Assessment of the impact of open waste dumpsite on
groundwater quality: A case study of the Payatas dumpsite in
Quezon City, Philippines

M A Belen¹, J L Jacinto¹, N Go¹, L T Santos², A J C Zagala³, R A Santos² and D C Apodaca¹,³

¹School of Chemical, Biological and Materials Engineering and Sciences, MAPUA University, Muralla St. Intramuros, Manila Philippines 1002, Philippines
²School of Civil, Environmental and Geological Engineering, MAPUA University, Muralla St. Intramuros, Manila Philippines 1002, Philippines

E-mail: dcapodaca@yahoo.com

Abstract. Open dumpsites such as Payatas dumpsite situated in Quezon City, Philippines could pose environmental and health risk. This is in addition to the fact that Payatas dumpsite is located at the edge of the hydrologic divide between the Novaliches Reservoir and Marikina River System. A series of groundwater samplings were conducted in eighteen water well sites peripheral to both the old and new dumpsites of Payatas. Physico-chemical analyses were performed and results were compared to Philippines’ National Standards for Drinking Water and to Environmental Water Quality Guidelines. The levels of heavy metals with the exception of lead (Pb) from residential wells were found to be generally below the Philippines’ Department of Environment and Natural Resources (DENR) Department Administrative Order (DAO) No. 2016-08 threshold guideline levels and below tolerable values for drinking water standard set by the Philippines’ Department of Health (DOH). The low heavy metal contents on adjacent residential wells maybe attributed to probable nondispersion in a halo-like pattern of the leachate from its source. Characterization of leachate samples indicated unusually high metals content and transport of the leachate through groundwater flow have been detected on nearby springs and well. Further, an unusually high Pb background (> 0.01 mg/L) relative to groundwater quality standard was inferred from the series of samples collected from residential wells around Payatas dumpsite. The very linear correlation between Zn and Pb contents in these water samples imply its inherent presence in groundwater. Experimentally calculated groundwater quality indices showed the groundwater samples collected from residential wells around Payatas dumpsite were unsuitable for human consumption. Based on the assessment findings, implications for policy and decision-making suggestions for sustainable management of Philippines’ groundwater resources are put forward.

1. Introduction
Access to basic drinking water is essential to economic growth of a country and in eradicating poverty [1]. As reported in 2017, there were more than 2 billion people worldwide lacking accesses to safe and clean drinking water [2]. In the Philippines, there are about more than 8 million Filipinos with no access to safe drinking water [3]. Recognizing these challenges, the United Nations Sustainable Development Goals shall ensure, among others, the availability of the clean water and sanitation to all by 2030 [4]. To achieve this, member-countries have included in their national agenda the following:
1) development of local/national drinking water policies and actions; 2) establish monitoring and management practices to ensure that water safety plans are being strictly implemented and 4) design of risk management approaches and actions and many others.

Groundwater resources are such important sources for drinking water for humans [5]. However, over the years, the quality of groundwater has deteriorated brought about by population explosion, urbanization and other anthropogenic activities. One social menace that has contributed to groundwater contamination is poor solid waste management [5]. According to International Solid Waste Association (ISWA 2016), solid waste management is considered as an international problem [6]. Developing nations have either poorly managed landfills or no engineered landfill at all [7,8]. Majority have opted for open dumpsites as a convenient and inexpensive means of managing solid wastes from the community. An offshoot of the dumpsite and in some cases, absence of landfill practices is the leachate generated from solid wastes. Leachate is any liquid that drains from the stockpiled solid wastes in dumpsites which contains toxic contaminants.

Facing similar problem on solid waste management, in addition to problem pertinent to lack of access to clean water, the Philippines is yet to address issues about open dumpsites particularly in urban areas [9]. This is despite the clear provision of Philippines’ Republic Act 9003 or the Ecological Solid Waste Management Act, which prohibits open dumpsites. The Payatas dumpsite, located in Quezon City, Philippines, is a repository of wastes mainly coming from nearby areas in the Metropolitan Manila. This dumpsite is located at the eastern edge of the La Mesa Watershed and Eco-Park, which is a part of the Angat-Ipo-La Mesa water system, which supplies most of the water supply of Metro Manila. Roughly, the Payatas dumpsite is located less than 500 meters from the La Mesa Dam Reservoir.

In this regard, it is important to fully understand the risks posed by open dumpsites and to identify key parameters which may influence these risks to enable the development of mitigating measures [10]. Hence, this study aimed to determine the impact of Payatas open dumpsite on groundwater quality. Specifically, this study established some heavy metals present in both leachate and in groundwater samples taken from Payatas community [11,12]. Further, this study investigated possible intrusion of leachate into the groundwater reservoir, which could affect the drinking water quality in the National Capital Region of the Philippines. Results of this study shall contribute to the goal of a nationwide assessment of groundwater resources in the Philippines, pursuant to the Philippine Clean Water Act of 2004, which stipulates sustainable groundwater management policy [13].

2. Materials and methods

2.1. Description of the study area

2.1.1. Location, accessibility and climate. The Payatas dumpsite is located at area IV Barangay Payatas in Quezon City. The study area is situated on the northernmost portion of Quezon City, which is about 3.0 km from Commonwealth Avenue via the Litex-Montalban road and barely 400 km southeast of the Novaliches reservoir (La Mesa Dam) as illustrated in figure 1. As have been previously mentioned, the location of the dumpsite is crucial due to the possible contamination it may bring to the Novaliches reservoir, a 27 square kilometer watershed, which is the main source of domestic water supply for most of the cities and municipalities within Metro Manila.

The Philippine Atmospheric Geophysical and Astronomical Services Administration (PAGASA) categorized the climate distribution in the Philippines according to the Coronas Scheme (based on temporal rainfall distribution), under this scheme the study area falls under Type 1 climate wherein it is dry from November to April and wet from May to October.

Based on the studies conducted by PAGASA, the mean annual rainfall over the study area is around 2000 millimeters. The temperature ranges from a min. of 20°C (January to February) to a max of 35°C (April to May). The mean annual temperature and humidity of 27°C and 76% respectively.
2.1.2. *Hydrogeology*. The Payatas dumpsite covers a total land area of not more than 20 hectares and rises to higher elevation at the northwest margin of the Marikina River near the Novaliches border. It is located at the edge of the hydrogeologic divide between Marikina and La Mesa Dam on the southwest of the Montalban area.

The general groundwater movement is from a higher to a lower elevation profile. Based on the studies conducted by the Metropolitan Water and Sewerage System (MWSS), the general groundwater flow is from the higher elevation Novaliches reservoir at the west draining towards the Marikina River at the east (figure 2).

2.1.3. *Tectonic setting*. The Payatas dumpsite is situated at the northeastern end of the Guadalupe plateau. The major fault system that dominates the study area is the NNE trending west Marikina Valley Fault (WMVF) that traverses the eastern side of Payatas. The normal fault displacement is characterized by the east facing linear scarp mark by presence of the Guadalupe formation to the west and Quaternary Alluvium to the east.
2.2. Geochemical sampling

Leachate and groundwater samples were collected from the Payatas dumpsite located in Quezon City. The total land area of the dumpsite is estimated to be about 30 hectares. Approximately 300 trucks deliver a daily volume of garbage from the different areas in Quezon City, translated to 1,200 tons of domestic wastes produced by estimated 2.9 million residents in the metropolis [15]. During sampling topographic and land use maps, and Global Positioning System (GPS) were used to locate the exact sampling point where groundwater samples were obtained. The sampling was done strategically in order to cover the vital points that are crucial for the possible concentration of heavy metals on the groundwater and as well as the possible movement and propagation of leachates.

Groundwater samples were taken in November 2004 characterized by fair weather conditions. Eighteen samples were collected from different wells and springs located within Payatas area and vicinity. The collected water samples were collected in plastic bottles and were acidified using concentrated nitric acid (HNO₃) and stored in an ice chest, in accordance with the protocol indicated in the Standard Methods for the Examination of Water and Wastewater [16]. The collected samples were stored immediately in a laboratory refrigerator maintained at a temperature of 4°C to retard spoilage of the samples.

Five of the samples were collected from the old and new dumpsite. From the five samples taken from the dumpsite proper, three of them were obtained from U-tubes placed underneath the garbage and the other two were obtained from the monitoring wells present in the area. The remaining thirteen samples were collected from the residential wells and natural spring water within and outside the vicinity of the dumpsite. Three (1 residential well and 2 from springs) from the eighteen samples were additional samples taken outside the Payatas area specifically from a nearby residential area. These residential wells were mainly used for washing and bathing and not for drinking purposes.
Other important parameters such as pH, total dissolved solids (TDS), conductivity was obtained by in-situ testing using HACH H230D pH/conductivity/LDO water probes. GARMIN eTREX H Global Positioning System was used to obtain the coordinates/locations where each water sample was taken. The depths of the water table as well as the prevailing rock lithology were taken into consideration during sampling using 50-meter tapes. Figure 3 shows the location of the monitoring and residential wells were the samples are collected.

![Figure 3](image_url)

**Figure 3.** Locations of residential wells where groundwater samples were obtained.

2.3. **Analytical procedures**

2.3.1. **Reagents.** Analytical grade reagents were used for the analysis of heavy metals present on the leachates and groundwater samples from Payatas dumpsite. Concentrated nitric acid (HNO₃) was used for the preservation samples at the time of collection. This was also used in the sample digestion of leachate and groundwater samples in order to recover the heavy metals present on the samples. Distilled deionized water was also used for the digestion and dilution of acidified samples.

2.3.2. **Materials and glass wares.** The materials and glass wares were soaked in 14% nitric acid solution to remove metals which may have previously leached for three days and were washed with distilled deionized water and were placed inside the oven for complete drying.

2.3.3. **Acid digestion of water samples.** The collected samples were digested with nitric acid in order to eliminate possible matrix interferences during the atomic absorption spectrophotometric measurements, following the analytical method specified in the Standard Methods for the Examination of Water and Wastewater, American Public Health Association (APHA). To ensure that the metals were completely recovered during sample preparation as stipulated in WHO/UNEP (1996), standard addition experiments and sample blank measurements were simultaneously conducted [16].
2.3.4. Heavy metal analysis using atomic absorption spectrometer. The digested samples were analyzed using Perkin Elmer AAnalyst 100 Atomic Absorption Spectrometer (AAS). Standard solutions of different element line such as copper (Cu), lead (Pb), zinc (Zn), cadmium (Cd), potassium (K), calcium (Ca) and magnesium (Mg) were prepared from Titrisol® solutions (1000 ppm concentration for each metal) to obtain calibration curves. Integration time was 5 seconds and absorbance was measured in triplicates. In the case of K, Ca and Mg analyses, aliquots taken from the digested solution were treated with lanthanum-cesium chloride solution to prevent ionization of the metals during atomization process.

2.4. Map generation
The obtained values of the heavy metals analyzed were plotted on the working map where the different locations of collected samples were obtained. The purpose of these generated maps is to delineate the possible high and low values of a certain heavy metal and as well as graphically illustrate potential adverse effect and attributes on the surrounding environment.

The geographical coordinates and the values obtained at each element line were separately inputted into Surfer 8.0 programs by Golden Software®. The inputted data were converted into GRD file in order to create grids that were later on used for the different maps. Classed post maps and contour maps were created using the software.

3. Results and discussion
3.1. Physico-chemical and heavy metal concentration in groundwater around the Payatas dumpsite
Results of heavy metal analysis showed that heavy metals such as copper, and cadmium yielded values that were lower than the threshold guidelines set by DENR DAO 2016-08 [17,18]. However, majority of the leachate monitoring wells and spring samples exhibited heavy metal concentrations that were higher than the environmental water quality guidelines for lead (Pb) and zinc (Zn). Nonetheless, the concentrations of these heavy metals on the groundwater samples obtained from the residential wells were low and were found to pass the DAO 2016-08 as set by the DENR for these heavy metals. Measured concentrations of the above mentioned heavy metals were also compared to the Philippine Standards for Drinking Water (PSDW) [19], results show that heavy metals content of groundwater samples passed the standards for drinking water except for lead in which samples yielded values >0.01 mg/L, higher than the threshold limit. High concentrations of lead were found to be present in all of the five monitoring wells as well as on the ten residential wells located in the immediate vicinity of the dumpsite. Elevated values of lead were also obtained on the additional samples taken from the two springs and on the residential well outside the Payatas dumpsite. Data sets were also compared with the International Standards for Drinking Water [20] and results showed that the water samples from Payatas community gave distinctly high concentrations of lead. As shown in the post and contour maps (figure 4), relatively high peaks corresponding to high lead values were obtained from monitoring wells that is, approximately almost ten times greater than the values obtained from residential wells. Lead values measured from residential wells (Sample (S) 6-15) suggest possible natural level of lead in groundwater in the area, gauging from the large difference between the level of lead in leachate and the level of lead in ground water sample. Further, results indicated that there was also minimal possibility for movement of the lead metal from the dumpsite proper into the residential area as manifested by the large discrepancies between the values obtained from leachate and groundwater samples. Results of analysis of the additional samples taken outside the dumpsite (Violago Homes) suggest that lead may be inherent in the area and that it exists at quite elevated concentration, when compared against both environmental quality and drinking water quality standards for lead.
Meanwhile, previous study conducted by Metropolitan Waterworks and Sewerage System (MWSS) in 2002 also showed that groundwater quality around Payatas Dumpsite failed to meet the standards set by Philippine Standards for Drinking Water (PSDW) for lead. Measured value ranges from 0.0681 - 0.0073 mg/L, both in monitoring and communal wells collected whereas those samples collected within the immediate vicinity of the study area yielded values < 0.0144 mg/L. The study was carried out during the dry summer season between April and May 2001.

Elevated concentrations of cations such as calcium (Ca), magnesium (Mg) and potassium (K) were
also established in groundwater samples collected, attributable to hardness of water in the area. Hardness of water is due to the prevailing lithology at the dumpsite. Moreover, groundwater in the area sits within the Guadalupe formation, which comprised of tuffaceous, and pyroclastic material that could possibly undergo rock mineral dissociation, causing the liberation of magnesium, potassium and calcium from the minerals of the rock such as feldspars and plagioclases and on trapped sediments with minerals such as orthoclases that are high in potassium. The concentrations of potassium were found to be within the threshold guidelines with values ranging from 1.58 mg/L to 7.91 mg/L.

Water quality maps were also prepared in order to provide a graphical view of the water quality around Payatas dumpsite. As earlier discussed, differences noted in the surface and contour maps were due to varying concentrations of heavy metals and cations along different sampling locations in the vicinity of Payatas dumpsite.

3.2. Correlation of groundwater quality parameters.

Correlation analysis was conducted using SPSS® software to identify relationships and possible association between and among cations and heavy metals analyzed. Statistical results indicate that data were correlated as suggested by the determinant = 0.015. Further Bartlett’s Test of Sphericity (sig. < 0.001) suggests that data are not normally distributed. The results of Factor Analysis indicated that the first 3 parameters had eigenvalues > 1 and accounted for 77% of variance in the measured variables. Strong positive correlations were noted among Pb, Mg and K, while a negative correlation was obtained with Cu. Positive correlation between these elements suggests a common source [13]. On the other hand, Pb and K were also found to associate with Zn and Cu to give the 2nd grouping. The association between Pb and Zn does occur naturally due to the fact that both of these base metals behave similarly and are always found associated with one another due to their similar susceptibility to mobility. And this observed trend was established throughout all the samples taken from residential wells.

3.3. Groundwater quality indices

Factor Analysis also enabled the determination of communalities among parameters measured. Communality estimates the variance of a parameter in common with all other parameters measured together [21].

The calculated water quality indices at each groundwater sample location around the Payatas dumpsite indicate that the groundwater quality was generally not good. The results indicate that the water samples were not fit for human consumption. In fact, only samples S1 and S15 gave excellent water quality indices. The high values of WQI obtained from other monitoring and residential wells were due to high concentrations of K and Mg in the samples [13]. Further, water quality indices could indicate anthropogenic inputs. Water quality indices were calculated using the following equations [5,22]:

\[
W_i = \frac{h_i^2}{\sum_{i=1}^{n} h_i^2}
\]  

(1)

where, \( W_i \) = relative weight, \( h_i^2 \) = communality of each parameter, \( i = \) water quality parameter, \( n = \) number of parameters.

\[
Q_i = \left( \frac{C_i}{S_i} \right) \times 100
\]  

(2)

where, \( Q_i \) = quality rating, \( C_i \) = concentration of each parameter in each groundwater sample, \( S_i = \) WHO Standard for drinking water for each parameter, \( i = \) water quality parameter.

\[
SI_i = W_i Q_i
\]  

(3)

where, \( SI_i \) = sub-index of the ith parameter, \( W_i = \) relative weight, \( Q = \) quality rating and where \( i \) is the water quality parameter.
\[ WQI = \left\lfloor \frac{\sum_{i=1}^{n} SI_i}{\sum W_i} \right\rfloor \] (4)

where, WQI = Water Quality Index, SI = sub-index of the ith parameter, W_i = weight of the ith parameter.

**Table 1. Summary of calculated water quality indices around Payatas community (this study).**

| Sample                          | Water Quality Index (WQI) | Descriptive Index |
|---------------------------------|---------------------------|------------------|
| U- tube Pipe (Old Dumpsite)     | 9.915356978              | Excellent        |
| U- tube Pipe (Old Dumpsite)     | 628.0990279              | Unsuitable       |
| Monitoring well (Old Dumpsite)  | 277.4055554              | Unsuitable       |
| Monitoring well (New Dumpsite)  | 622.9956128              | Unsuitable       |
| U- tube Pipe (New Dumpsite)     | 452.4477485              | Unsuitable       |
| Residential well                | 719.2929786              | Unsuitable       |
| Residential well                | 361.9072608              | Unsuitable       |
| Residential well                | 440.5620289              | Unsuitable       |
| Residential well                | 229.1739642              | Unsuitable       |
| Residential well                | 151.2413249              | Unsuitable       |
| Residential well                | 328.0594567              | Unsuitable       |
| Residential well                | 130.3904647              | Unsuitable       |
| Residential well                | 338.6153073              | Unsuitable       |

4. Conclusions and recommendations

This study evaluated the groundwater quality within the vicinity of Payatas open dumpsite using water quality index rating. Levels of lead and potassium in groundwater samples were found to be elevated. Further, Pb was found to be strongly correlated with Mg, K and Zn, suggesting similarity in source however is negatively correlated with Cu and Ca. Out of 15 sample locations around Payatas dumpsite, only two yielded excellent water quality index rating and the rest of the well locations were found to be unsuitable for human consumption.

Based on the results of the study, it is highly recommended that continuous sampling must be carried out to monitor groundwater near the Payatas dumpsite to ensure the safety and cleanliness of groundwater accessible to residents living near the dumpsite.

It is recommended that the residents of Payatas community must take precautions regarding the use of groundwater wells for drinking purposes since that the groundwater wells did not meet the Philippine Standards for Drinking Water due to appreciable amounts of lead measured.

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Declaration of no competing interests

We declare we have no competing interests and/or no non-financial competing interests, or other interests that might be perceived to influence the interpretation of this article.

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