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Effect of distance from the Cagayan de Oro, Philippines, dumpsite on the groundwater quality of shallow dug wells

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Abstract: Leachate from dumpsites is generated as a result of the contact of water, during precipitation, with solid wastes. In this study, selected physical and chemical parameters of water were compared in the areas near and far from the dumpsite. Findings showed that the proportion of sampled wells that yielded poor in color was not significantly different in both near and far from the dumpsite areas; but, the levels of turbidity were observed to be significantly poor in the areas far from the dumpsite. On the chemical parameters of water, the proportion of sampled wells that yielded poor in TDS was significantly higher in the areas far from the dumpsite compared to the areas near the dumpsite. The chemical parameters pH, sulfate, chloride, and nitrate of the groundwater in wells were within the permissible limits of Philippine National Standards for Drinking Water (PNSDW). With these assessments of groundwater quality understudied, it is recommended that further study, with an appropriate plan and design, on the hydrogeological formation of the dumpsite be conducted and trace the flow of leachate.

Key words: Groundwater; Water quality; Dug wells; Dumpsite; Leachate; Solid waste

1. Introduction

The dumpsite of Cagayan de Oro is located near the city proper and has been actively operating since 1975. It has no linings and the potential of the leachate to migrate into the surrounding soil is alarming. In consequence, the underlying soil and the groundwater sources can be at risk of being contaminated. The unfavorable condition of groundwater sources contaminated by pollutants and the subsequent protection of groundwater sources have become a point of vital interest of this study as safe groundwater sources are the key to having a healthy well-being. Previous studies (Mor et al., 2006; Sia Su, 2008) have indicated that dumpsites contribute to the contamination of the quality of water sources way beyond the permissible limits set by WHO for drinking water. However, a different study (Longe et al., 2010) indicated that the distance of water sources to dumpsites, whether near or far, may have no differences on the quality of the water sources. Therefore, this study aims to assess the groundwater quality of areas that are situated near and far from the Cagayan de Oro dumpsite. No widely disseminated information on the effect of distance from the dumpsite on the groundwater quality of shallow dug wells of Cagayan de Oro City is available.

2. Materials and methods

2.1. The Study Area

As seen in Fig. 1, Cagayan de Oro City is geographically nestled between the central coastline of Macajalar Bay to the north and the naturally-rich plateaus and mountains of Bukidnon and Lanao del Norte to the south. The city has only one dumpsite located at the most populous area, Sitio Zayas, Brgy. Carmen (Fig. 2). The dumpsite has a 13-hectare area, located 8°28'34"N and 124°37'10"E. The base of the dumpsite is unlined. The dumpsite is right beneath the watershed. The only surface water that passes through the site is the runoff caused by rains.

Fig. 1: Map of the location of Cagayan de Oro City, Philippines.

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Fig. 2: Map of the location of the dumpsite at Sitio Zayas, Carmen, Cagayan de Oro, Philippines.

2.2. Collection of samples

In an effort to study the quality of groundwater in the areas near and far from the dumpsite, repeated cross-sectional descriptive study was used. There were 14 wells in the areas near the dumpsite and 17 wells in the areas far from the dumpsite sampled in this study (Fig. 3). The sampled area is within 2.0 kilometers from the dumpsite at the western and eastern sides of Cagayan de Oro River. In this study, privately-owned wells were not included. Dug wells included in this study were continuously or actively used as sources of drinking water and for other domestic purposes, found downstream of the Cagayan de Oro controlled dumpsite, and not undergoing or not have undergone any chemical treatment.

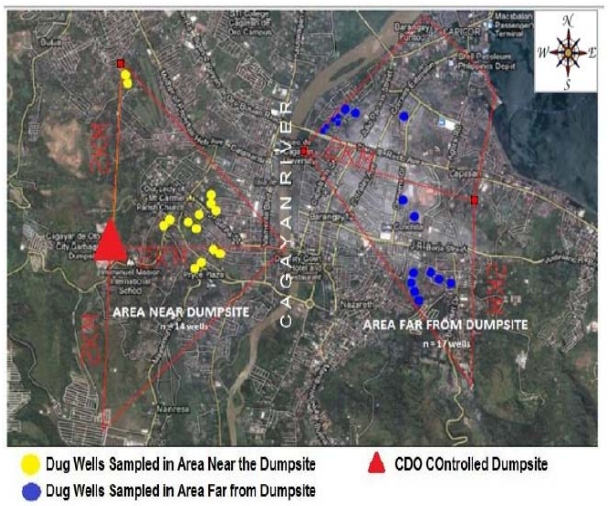

Fig. 3: Map showing the distribution of dug wells sampled in the areas near the dumpsite and far from the dumpsite

"Grab water sampling" was performed on all dug wells. The selected physical parameters were color and turbidity whereas the chemical parameters were pH, TDS, sulfate, chloride and nitrate. Collection and analysis of water samples were repeatedly done, once a month for six consecutive months, covering both wet and dry seasons. In the analysis of parameters, duplicate samples were tested and read in triplicate. The criteria for interpreting results of the physical and chemical quality of selected parameters were obtained from the Philippine National Standards for Drinking Water.

2.3. Analysis of data

The descriptive analysis provides a summary of data that gives the overview of the characteristics of dug wells under study. On the other hand, there were sufficient wells sampled that yielded poor in color, turbidity and TDS, the data of these selected parameters were subjected to inferential analysis. The inferential analysis estimated the magnitude of association of these selected water parameters with location, season and linings.

3. Results and discussion

The sampled wells were "dug" with depths ranging from 5 to 16 feet. In the total sample of 31 wells, 14 (45%) of these are in the areas near the dumpsite while 17 (55%) are in the areas far from the dumpsite (Table 1). On the other hand, less than half of the sampled wells in the study are with no linings (45%). The others are with linings (55%). About 57% of the wells in the areas near the dumpsite are with linings while 53% of the wells in the areas far from the dumpsite are with linings.

Table 1: Distribution of the sampled wells according to the location and linings

Variables	No. of Wells	%
Location		
Near the Dumpsite	14	45
Far from the Dumpsite	17	55
TOTAL	31	100
Linings		
No Linings	14	45
With Linings	17	55
TOTAL	31	100

As shown in Table 2, about 61% and 39% of the wells sampled have exceeded the permissible limits for color and turbidity, respectively. In Table 3, about 55% of the wells sampled had exceeded the permissible limits for TDS. On the other hand, 3% of the wells sampled had exceeded the standard for sulfate.

Table 2: Distribution of the sampled wells according to color and turbidity

Parameters	No. of Wells	%
Color		
≤10.0 ACU	12	39
>10.0 ACU*	19	61
TOTAL	31	100
Turbidity		
≤5.0 NTU	19	61
>5.0 NTU*	12	39
TOTAL	31	100

*poor levels according to PNSDW (2007)

Table 3: Distribution of the sampled wells according to the selected chemical parameters of water

Parameters	No. of Wells	%
pH		
0-6.49*	0	0
6.50-8.50	31	100
8.51-14.00*	0	0
TOTAL	31	100
TDS		
≤500.0 mg/L	14	45
>500.0 mg/L*	17	55
TOTAL	31	100
Sulfate		
≤250.0 mg/L	30	97
>250.0 mg/L*	1	3
TOTAL	31	100
Chloride		
≤250.0 mg/L	31	100
>250.0 mg/L*	0	0
TOTAL	31	100
Nitrate		
≤50.0 mg/L	31	100
>50.0 mg/L*	0	0
TOTAL	31	100

*poor levels according to PNSDW (2007)

As shown in Table 4, there was no significant difference noted for color among the well waters in the areas near and far from the dumpsite (p>0.10). However, the results suggest that the season and the linings are probable confounders (p<0.25). The stratified analysis showed that neither the season nor the linings are effect measure modifiers (Table 5). In the full model (Table 6), the season is a significant confounder. When season was taken out from the model, the direction of the bias is leaning towards the null which implies that season confounds the relationship between the location of the wells from the dumpsite and the color of the well waters.

Table 7 presents that the proportion of sampled wells with poor turbidity levels is significantly higher in the areas far from the dumpsite compared to the areas near the dumpsite (p≤0.10). However, the crude analysis suggests that the season and the linings were not probable confounders. In Table 8, results specify that neither the season nor the linings are effect measure modifiers. However, there is an association in the levels of turbidity among wells with linings and the location of the wells from the dumpsite (OR 0.07; CI 0.01-0.96). As shown in the model (Table 9), the effect measure of location of wells from the dumpsite to the levels of turbidity among those wells with linings (OR 0.12; 90% CI 0.03-0.44) is lower than those wells with no linings (OR 0.56; 90% CI 0.14-2.22).

Table 4: Crude association of color with location, season and linings

Parameter	% Poor	OR (90% CI)	p-value
Color			
Location			
Near The Dumpsite	50	0.67 (0.29 – 1.55)	0.43
Far From Dumpsite	71		
Season			
Wet	16	0.05 (0.02 – 0.14)	0.00PC
Dry	81		
Linings			
No Lining	50	0.42 (0.12 – 1.44)	0.25PC
With Lining	71		

OR – odds ratio, CI – confidence interval, PC – probable confounder (p≤0.25)

Table 5: Association of color with location of wells from the dumpsite stratifying for season and linings

Parameter	Strata Specific Or	90% Ci	Test For Homogeneity P-Value
Color			
Season			
Wet	0.78	0.15 – 4.11	0.55
Dry	0.33	0.06 – 1.71	
Linings			
No Lining	1.0	0.16 – 6.32	0.23
With Lining	0.13	0.01 – 1.36	

OR – odds ratio, CI – confidence interval

Table 6: Result of the assessment of confounding for the association of color with location of wells from the dumpsite

MODELS	OR	% Change
location + season + lining	0.49	-
location + season	0.49	0%
location	0.67	37%

OR – odds ratio

Results suggest that the effect of the location of wells from the dumpsite was modified by the linings of the well. This implies that the turbidity levels of water in wells with linings from the areas near the dumpsite are better in terms of quality compared to the water in wells with linings from the areas far from the dumpsite.

Table 7: Crude association of turbidity with location, season and linings

Parameter	% Poor	OR (90% CI)	P-Value
Turbidity			
Location			
Near The Dumpsite	21	0.24 (0.09 – 0.62)	0.01[s]
Far From Dumpsite	53		
Season			
Wet	35	0.76 (0.32 – 1.80)	0.60
Dry	42		
Linings			
No Lining	36	0.79 (0.23 – 2.70)	0.76
With Lining	41		

OR – odds ratio, CI – confidence interval, S – significant (p≤0.10)

Table 8: Association of turbidity with location of wells from the dumpsite stratifying for season and linings

Parameter	Strata Specific Or	90% CI	Test For Homogeneity P-Value
Turbidity			
Season			
Wet	0.15	0.03 – 0.77	0.49
Dry	0.36	0.09 – 1.33	
Linings			
No Lining	0.83	0.12 – 5.77	0.17
WITH LINING	0.07	0.01 – 0.96	

OR –odds ratio, CI – confidence interval

Table 9: Result of the assessment of effect measure modification for the association of turbidity with location of wells from the dumpsite

MODEL	OR	CI
location + location*lining		
location + no lining	0.56	0.14 – 2.22
location + with lining	0.12	0.03 – 0.44

OR – odds ratio, CI – confidence interval

In Table 10, the proportion of sampled wells with poor TDS is significantly higher in the areas far from the dumpsite than in the areas near the dumpsite (p≤0.10). Results also revealed that the season and the linings are probable confounders (≤0.25). The stratified analysis showed that neither the season nor the linings are effect measure modifiers (Table 11). In the full model (Table 12), results suggest that the variable "linings" is not a confounder. When the variable "season" was retained in the model, the difference in the odds ratios is more than 10%. Thus, the variable "season" is a confounder.

Apparently, results showed that the quality of some physical and chemical parameters of water was unfavorable in the areas near the dumpsite rather than in the areas far from the dumpsite. The poor groundwater quality of wells in the areas far from the dumpsite might be due to the proximity of the wells to the coastal zone, which further inferred saline intrusion. This probability could be based on the presence of chloride in the groundwater which indicates an imbalance between fresh water and salt water in coastal aquifers (Barlow, 2005). Furthermore, the imbalance might be caused by excessive groundwater withdrawals and other human activities that lower groundwater levels or reduction of fresh groundwater flow to coastal waters. Shallow aquifers near coastal areas are enriched with chloride and sodium (Laluraj et al., 2005). Water that passes through soils high in soluble salts or minerals also have higher TDS levels (SEHSC, 2009). This condition explains the high concentration of TDS among the well waters obtained along the areas far from the dumpsite. More findings (Mor et al., 2006; Laluraj et al., 2005) indicated that the pH levels of groundwater from shallow wells along coastal areas ranged from 7.01 to 8.20 which were characterized as basic.

Some uncontrollable confounders might have influenced the increased concentration of the selected physical and chemical parameters among well waters in the areas far from the dumpsite. These include the absence of septic tanks in the areas and the anthropogenic activities done beside the well. Since the population in the areas far from the dumpsite is dense, large inputs of organic suspended wastes from domestic use, usually humics, to the well waters are expected (EPA, 1998).

The high turbidity levels and TDS concentrations of the well waters might be caused by the presence of the organic matters (EPA, 1998) that come from domestic sewage which discharge might have contributed to the increased production of nitrate in the well waters (Sia Su, 2008). Domestic activities like washing clothes and bathing beside the well by local residents in the areas far from the dumpsite might have likewise contributed to the increased concentrations of sulfates in the well waters. The use of household detergents increases the concentrations of sulfate in groundwater sources (Li et al., 2006).

Table 10: Crude association of total dissolved solids (TDS) with location, season and linings

Parameter	% Poor	OR (90% CI)	p-value
TDS			
Location			
Near The Dumpsite	43	0.30 (0.13 – 0.73)	0.03[S]
Far From Dumpsite	65		
Season			
Wet	61	2.19 (0.93 – 5.14)	0.13[PC]
Dry	42		
Linings			
No Lining	43	0.41 (0.12 – 1.38)	0.23[PC]
With Lining	65		

OR – odds ratio, CI – confidence interval, S – significant (p≤0.10), PC – probable confounder (p>0.25)

Table 11: Association of total dissolved solids (TDS) with location of wells from the dumpsite stratifying for season and linings

Parameter	Strata Specific Or	90% CI	Test For Homogeneity P-Value
Tds			
Season			
Wet	0.42	0.11 – 1.51	0.51
Dry	0.19	0.04 – 0.83	
Linings			
No Lining	0.50	0.07 – 3.46	0.73
With Lining	0.29	0.04 – 1.90	

OR – odds ratio, CI –confidence interval

Table 12: Result of the assessment of confounding for the association of TDS with location of wells from the dumpsite

MODELS	OR	% Change
location + season + lining	0.25	-
location + lining	0.27	8%
location + season	0.29	16%
location	0.30	20%

OR – odds ratio

The association between turbidity levels and location of wells from the dumpsite was determined by the protective effect in wells with linings on turbidity levels in the areas near the dumpsite (OR 0.12; 90% Cl 0.03-0.44). Based on ocular inspection, the linings of most wells in the areas near the dumpsite were intact than those linings constructed in the areas far from the dumpsite. Hence, the sediments of soil are stable and soil erosion is prevented in the wells with properly constructed linings. Soil erosion can greatly contribute to the high levels of turbidity in the well waters. The inner linings of the wells serve to protect the well waters from soil erosion (UNEP, 1998).

4. Conclusion

In the analysis of the physical parameters of water, focusing on color and turbidity revealed that there is no association between the location of wells from the dumpsite and the color of the groundwater. On the other hand, there is an association between the location of wells from the dumpsite and the turbidity levels of the groundwater. Results revealed that the proportion of wells that yielded poor in turbidity is significantly higher among wells sampled in the areas far from the dumpsite than in the areas near the dumpsite.

In the analysis of the chemical parameters of water, this study concludes that there is an association between the location of wells from the dumpsite and the TDS levels of the groundwater. Results revealed that the proportion of wells that yielded poor in TDS levels is significantly higher among wells sampled in the areas far from the dumpsite than in the areas near the dumpsite. On the other hand, the mean concentration of pH, sulphate, chloride and nitrate of the groundwater in wells obtained from both areas was within the permissible limits set by PNSDW.

Based on the findings and insights of this study, the hydrogeological formation of the Cagayan de Oro dumpsite must be mapped and trace the flow of leachate with an appropriate plan and design. Also, linings of the wells must be properly constructed to assure their durability, stability and prevention from soil erosion in protecting and safeguarding the groundwater from intrusion of contaminants.

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