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Assessing the Effect of a Dumpsite to Groundwater Quality in Payatas, Philippines

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Abstract: The study assessed and compared the groundwater quality of 14 selected wells continuously used in the with (Payatas) and without dumpsite (Holy Spirit) areas at the Payatas estate, Philippines. Water quality monitoring and analyses of the bio-physico-chemical variables (pH, Total Suspended Solids (TSS), Total Dissolved Solids (TDS), total coliform, conductivity, salinity, nitrate-nitrogen, sulfate, color, total chromium, total lead and total cadmium) were carried out for six consecutive months, from April to September 2003, covering both dry and wet seasons. Results showed most of the groundwater quality variables in both the with and without dumpsite areas of the Payatas estate were within the normal Philippine water quality standards except for the observed high levels of TDS, TSS and total coliform and low pH levels. No significant differences were observed for nitrate-nitrogen, total cadmium, total lead, total chromium and total coliform in both the with and without dumpsite areas. TDS, conductivity, salinity and sulfate concentrations in the with dumpsite groundwater sources were significantly different compared to those in the without dumpsite areas. Continuous water quality monitoring is encouraged to effectively analyze the impact of dumpsites on the environment and human health.

Key words: Water quality, environmental assessment

INTRODUCTION

The 15-ha Payatas open dumpsite is within the Payatas estate located at the northeastern district of Quezon City, Philippines. The Payatas dumpsite is situated half a kilometer southeast of the Novaliches Reservoir, the main source of drinking water for Metro Manila. Garbage dumped and accumulated for several years at the Payatas open dumpsite had been identified as a potential threat to the metropolis water supply. Bacud *et al.*[1] reported that the acidification and the presence of nitrates and coliform bacteria found in the groundwater along the dump may be traced to the Payatas open dumpsite.

A study of the Smokey Mountain dumpsite (also in the Philippines) showed that 90% of drinking water samples obtained in its surrounding areas were found to be positive for bacterial contamination[2]. The presence and potential exposures of the community to groundwater contaminants may contribute to the predilection of human health impacts, from simple poisoning to cancer, heart diseases and teratogenic abnormalities. Although there have been no in-depth studies yet concerning groundwater quality along and within the Payatas dumpsite, many sectors, including some environmentalist groups, had expressed serious concerns that the Novaliches Reservoir is now contaminated with toxic substances beyond safe concentrations.

This study aimed to assess the quality of groundwater sources serving the selected communities situated in the with dumpsite and without dumpsite areas. This study also aimed to provide benchmark information on the extent of pollution brought about by the open dumpsite along groundwater sources of those selected areas.

MATERIALS AND METHODS

The community of Payatas was chosen to represent the with dumpsite simply because of the dumpsite that is situated in the area. As a control, the Holy Spirit community was chosen to represent the without dumpsite. These two communities are both situated within the Payatas estate. Prior to data collection, a selection criterion was established to aid in the identification of appropriate sampling stations for the groundwater quality assessment in both the with dumpsite and without dumpsite areas. The wells were selected based on the following criteria: (a) wells must be active and functional and continuously used for drinking and domestic purposes; (b) wells must be located away from toilets and piggeries; and (c) wells must not have undergone any chemical treatment. There were 22 wells identified, of which 14 were from the with dumpsite area and eight were from the without dumpsite area. Ten wells in the with dumpsite area and four wells in the without dumpsite area passed the selection criteria. Water sampling was then carried out in the 14 wells for six consecutive months, April to September 2003, covering both the wet and dry seasons.

Water samples were collected following the sampling procedures of Csuros[3] and were then examined in terms of bacteria and physical and chemical contents using the Standard Procedures of the American Public Health Association (APHA), American Waterworks Association (AWWA) and Water Environmental Foundation (WEF)[4]. The variables examined included total coliform count using the Swaroop's method[4], pH using the Suntex pH/ORP meter SP-2200 (Suntex Instruments Co., Ltd., Taipei, Taiwan), Total Suspended Solids (TSS) using the gravimetric determination[4], color determinations using the HACH spectrophotometer DR/2010 (HACH Company, Loveland, Colorado, USA) and Total Dissolved Solids (TDS) and conductivity using the HACH Conductivity-TDS meter (HACH Company). In addition, salinity was extrapolated from conductivity measurements; nitrate-nitrogen (NO_3-N) and sulfate (SO_4^{2-}) determinations were tested using the HACH spectrophotometer DR/2010 (HACH Company); and heavy metals, particularly total lead (Pb), total cadmium (Cd) and total chromium (Cr), were analyzed using the Shimadzu AA-65015 atomic absorption spectrophotometer (Shimadzu Scientific Instruments, Inc., Nakagyoku, Japan).

The groundwater quality criteria used for interpreting results were obtained from the 1990 Department of Environment and Natural Resources (DENR)-Environmental Management Bureau (EMB) Administrative Order No. 34 series of 1990 for Class A waters[5] and the 1993 Philippine National Drinking Water Guidelines of the Department of Health (DOH)[6]. Appropriate controls and standards and calibration curves were prepared for each of the variables that were tested. Duplicate samples were tested and read in triplicate.

Results of the water samples tested for bacteriological, physical and chemical examinations were analyzed for significant differences on the extent of environmental pollution in groundwater sources among the with dumpsite and without dumpsite areas using the t-test for unpaired observations. The t-test assumed that all the variables analyzed were normally distributed with a 95% significance level. As the t-test requires that variances be equal, Bartlett's test for homogeneity of variance was conducted to determine the equality of variances, whereas Satterthwaite's test was done to adjust the unequal variances. The null hypothesis for the t-test indicated no significant difference on water quality among the with dumpsite and without dumpsite areas, whereas the alternate hypothesis presented a significant difference on the water quality among the with dumpsite and without dumpsite areas. The test indicating $p<0.05$ could be a reason to conclude that the differences between areas were significant. Data were analyzed using the Statistical Package for Social Sciences (SPSS) software.

RESULTS AND DISCUSSION

The study areas are characterized as flatlands that rise to an elevation of about +95 mean sea level (msl) at the northwest margin of the Marikina River watershed. The with dumpsite area is positioned along the northeastern end of the Guadalupe Plateau Formation and at the eastern edge of the Novaliches Reservoir, whereas the without dumpsite area is along the northwestern ends of the Guadalupe Plateau Formation and at the western edge of the Novaliches Reservoir. The Guadalupe Plateau Formation is mainly composed of clastic facies, such as tuffaceous sandstone, conglomerate and coarse tuff. The soil type in both study areas is clay loam mixed with occasional layers of coarser material[7].

Groundwater quality assessment was done with 14 sampling points identified in both the with dumpsite and without dumpsite areas. Table 1 shows all sampling points assessed in terms of the following water quality variables: pH, TDS, TSS, color, conductivity, salinity, total Cr, total Pb, total Cd, total coliform, SO_4^2 and NO_3-N.

Results showed that total coliform exceeded the Philippine national drinking water standards set by the DOH[6] and the variables NO_3-N, total Cd, total Pb and total Cr were all within the prescribed limits of Class A waters of the Administrative Order 34 series of DENR-EMB[5]. The analyses have also shown that waters obtained from groundwater sources in both the with dumpsite and without dumpsite areas were slightly acidic and have high TSS. Well waters in the with dumpsite areas showed mean concentrations that were high in TDS, salinity, conductance, color and SO_4^2. Mean concentrations of well waters in the without dumpsite showed higher turbidity levels than those in the with dumpsite area.

Table 1: Mean concentrations and t test results of water quality variables obtained in the with dumpsite and without dumpsite areas for the months of April to September 2003

Parameter	Normal standard[a]	With dumpsite (n = 10)	Without dumpsite (n = 4)	t-test
NO_3-N (mg L^{-1})	10	3.36	2.23	0.062^{NS}
Total Cd (mg L^{-1})	0.01	<0.007	<0.007	0.928^{NS}
Total Cr (mg L^{-1})	0.05	<0.019	<0.013	0.114^{NS}
Total Pb (mg L^{-1})	0.05	<0.015	<0.015	0.900^{NS}
Total coliform (MPN 100 mL^{-1})	0^b	16	16	0.154^{NS}
pH	6.5-8.5	6.16	6.34	0.264^{NS}
Conductivity (µS cm^{-1})		1682.44	681.05	<0.001*
TDS (mg L^{-1})	1000	800.70	356.28	<0.001*
Salinity (mg L^{-1})		1084.70	435.43	<0.001*
Color (Pt Co)		68.82	60.18	0.546^{NS}
TSS (mg L^{-1})	50	1770.71	1355.60	0.377^{NS}
SO_4 (mg L^{-1})	250^b	69.06	17.23	<0.001*

[a]DENR-EMB[5], [b]DOH[6], p values: *, p<0.05; NS, not significant

Significant differences were noted for TDS, conductivity, salinity, SO_4^2 and turbidity in the with dumpsite and without dumpsite areas ($p<0.05$). No significant differences were noted for total Cr, total Pb, total Cd, total coliform and NO_3-N in groundwater sources in both areas.

Heavy metals in the well sources may be the result of domestic sewage containing heavy metals[8] discharged in the environment. This is likely the case in both the with dumpsite and without dumpsite areas because most households do not have septic tanks. Beck *et al.*[9] indicated that clayey soils contain more humus and, thus, retain and affect the availability of heavy metals in the environment. The low levels of heavy metals in the well waters in both study areas may be because of the presence of the soil organic matter, which may have combined with the toxic metal cations (i.e., Cr, Pb and Cd) and then reduced the availability of the toxic metals[10]. Beck *et al.*[9] likewise indicated that the organic matter present in the soil helps retain metals in the soil surface and, hence, prevents the leaching of the metals toward the groundwater.

The discharge of domestic sewage may have contributed to the production and occurrence of NO_3-N in the well waters of the study areas[11] indicated that NO_3-N concentrations in the groundwater might result from point sources such as sewage disposal. The range of results obtained for NO_3-N in both study areas did not vary, although certain stations showed high levels of NO_3-N in the well waters of the with dumpsite area. The varied levels of the NO_3-N in the well waters may be influenced by denitrification and the occurrence of precipitation. Well waters having low levels of NO_3-N in both study areas may be explained by the NO_3-N denitrification[12] by *Nitrosomonas* species and heterotrophic microorganisms, like *Escherichia coli*, *Aerobacter aerogenes, Bacillus subtilis, Aspergillus flavus* and *Penillium atrovenetum*[13]. The absence of oxygen in some deep well sources could have triggered the denitrification of NO_3-N in the water[14]; hence, low levels of oxygen were detected during the water analysis.

High levels of NO_3-N in the well waters are expected during the wet months because NO_3-N moves downwards as more amount of rainfall occurs. Ahuja[15] noted that chemicals at or near the soil surface could reach the groundwater zone due to factors like the increase in rainfall's kinetic energy, intensity, slope and permeability of the soil surface layer.

Results likewise showed higher color concentrations in the with dumpsite than those in the without dumpsite area. Higher color concentrations in the groundwater sources of the with dumpsite area are probably due to the input of domestic sewage, colored organic matter (primarily humic substances), metals, highly colored industrial wastes[16], or the presence of inorganic particulate matter in some groundwater sources[6]. There were no differences in the color concentrations in both study areas ($p>0.05$).

Varied pH levels in the well waters of both study areas, ranging from slightly acidic, neutral, to alkaline, may be partly attributed to the presence of an organic matter[10] and may be brought by the discharge of domestic sewage in the environment. Richardson[17] noted that low pH levels obtained in well waters may be traced to the acidity produced by organic wastes decomposing under partially reducing conditions into organic acids. It is likely that there were no differences in the pH levels of the well waters in both study areas ($p>0.05$) because the well waters were exposed to the deposition of acidic substances from the atmosphere. Sulfurous and nitrogenous gases emitted primarily from fossil fuel combustion and distributed by the atmosphere were deposited on the area, thereby affecting the water quality of the dug wells[18].

Levels of SO_4^2 were detected in most well waters in both study areas, with SO_4^2 concentrations ranging from 3 to 213.0 mg L^{-1}. The SO_4^2 levels obtained were all within the drinking water guidelines of the DOH. Although increases in the SO_4^2 levels were small, the levels obtained in the with dumpsite area were significantly different from those in the without dumpsite area ($p<0.05$). The differences in the SO_4^2 levels in the well waters may be, to some extent, attributed to the hydrogen sulfide gases emitted from the dumpsite where constant contact of the air with the water surface could have contributed to the high dissolved sulfates in the well waters[19].

The absence of septic tank systems in both study areas could have contributed to the high coliform bacteria present in the well waters. No differences on the total coliform in both study areas were noted ($p>0.05$). This is because the well waters in both areas were likely to be contaminated. Inputs of domestic sewage and organic matter in the well waters play a significant role in the presence of pathogenic bacteria and viruses into the water source. The study noted varied indices of sewage pollution and also showed that the coliform bacteria decreased during the dry month of April but increased during the succeeding wet months. As explained by Csuros[3], regrowth of bacteria increases when sufficient amounts of organic matter are available, especially in moist conditions and during periods of higher rainfall and lower temperatures.

High mean values for TSS in both study areas were reported, but no significant differences among the well waters in the with dumpsite and without dumpsite areas were found ($p>0.05$). Results suggest that wells in both areas have high-suspended sediments and the presence or absence of the dumpsite does not contribute to the levels of TSS in the well water. Since most wells are open dug wells, this increases the likelihood that suspended sediments would enter the wells. Results likewise showed that higher concentrations of TSS were more evident during the dry months. Townsend[20] indicated that seasonal changes significantly influence the quality of water bodies. During the dry season, the solutes, colloids and suspended materials in the water get concentrated due to faster evaporative rates at high temperatures.

In the with dumpsite area, TDS, conductivity and salinity were significantly higher than those well waters in the without dumpsite area ($p<0.05$). The higher levels obtained were perhaps due to the leaching of contaminants from the dumpsite toward the groundwater source or the presence of high dissolved mineral matter. The greater concentrations of ions, as a result of leaching of the contaminants or due to the geology of the area, could have contributed to the results obtained. Nielsen and MacDonald[21] noted that the inputs of chloride ions in the environment, particularly in well waters, might be attributed to the contributions of inorganic fertilizers, soil amendments and organic materials.

CONCLUSION

The study assessed and compared the groundwater quality of wells situated at the with dumpsite and without dumpsite areas of the Payatas estate. The variables tested were NO_3-N, total Cd, total Pb, total Cr, total coliform, TDS, TSS, SO_4^2, conductivity, salinity and pH. Groundwater quality assessment was carried out for six consecutive months, from April to September 2003, covering both the dry and wet seasons.

Significant differences were noted in water quality, particularly TDS, SO_4^2, conductivity and salinity ($p<0.05$) and no significant differences were observed in terms of total Cd, total Pb, total Cr, total coliform and NO_3-N ($p>0.05$) between the with dumpsite and without dumpsite areas. Results of the water quality analyses, both of the DENR-EMB[5] and the DOH[6], have shown that most of the variables were within the water quality standards except for the total coliform (MPN>0), TDS (>1000 mg L^{-1}), TSS (>50 mg L^{-1}) and pH (<6.5). The significant differences at the levels of the pollutants (TDS, sulfate, conductivity and salinity) strongly indicate the existence of pollution at the community with the Payatas open dumpsite.

Continuous water quality monitoring in both the with dumpsite and without dumpsite areas is encouraged. Increasing the frequency of sampling and analysis on the study areas is needed to effectively monitor the impact of dumpsites, particularly on environment and human health.

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