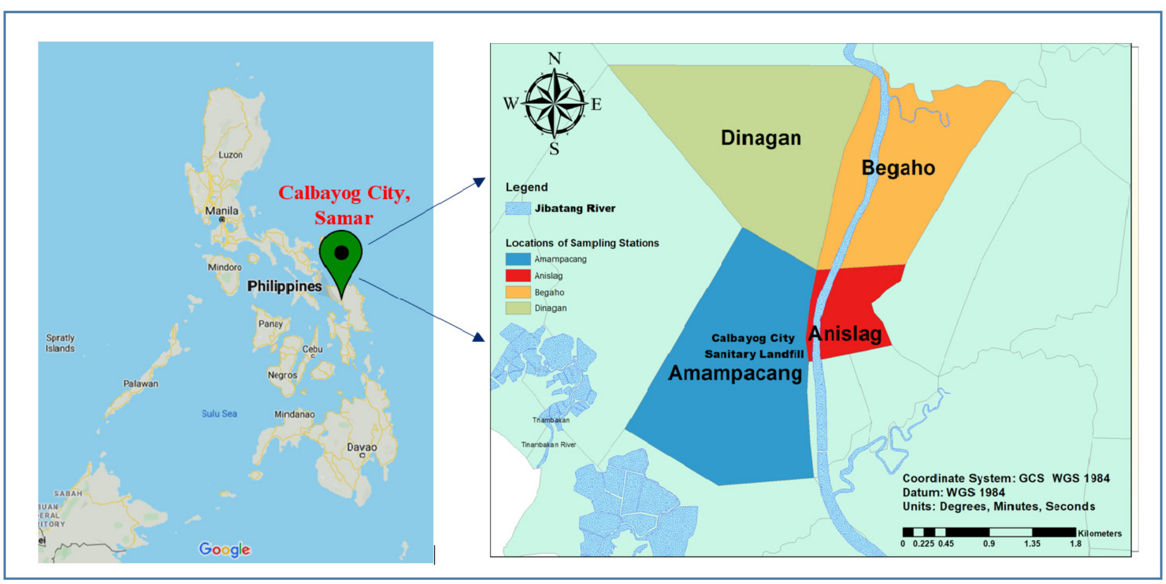

Figure 1. Map of Calbayog City, Samar, Philippines, indicating the sanitary landfill and sampling areas of the study.

exceeded the standard.

The chloride and sodium contents of the groundwater samples are within the permissible limit or standard. Chloride and sodium not usually harmful to people yet served as essential nutrients (Raman and Sathiya Narayanan, 2008); however, it has been linked to heart and kidney disease. Sodium chloride of 250 mg/L may impart a salty taste for humans (Raman and Sathiya Narayanan, 2008), and it is a desirable limit. According to Akinbile (2012) and Gwisai *et al.* (2019), the high presence of chloride and sodium is pollution indicators. The water is advised to be treated before use for potability.

Nitrate is considered as one of the contaminant indicators for water. The excess nitrate level may affect infants (blue baby disease) but not directly older children and adults. Nitrate in groundwater originates from fertilizers, pesticides, septic systems, sewage, and manure storage (Raman and Sathiya Narayanan, 2008 and Mendoza *et al.,* 2017). Based on the analysis, the nitrate level of the water samples is within the permissible limit. On the other hand, the water groundwater samples' pH level is almost neutral, as shown in the table. This data means that groundwater in the area suitable for drinking (Gwisai *et al.,* 2019) and free from toxic chemicals (Akinbile, 2012) as looking for the pH indicator alone. TDS is considered an indicator of the aesthetic quality of drinking water and an aggregate indicator of a broad array of chemical contaminants (Raman and Sathiya Narayanan, 2008). Among the values of the TDS of the water samples, it is only DW2 during the wet season that failed from the allowable limit of TDS. It shows that it is a rainy season that deep well contains several chemical contaminants that could probably originate from runoff water came the sanitary landfill as leachate migration is assumed. According to Mendoza *et al.* (2017), TDS is an indicator of high water hardness, unpalatability, and mineral deposition. A high concentration of TDS decreases the palatability of water and may cause gastrointestinal irritation in human and laxative effects (Pandey and Tiwari, 2013). Akinbile (2012) stated that the high turbidity presence unlined and disinfection of the water is recommended (WHO, 2017 as cited by Contruvo, 2017). With the samples analyzed, DW3 during the wet season failed from the standard limit of PNSDW and WHO. It indicates that the deep well water (DW3) contains suspended materials that decrease the passage of light because it is somehow murky (Migo *et al*., 2018 and Mendoza *et al.,* 2017).

Generally, the physicochemical parameters of groundwater samples that are taken from the deep wells within the one-kilometer radius of the sanitary landfill conform to the water quality standards set by the PNSDW and WHO. Except for TDS of DW2 and turbidity of DW3 during wet seasons,

Table 1. Location of Sampling Sites for Water Quality Assessment of the Groundwater and Surface Water

Sampling Stations	Location	Geographical Coordinates
Groundwater		
Deep Well 1	Inside the vicinity of Sanitary Landfill	12º6′14"N, 124º31′25"E
Deep Well 2	Barangay Amampacang	12º5′40"N, 124º31′12"E
Deep Well 3	Barangay Begaho	12º7′14"N, 124º32′10"E
Surface Water		
Spring 1	Inside the vicinity of Sanitary Landfill	12º6′14"N, 124º31′25"E
Spring 2	Barangay Dinagan	12º7′15"N, 124º31′30"E
Jibatang River	Barangay Anislag	12º6′3"N, 124º31′49"E

Table 2. Physicochemical parameters of groundwater water samples from the different sampling sites

Parameters	Wet Season			Dry Season			PNSDW	WHO
	DW1	DW2	DW3	DW1	DW2	DW3	2007	1997
Chloride, mg/L	27.00	127.30	14.00	23.80	183.40	22.80	250	300
Sodium, mg/L	16.07	149.57	27.79	9.86	174.15	22.88	200	200
Nitrate, mg/L	0.23	1.73	0.28	0.29	0.31	0.24	50	50
pH	7.10	7.30	7.60	7.02	7.28	7.60	6.5-8.5	6.5-9.2
TDS, mg/L	312.00	**984.00**	428.00	0.00	5.50	2.60	600	500
Turbidity, NTU	0.38	0.71	**13.13**	0.00	5.50	2.60	5.0	4.0

which can be associated with surface runoff during precipitation runs over the groundwater sites. However, during the dry season, all the water parameters are within the permissible limits. This observation is the same as the study of Mendoza (2012). This data can be concluded that deep well water is safe for drinking. Still, disinfection is recommended to kill bacteria's presence, maybe by boiling or by the filtration process.

Surface Water Quality

Table 3 shows the water samples' physicochemical parameters taken from the surface water within the one-kilometer radius of the sanitary landfill, such as springs and its adjacent Jibatang River.

The laboratory analysis of the surface water samples and its physicochemical parameters have almost passed the DENR standards for water quality guidelines, specifically on freshwater.

The parameters such as chloride, sodium, nitrate, pH, TDS, and turbidity are within the permissible limits of the DENR AO 2016-08 in both wet and dry seasons, except for the TDS level of the water during the rainy or wet season. The high TDS level of the surface water from springs and rivers can be attributed to the surface runoff during precipitation runs over the groundwater sites. However, during the dry season, all the water parameters are within the permissible limits. The study of Gwisai *et al.* (2019) does not conform to the present study because, in their research, the water parameters of the surface waters in the Gaborone sanitary landfill have exceeded the allowable limits. The study of Gaborobe significantly denotes that there are probable impacts of the sanitary landfill on the water quality of the surface waters around on it. It also indicates that the level of heavy metals contamination is present in the surface waters.

By and large, the surface waters around or within the sanitary landfill are safe for recreational, agricultural, and domestic purposes except for drinking for health safety reasons. In 2010, the DENR-EMB classified the Jibatang River as a class Type C river. This means that the intended beneficial uses of the Jibatang River as type C served as fishery water for aquatic resources' propagation and growth, recreational, agricultural, irrigation, and livestock watering. However, dissecting the present laboratory analysis of the surface water can be classified as Class B, which allows the river's recreational activities not to limit boating and fishing. Still, it is good for bathing and swimming; in fact, community people and individuals living along the river are doing those activities since then.

Furthermore, it can be clinched from the study that sanitary landfill has no damaging impact on the water quality of the surface water bodies. However, regular inspection and monitoring of the sanitary landfill is advisable due to the potential threat that leachate contamination can drive to an adverse effect on the environment, community, and most especially to groundwater and surface water bodies (Przydatek and Kanownik, 2019).

Conclusion and Recommendations

With the present analysis of the study, it can be concluded that the sanitary landfill of Calbayog City has less or minimal impact on the surface and groundwater quality because the water quality of both surface and groundwater are still good and free from leachate contaminations. This study further concluded that the city's solid waste management office had effectively and efficiently managed the sanitary landfill for over ten years of operation. The present study strongly recommends the more continuous effective, efficient management of the sanitary landfill and strict observance of the RA 9003 and policies, specifically on sanitary landfills. These measures would avoid and curtail tragic pub-

Table 3. Physicochemical parameters of surface water samples from the different sampling sites

Parameters	Wet Season			Dry Season			DENR 2016	DENR 2016	DENR 2016
	SW1	SW2	JR	SW1	SW2	JR	(Class A)	(Class B)	(Class C)
Chloride, mg/L	20.00	13.00	3095.20	22.30	9.50	475.00	250	250	350
Sodium, mg/L	13.25	37.42	2409.34	19.39	12.30	234.34	200	200	200
Nitrate, mg/L	0.37	0.19	0.30	0.25	0.28	0.26	7	7	7
pH	7.10	7.90	7.80	7.69	6.95	7.19	6.5-8.5	6.5-8.5	6.5-9.0
TDS, mg/L	**194.00**	**280.00**	**8640.00**	5.00	0.00	15.10	50	65	80
Turbidity, NTU	34.12	4.17	4.96	5.00	0.00	15.10	50	50	75

lic health and environmental impacts and attain sustainable development of the city and, most especially, for the communities living within reach of the landfill for their healthy and sustainable living. Lastly, the researchers suggest that other significant parameters of water quality monitoring, leachate quality assessment, and assess the operations of the landfill in accordance to the implementing rules and regulations of the Philippine RA 9003 and social impact will be included for further research for more intensive assessment of the sanitary landfill.

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