Investigation of heavy metals pollution in Piyungan Landfill underground and surface water

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Abstract. Assessing the potential hazard to the groundwater resource and surface runoff from solid waste disposal activities is considered necessary. This study focused on the effect of the leachate produced from the Piyungan landfill to both groundwater resources and surface runoff water quality. Groundwater samples were taken from point W1 (control) and W26, leachate samples were taken from LP1 (before treatment) and LP5 (after treatment), and drain samples were taken from L6 and L14, respectively. Heavy metals in these samples were analyzed using Inductively Coupled Plasma-Mass Spectrometer (ICP-MS). The results showed that leachate and drain samples had higher heavy metals content compared to groundwater samples. Leachate migration might happen in W26 since it located in the lower elevation of the landfill. For the leachate sample, the concentrations of Cr, Mn, Ni, As, and Se exceeded the allowable limit for raw water and leachate effluent. Deposition of heavy metals (Cr, Mn, Ni, As and Se) were also detected in W1 and W26 but still within the permissible limit. Continuous monitoring for heavy metals migration and the addition of leachate treatment processes in the landfill are suggested to avoid the occurrence of risky pollution to the surrounding area.

1. Introduction
Landfill disposal sites are common in Indonesia. Landfill is also the easiest and most cost effective method of disposing of waste. One of the landfills in Yogyakarta, namely, Piyungan landfill receive an amount of 470 ton/day which containing of 77% organic and 23% inorganic fractions. This amount was collected from lower and middle level in Yogyakarta province. The waste from lower level, which mostly from residential area was transported to middle level that consist of integrated waste management site (TPST). In TPST, an amount of inorganic waste was recycle and organic waste was composted. Then, the remaining waste was transported to Piyungan landfill. Annually, an increase as 8% per annum for the amount of MSW and residents in Yogyakarta were encourage reduction of MSW by recycling and composting. For recycling, it was assumed that 23% of inorganic waste can be recycled [1].

In Piyungan landfill area, there are a facility to treat the leachate that produce from MSW. Aerated lagoon and sedimentation lagoon were applied to treat the leachate. During site visit in August 2019, some leachate is not channelled into the leachate treatment plant and directly discharge without
treatment into the drain. The operational life of the landfill can give an impact on leachate quality. During the landfill operation, which at early stage of waste degradation and leachate production, the leachate composition is acidic and high in volatile fatty acids [2]. In this stage, high heavy metals concentration can be detected due to dissolve other components of the waste. The pH of this leachate commonly less than 7 and heavy metals concentrations can be high [3]. The Piyungan landfill was in operation during the sampling work. Thus, measurement of heavy metals concentration in leachate, groundwater and surface runoff were focused in this study. The leachate can threaten the groundwater and surface water resources.

One of environmental concern associated with landfill leachate is groundwater pollution. Decomposition products from the waste from landfill area can cause susceptible to dissolution by infiltrating water percolating through the waste, giving rise to leachate which can contaminate groundwater [4]. Areas near landfills have a greater possibility of groundwater pollution due to the potential pollution source of leachate originating from the nearby landfill. High numbers of deep and shallow wells were developed in residential areas, which nearby to the landfill. The groundwater was used for daily activities in the residential area.

Beside groundwater, drain sample was also measured in this study. This stream from landfill area is one of tributaries for Opak river, which is one of water resources in Yogyakarta province. The surface runoff is flowed into low level of the landfill area which compact with residential area and the rice fields. The impact on the groundwater and surface runoff from landfill leachates has given increase to a great number of studies in current years. These include the researches done by Hossain et al. [4], Abu-Rukah and Al-Kofahi [5], Fattah et al. [6], and Maqbool et al. [7].

Municipal landfills usually produce leachate with heavy metal concentrations in the microgram per litre to low milligram per litre level. Metal content is a function of the waste stream composition. For example, high concentration of chromium was detected from waste produced during manufacture of leather in one of landfill in Bandung, Indonesia. In addition, acetogenic leachates produce high concentration of manganese and zinc [2]. Abu-Rukah and Al-Kofahi [5] studied the various metal ions migration in the El-Akader landfill site and concluded that there is a migration of metal ions to the deep layers.

2. Methodology

Leachate, groundwater and drain samples were collected from landfill Piyungan during dry season. Landfill Piyungan is located in Ngablak Hamlet, Sitimulyo Village, Piyungan District, Bantul Regency, Yogyakarta. Every day this landfill site is able to accommodate around 580 tons of waste with a shelter area of 14.5 hectares and uses the Landfill Control Waste Management System. This Piyungan TPST is operated to collect garbage from 3 capital areas i.e City of Yogy, Sleman Regency, Bantul Regency. Landfill Piyungan was built in 1995 and operated in 1996. From topographic condition, this site is located in hilly areas and steep valleys with limestone as soil layers. The ground water depth range is 5-15 meters. Since 2000, the management of Landfill Piyungan has been the joint responsibility among Yogyakarta City, Slema Regency, and Bantul Regency.

The grab samples were taken from the selected sampling stations (Figure 1 and Table 1) by using a 1 L polyethylene or glass bottle. Polyethylene bottle is suitable for sample to be analysed for chemical characteristics. The leachate and water samples were filled the total volume of the container and a cap was sealed, thus no air space can be remained inside the bottle. The bottles were first washed thoroughly using Decon 90 detergent and dried. Before sampling, the bottles were rinsed with the water sample to be taken as sample. Water samples both surface water and ground water along with leachate were collected after some flush outs. After taking water samples, acid nitric was added to samples to reduce to pH 2, kept below 4°C by using ice storage box and transport to Malaysia by using air transportation. The bottles were labelled accurately by stating the name and location of the sample site, date and time of collection.

Water samples were tested at Environmental Laboratory in Universiti Tun Hussein Onn Malaysia. All the heavy metals were analyzed through Inductively Coupled Plasma-Mass Spectrometer (ICP-MS) (Agilent).The instrument was calibrated with appropriate set of calibration standards in each case, prepared by using available 1 mg/ml ICP-MS standard solutions. The leachate sample was first filtered
through Whatman filter paper. Comparison of heavy metals was carried out by referring to several available standard. As for leachate, there is no available leachate standard for Indonesia. Thus, results of heavy metals in leachate were compared with Malaysia leachate effluent standard. While for groundwater, no available standard for heavy metal from Indonesia. Thus, groundwater data was compared with Malaysia raw water standard.

![Figure 1. Location of sampling points](image)

Table 1. Sampling points and type of samples

| No. | Sampling Points | Type of samples               |
|-----|----------------|-------------------------------|
| 1   | W1             | Ground water                  |
| 2   | W26            | Ground water                  |
| 3   | LP1            | Influent of leachate treatment plant |
| 4   | LP5            | Effluent of leachate treatment plant |
| 5   | L6             | Drain                         |
| 6   | `L14           | Drain                         |

3. Results and Discussion

Heavy metals value in groundwater, leachate and surface water samples collected in/around Piyungan landfill in August 2019 are summarized in Table 2. Most of heavy metals concentration were high in leachate and drain samples compared to groundwater sample. Be, Co, Ni, Ga, Ag, Cd, In, TI, Pb, and Bi were undetected for both groundwater samples. W1 is the control sample for groundwater which located in higher elevation from Piyungan landfill. Thus, the leachate migration does not occurred in W1. Based on Table 2, most of heavy metals concentration for W26 were higher than W1. W26 is on lower part of Piyungan Landfill and migration of leachate probably existed for this well. However, all of the heavy metals monitored were below then the permissible limit compared. Therefore, the heavy metal migration in groundwater originated from Piyungan landfill is still in allowable concentration.

The concentrations of heavy metals of leachate samples taken before (LP1) and after (LP5) treatment plant also were listed in Table 2. Significance differences between leachate and groundwater heavy metals were recorded for Li, Mg, Al, Ca, V, Cr, Mn, Co, Ni, Cu, Zn, Ga, As, Se, Rb, Sr, Ag, Cs, Ba, Bi and U. Furthermore, for Co, Ni, Ga, Ag, Cd, In, Cs, Pb and Bi were existed in leachate and not in groundwater. Thus, proven that this heavy metals originated from solid waste in Piyungan landfill. However, not migrated into the groundwater due to proper liner system of Piyungan landfill.
## Table 2. Heavy metal concentration in /around Piyungan landfill

| Heavy metals / Sampling points | Ground water | Leachate | Drain | Standard 1* | Standard 2* | Standard 3* |
|-------------------------------|-------------|---------|-------|------------|------------|------------|
|                               | W1         | W26     | LP1   | LP5        | L6         | L14        |
| Li                            | 0.001      | 0.004   | 0.024 | 0.046      | 0.036      | 0.024      |
| Be                            | 0.000      | 0.000   | 0.000 | 0.000      | 0.000      | 0.000      |
| Mg                            | 13.862     | 50.767  | 117.860 | 144.377   | 154.413    | 123.760    |
| Al                            | 0.002      | 0.001   | 1.213 | 1.092      | 1.369      | 1.656      |
| Ca                            | 5.093      | 19.690  | 11.907 | 18.903     | 19.531     | 18.993     |
| V                             | 0.012      | 0.014   | 0.128 | 0.138      | 0.130      | 0.119      |
| Cr                            | 0.001      | 0.001   | 1.251 | 1.138      | **0.991**  | **1.129**  | 0.05/0.2  | 0.05     |
| Mn                            | 0.001      | 0.000   | **0.621** | 1.078   | **0.888**  | **1.099**  | 0.2       | 0.2      |
| Co                            | 0.000      | 0.000   | 0.162 | 0.165      | 0.163      | 0.148      |
| Ni                            | 0.000      | 0.000   | **0.344** | **0.403** | **0.357**  | **0.370**  | 0.2       |
| Cu                            | 0.001      | 0.001   | 0.042 | 0.055      | 0.047      | 0.206      |
| Zn                            | 0.011      | 0.001   | 0.345 | 0.552      | 0.386      | 0.560      |
| Ga                            | 0.000      | 0.000   | 0.015 | 0.006      | 0.004      | 0.004      |
| As                            | 0.001      | 0.002   | 0.048 | 0.053      | **0.051**  | **0.046**  | 0.05      | 0.01     |
| Se                            | 0.001      | 0.006   | 0.090 | 0.091      | **0.093**  | **0.072**  | 0.02      | 0.01     |
| Rb                            | 0.006      | 0.006   | 2.893 | 3.017      | 2.609      | 2.580      |
| Sr                            | 0.205      | 0.407   | 0.823 | 0.912      | 10.164     | 0.963      |
| Ag                            | 0.000      | 0.000   | 0.012 | 0.022      | 0.004      | 0.015      |
| Cd                            | 0.000      | 0.000   | 0.002 | 0.003      | 0.002      | 0.002      |
| In                            | 0.000      | 0.000   | 0.001 | 0.001      | 0.001      | 0.001      |
| Cs                            | 0.000      | 0.000   | 0.018 | 0.018      | 0.015      | 0.016      |
| Ba                            | 0.024      | 0.021   | 0.629 | 0.517      | 0.686      | 0.644      |
| Tl                            | 0.000      | 0.000   | 0.000 | 0.000      | 0.000      | 0.000      |
| Pb                            | 0.000      | 0.000   | 0.021 | 0.036      | 0.024      | 0.037      |
| Bi                            | 0.000      | 0.000   | 0.060 | 0.041      | 0.032      | 0.030      |
| U                             | 0.002      | 0.000   | 0.044 | 0.039      | 0.033      | 0.025      |

Standard 1*: Malaysia Leachate Discharged standard (ppm)
Standard 2*: Malaysia Raw water standard (ppm)
Standard 3*: Peraturan Menteri Lingkungan Hidup Dan Kehutanan, Republik Indonesia, Nomor 59/Merlhk/Setjen/Kum.1/7/2016, Tentang Baku Mutu Lindi Bagi Usaha Dan/Atau Kegiatan Tempat Penrosesan Akhir Sampah

Higher value of heavy metals in leachate, remarked deposited of solid waste contains hazardous elements. Cr, Mn, Ni, As and Se exceed the allowable limit for raw water and leachate effluent. Se concentration found higher than the limit and can caused Selenosis to the people that ate food contaminated with Se [8] and serious long–term risk to fishery resources [9]. High level of Ni in the leachate sample indicates the disposal of Ni batteries, electronic products or others industrial waste in Pinyungan landfill. Excessive released of Cr in Piyungan leachate is harmful to wildlife and humans [10]. The leachate treatment reduced the concentration of some heavy metals yet still surpassed the limit (refer to sampling point influent: LP1 and effluent: LP5). Some of heavy metals (Mg, Ca, V,Mn, Co, Ni, Cu, Zn, As, Se, Rb, Sr, Cd, and Pb) increased after treatment. This probably, a chemical and biological reaction induced the increment of some heavy metal. Based on the data analysis of the LP1 and LP5, the existed leachate treatment plant is not sufficient. Thus, redesign of treatment plant and
additional treatment must be included to prevent released of these heavy metals to the environment. As concentration in leachate is high, however this element do not imply present of antrophogenic sources as probably its coming from natural sources such as geological origin [11]. However, this need to be proven through soil sampling.

The samples of L1 and L14 were located after leachate treatment plant. Opak River located about 5 km from Piyungan landfill. The spreading of heavy metals from the treated leachate were through the earth drain and probably along the soil across the earth drain. Almost not far value of heavy metals recorded from LP1, LP2, L1 and L14. Exceeded limit of Cr, Mn, Ni, As and Se were also recorded in L1 and L14 drain samples. Deposition of these heavy metals must be avoided to prevent transportation of these elements into the food resources which exposed people to health risk.

4. Conclusion
Cr, Mn, Ni, As and Se were exceeded the permissible limit in leachate and drain samples. Nevertheless, all of these heavy metals in groundwater is within the permissible limit and indicated no migration of these heavy metals in the nearby well. However, increment of most of heavy metals monitored were recorded for leachate and drain samples. Suggesting the needs to upgrade the Piyungan leachate treatment plant. Overall, the state of heavy metal spreading from Piyungan landfill should still be continued monitored to assured no increasing trend recorded.

5. References
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