The analysis of groundwater quality around a material (solid waste) recovery facility (a case study of the Merdeka 2 material recovery facility in Depok, West Java)

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Abstract. Merdeka 2 Material Recovery Facility (MRF) is an organic waste management facility located in West Java. MRF also produces leachate water which came from organic waste that could potentially pollute shallow groundwater around the facility. Purpose of this study is to obtain knowledge regarding amount of MRF’s waste intake and composition, composition of leachate water that came from the waste, and the groundwater quality around MRF with parameters including pH, temperature, BOD, COD, Nitrite, Nitrate, Ammonia, KMnO4, Iron (Fe), and Fecal Coliform. Quality of the groundwater was analysed by knowing pollution rate based on pollution index and its association with distance variation from MRF. Results showed that amount waste that came to the facility is 0.954 ton/day with an average of waste volume 1449.20 l/day and consists of 93.4% organic waste and 6.4% non-organic waste. For MRF’s leachate water quality showed that pH, temperature, BOD and COD parameters exceeded over required standard. Shallow groundwater around MRF showed that average rate of pH, BOD, COD, Nitrate parameters is still above required standard and other parameters average is still in required standard and there is no significant correlation between distance variation with the groundwater. It can be concluded that the pollution index of the local’s shallow groundwater fall into low to mid polluted category.

1. Introduction
Several big cities in Indonesia face the same problem which is waste issue. One of those cities is Depok City which is located south of The Capital Region of Jakarta, with the population of 2,179,813 people as of 2016 [1]. The Government of Depok City with its Department of Cleanliness and Gardening is currently promoting the construction of The Material Recovery Facility (MRF) in Depok. Based on The Law of Depok City Region Number 05 Year 2014 Regarding Waste Management, The MRF is a place where organic waste will be processed into compost. When accumulating the organic waste, the waste produces leachate water. The poor condition of the MRF drainage causes the resulting leachate uncontrollable. In addition, there is no special treatment towards the leachate water in MRF.

In addition to the waste issues, the high density of the population also causes other problems such as the increase in the demand for water. As the population increase, the demand for water will grow at both a better and faster rate if the population growth must follow better living standard growth [2]. The population growth affected the rate of waste and water necessities. Because of this, the existence and quality of local groundwater are necessary to maintain.

In this study, the researchers aimed to analyse the local groundwater quality around The Material Recovery Facility (MRF) with the parameters tested include pH, temperature, BOD, COD, Nitrite,
Nitrate, Ammonia, KMnO4, iron and fecal coliform based on quantitative measurements. The sample were directly taken from the shallow groundwater source from the surrounding settlement. There are 16 sample points with one point located in the MRF facility itself. The sampling point was decided based on the ground height and the groundwater flow.

The purpose of this study are: (1) describe the amount and composition of solid waste in the Material Recovery Facility, (2) Compare the results of the obtained groundwater quality with the applied regulation in Indonesia regarding shallow groundwater which is Government Regulation Number 82 year 2001 regarding Water Quality Management and Water Pollution Control, (3) analyse the linear regression between the distance variation with the groundwater quality around the MRF, and (4) detect the pollution rate based on The Shallow Groundwater Pollution Index based on The Ministry of The Living Environment Law Number 115 Year 2003 [3].

2. Methods

2.1. Study Area
The study was located around The Merdeka 2 Material Recovery Facility in Sukmajaya, Depok, West Java. Based on Depok City White Book and Sanitation (Buku Putih dan Sanitasi Kota Depok) (2011), geographically, Depok City is located at 6° 19’00’’ - 6° 28’00’’ South Latitude and 106°43’00’’ - 106°55’30’’ East Longitude [4]. With an area size of 650 m², the MRF is located on both streets, the figure below shows the study location and the coordinates of the groundwater sample extraction.

![Figure1. The study location and coordinates of the groundwater sample extraction.](image)

2.2. Data Collection and Analysis Method
a. The Amount and Composition of Solid Waste
The waste sample extraction is based on The SNI 19-3964-1994 regarding The Method of Taking and Measuring Examples of Urban Waste Generation and Composition (Metode Pengambilan dan Pengukuran Contoh Timbulan dan Komposisi Sampah Perkotaan). However, the mentioned standard was not used when extracting the sample for the amount and composition of solid waste. The study was conducted by obtaining the waste population data for 8 days. The duration of the study was in accordance the time estimation regulated in SNI 19-3964-1994. The data was then processed using STAN (Substance Flow Analysis) version 2.0, which is a freeware that could analyse the substance flow in line with the Austria O Norm S 2096 Standards (Substance flow analysis – waste management application). The STAN program helps with the analysis of substance flow of activities.

b. Leachate Characteristics
The leachate sample extraction was done for 3 days to obtain data variation. The first day extraction was done simultaneously with the extraction of groundwater sample extraction then followed the next day. The extraction was in accordance with SNI 6989.59: 2008 regarding Water and Waste Water – Section 59: The Method of Waste Water Sample Extraction. The leachate sample was then kept inside the laboratory to test these parameters: pH, temperature, BOD, COD, Nitrite, Nitrate, Ammonia, KMnO4, and iron.
c. Groundwater Quality
The shallow groundwater sample extraction was in accordance with SNI 6989.59: 2008 regarding Water and Waste Water – Section 58: The Method of Groundwater Sample Extraction. The method of extraction is by draining the water from the valve for 1-2 minutes and then put it inside a container based on the criteria. The Table 1 shows the sample extraction points and its coordinates. As for the obtained water quality, pollution index was then used to compare the results with the standards or required standards according to Government Regulation Number 82 year 2001. The pollution index was used to know the water quality status. Based on The Ministry of The Living Environment Law Number 115 year 2003 Regarding the Water Quality Status Decision Guide, the water quality status refers to the degree of the water quality that indicates good or polluted condition of a certain water source in a certain period of time by comparing it with the established quality required standard. Moreover, the correlation between the water quality alteration with the distance variation.

3. Result and Discussion
3.1. The Amount and Composition of Solid Waste in the MRF.

The measurement of the amount of waste was conducted by directly weigh and measures the waste volume that came to the facility. Next, the results showed the amount of waste that came into the facility in kilogram (kg) and the waste volume in litre (l).

| Day | The Amount of Solid Waste (kg) | Volume of Solid Waste (litre) | Density (kg/l) | Organic Waste (Kg) | Non-Organic Waste (Kg) | Total (Kg) |
|-----|-------------------------------|------------------------------|----------------|--------------------|------------------------|------------|
| 1   | 534.10                        | 900.36                       | 0.59           | 499.95             | 33.54                  | 533.49     |
| 2   | 1185.4                        | 1748.84                      | 0.68           | 1107.75            | 73.55                  | 1181.30    |
| 3   | 372.75                        | 667.39                       | 0.56           | 350.30             | 22.39                  | 372.69     |
| 4   | 906.93                        | 1441.40                      | 0.63           | 835.00             | 68.75                  | 903.75     |
| 5   | 1135.42                       | 1622.69                      | 0.70           | 1069.97            | 63.35                  | 1133.32    |
| 6   | 1798.59                       | 2688.48                      | 0.67           | 1695.81            | 102.78                 | 1798.59    |
| 7   | 363.85                        | 501.56                       | 0.73           | 326.11             | 32.10                  | 358.21     |
| 8   | 1340.36                       | 2022.92                      | 0.66           | 1248.81            | 91.55                  | 1340.36    |
| Total| 954.68                        | 1449.20                      | 0.65           | 891.71             | 61.00                  | 952.71     |

The average amount of waste that came into the facility is 899.58 kg with a volume average of 1536.91. After knowing the amount of waste and volume then the density of the waste was calculated. The density rate was 0.59 kg/l. the waste that came into The MRF was organic waste which has the density ranging from $0.3 – 0.4$ kg/l [5].

There is a difference between the amount of waste intake with the amount of waste after separation. The waste intake has the average of 954.68 kg and the amount of waste after separation is 952.71 kg, which amounts to 1.97 kg difference. This could be caused by a few wastes that weren’t calculated such as waste that became livestock food or leaf waste that went straight into the leaf mincer. Then, there is leachate that wasn’t contained in the container and that reduces the mass of the waste.

The non-organic waste that came into the MRF include coloured and clear plastic, sachet, hygiene products (diapers, etc), plastic cups, Styrofoam and duplex. The non-organic mainly consists of plastic waste, this is because when sorting the waste, the locals tends to wrap the organic waste inside a plastic rather than directly throwing it inside a bucket. That is also true for waste that came from the market, every waste that came into the MRF was wrapped inside a plastic. The plastic waste that came into the Merdeka 2 MRF consist of $30.64\%$ coloured plastic waste and $35.47\%$ clear plastic. This is followed by sachet which is the next highest rate of non-organic waste that came into the MRF. Sachet waste came from both the market and the locals. The sachet waste consists mainly of food sachet, cooking spices. And for bath and washing (soap sachet, shampoo, detergent, etc).
3.2. The Lifecycle Analysis of The Material Recovery Facility (MRF)

Based on the analysis that was done, the waste that came into the MRF reached 0.95 ton/day or about 348.46 ton/year. After the waste was let down and weighed, the waste then will be sorted on a sorting table. Then, some of the organic waste was processed with other method that is bioconversion. The bioconversion that was done in this MRF used the Black Soldier Fly (*Hermetia illucens*) larvae with an average of bioconversion efficiency of 85.19%. With this rate of efficiency, the bioconversion still leaves residue, that will be used in the composting phase if there isn’t any organic waste or the bioconversion residue leftovers were thrown away. Merdeka 2 MRF added additional materials including bioconversion residue leftovers and a mixture of mostly brown and a few green leaves. This addition of leaf was done to fulfill the C-N ratio that is needed in the process of making compost. The leaf was added in the composting process with 1:1 ratio between the organic waste and the leaves. Before getting mixed with the organic waste, the leaves will be minced first so the size of the leaves are homogenous.

This homogenization process is important to distribute the leaves evenly to the organic waste so that the temperature remain constant in various windrow parts. The researcher speculates that the organic waste water level is 70% and the leaves are 20% [6]

![Figure 2](image)

**Figure 2.** The Average Composition of Non-organic Waste variants in Merdeka 2 MRF

![Figure 3](image)

**Figure 3.** The Merdeka 2 MRF Substance Flow

3.3. Characteristics of The Leachate

The leachate test was conducted in lab by testing several parameters which include pH, temperature, BOD, COD, Nitrite, Nitrate, Ammonia, KMnO4, and iron
Table 1. The Merdeka 2 MRF Leachate Characteristics

| Parameters | pH* | Temperature* (°C) | BOD* (mg/l) | COD* (mg/l) | Nitrite (mg/l) | Nitrate (mg/l) | Ammonia (mg/l) | KMnO4 (mg/l) | Iron (mg/l) |
|------------|-----|-------------------|-------------|-------------|---------------|---------------|---------------|--------------|-------------|
| L1         | 2.8 | 34.5              | 4000        | 188577.4    | 0.026         | 90            | 12.5          | 138233.6    | 2.13        |
| L2         | 3   | 32.7              | 4000        | 184358.7    | 0.026         | 60            | 15.2          | 101371.3    | 2.03        |
| L3         | 2.78| 33                | 4000        | 155995.8    | 0.026         | 105           | 8.82          | 113658.7    | 1.48        |

*: Based on the Ministry of The Living Environment Regulation No. 59 Year 2016
L1 = Leachate Sample 1
L2 = Leachate Sample 2
L3 = Leachate Sample 3

From the table above, it is shown that the pH, temperature, BOD, and COD parameters are below the required standard established by the Ministry of The Living Environment that states the required standard for leachate are 6-9 pH level, an average temperature of 27 °C with 3 °C deviation, which mean the temperature level that is necessary for the leachate to be in a normal condition are in the range of 24 to 30 °C. The COD and BOD parameters has the rate of 150 mg/l and 300 mg/l respectively. Other parameter rates such as Nitrite, Nitrate, Ammonia, organic substances, and iron are not stated in the regulation.

Table 5. The Parameter results of The Groundwater Quality

| Parameters | pH | Suhu | BOD | COD | Nitrite | Nitrate | Ammonia | KMnO4 | Iron | Coliform |
|------------|----|------|-----|-----|---------|---------|---------|-------|------|----------|
| Units      | 6 - 9 | 24 - 30 | mg/l | mg/l | mg/l | mg/l | mg/l | mg/l | mg/l | MPN/100ml |
| Required standards |
| UPS | 5.56 | 32 | 11 | 34 | 0.026 | 48 | 0.069 | 8.9 | 0.01 | 0 |
| A30 | 4.9 | 31.2 | 36 | 111.8 | 0.026 | 57 | 0.069 | 7.09 | 0.01 | 90 |
| A45 | 5 | 33 | 17 | 50.2 | 0.026 | 55 | 0.069 | 9.72 | 0.01 | 0 |
| A60 | 4.56 | 30 | 14 | 47 | 0.026 | 64 | 0.069 | 8.9 | 0.01 | 0 |
| A75 | 4.53 | 30.5 | 22 | 73.1 | 0.05 | 58 | 0.18 | 430 | 0.01 | 430 |
| A90 | 4.4 | 32.4 | 14 | 47 | 0.026 | 58 | 0.069 | 7.7 | 0.01 | 230 |
| A105 | 4.53 | 32 | 12 | 38.2 | 0.026 | 58 | 0.46 | 9.81 | 0.01 | 0 |
| A120 | 4.45 | 31 | 9 | 27.6 | 0.42 | 54 | 8.16 | 9.72 | 0.01 | 0 |
| A135 | 4.35 | 29.8 | 17 | 51.9 | 0.04 | 80 | 0.11 | 11.3 | 0.01 | 0 |
| B45 | 5.1 | 28.8 | 8 | 24.3 | 0.026 | 55 | 0.25 | 8 | 0.01 | 0 |
| B60 | 4.9 | 29 | 18 | 56.7 | 0.026 | 54 | 0.21 | 9.42 | 0.01 | 150 |
| B75 | 4.83 | 29.2 | 5 | 11.4 | 0.07 | 35 | 0.16 | 9.81 | 0.02 | 430 |
| B90 | 5.3 | 28.3 | 13 | 43.8 | 0.1 | 51 | 0.14 | 7.7 | 0.01 | 0 |
| B105 | 5.5 | 30.2 | 3 | 4.86 | 0.026 | 20 | 0.19 | 11.9 | 0.01 | 2800 |
| B120 | 5.55 | 29.6 | 5 | 11.4 | 0.026 | 46 | 0.23 | 8.52 | 0.01 | 2400 |
| B135 | 5.75 | 28.7 | 12 | 40.5 | 0.03 | 29 | 0.07 | 9.72 | 0.01 | 90 |

3.4. **Groundwater Quality**

The local groundwater sample will be tested inside a laboratory with few parameters such as BOD, COD, Nitrite, Nitrate, Ammonia, KMnO4, Iron and Fecal Coliform. This test is in accordance to the
Government Regulation No. 82 Year 2001 regarding The Water Quality Management and Water Pollution Control. The table below shows the results of the groundwater tests:

3.5. **Analysis of the Distance Variation effects on The Groundwater Quality**

This study was conducted based on the assumption that the change in distance would affect the groundwater quality. The $R^2$ value represents the percentage of correlation between the distance variation and the groundwater quality. Then, the $X$ value represents the linear line of the graph, if $X$ has a negative value then the line will go downwards, and if the $X$ has a positive value then the line will go upwards.

**Table 7. Linear Regression Analysis of the Distance Variation towards the Groundwater Quality**

| Parameters | Sampling Line | $y$         | $R^2$  |
|------------|---------------|-------------|--------|
| pH         | Point A       | -0.1215x + 5.3053 | 0.7249 |
|            | Point B       | 0.14x + 4.4357  | 0.7604 |
| Temperature| Point A       | -0.15x + 32.072  | 0.1384 |
|            | Point B       | 0.0679x + 28.707 | 0.0544 |
| BOD        | Point A       | -1.1167x + 22.472 | 0.1415 |
|            | Point B       | -0.5714x + 12.571 | 0.0523 |
| COD        | Point A       | -3.4167x + 70.506 | 0.1356 |
|            | Point B       | -1.7336x + 37.967 | 0.0361 |
| Nitrite    | Point A       | 0.0017x + 0.0233  | 0.2561 |
|            | Point B       | -0.0011x + 0.0503 | 0.0069 |
| Nitrate    | Point A       | 1.9833x + 49.194  | 0.3717 |
|            | Point B       | -3.8929x + 64.786 | 0.3824 |
| Ammonia    | Point A       | 0.0531x - 0.0532  | 0.3135 |
|            | Point B       | -0.0168x + 0.2793 | 0.3509 |
| KMnO4      | Point A       | 0.2745x + 7.2319  | 0.1369 |
|            | Point B       | 0.1946x + 8.1279  | 0.0879 |
| Iron (Fe)  | Point A       | 2E-18x + 0.01    | 8E-16  |
|            | Point B       | -0.0004x + 0.0136 | 0.0417 |
| Fecal Coliform | Point A   | -0.6667x + 86.667 | 0.0001 |
|            | Point B       | 255x - 691,43    | 0.2047 |

3.6 **Groundwater Contamination Values Based on The Pollutant Index.**

The value of $C_i/L_i j$ showed the relative pollution caused by the water quality. The below table shows the examples of $P_{ij}$ calculation or in other words the Relative Pollution Index at the 0 m point or MRF. The average of the overall $C_i/L_i j$ value was then calculated as a benchmark for the pollution rate, however this value will be invalid if the $C_i/L_i j$ value a higher than 1. So, the index should include the highest $C_i/L_i j$ value. [7]

After obtaining the $(C_i/L_i j)_R$ and $(C_i/L_i j)_M$ value, the overall Pollution Index value can be calculated using the equation below:

$$P_{ij} = \sqrt{\frac{(C_i/L_i j)_M^2 + (C_i/L_i j)_R^2}{2}}$$

The following table summarizes the Pollution Index value in all of the sample point for the local groundwater quality test around the Merdeka 2 MRF.
Table 2. Groundwater Pollution Index Value around the MRF

| Sampling Points | Pij  | Status            | Sampling Points | Pij  | Status            |
|-----------------|------|-------------------|-----------------|------|-------------------|
| UPS             | 3.55 | Lightly Contaminated | A150           | 4.00 | Lightly Contaminated |
| A30             | 5.40 | Moderately Contaminated | B45            | 3.48 | Lightly Contaminated |
| A45             | 4.22 | Lightly Contaminated | B60            | 4.33 | Lightly Contaminated |
| A60             | 3.92 | Lightly Contaminated | B75            | 3.17 | Lightly Contaminated |
| A90             | 6.91 | Moderately Contaminated | B90            | 3.80 | Lightly Contaminated |
| A105            | 4.00 | Lightly Contaminated | B105           | 5.96 | Moderately Contaminated |
| A120            | 3.73 | Lightly Contaminated | B135           | 5.77 | Moderately Contaminated |
| A135            | 5.39 | Moderately Contaminated | B150           | 3.64 | Lightly Contaminated |

The above table shows that the Pollution Index average fall into the range from 1 to 5 where that values can be grouped into Lightly Contaminated and the rest is Moderately Contaminated. The highest Index Value came from the 90 m point A with the value of 6.91, while the lowest value came from the 75 m point B with the value of 3.17.

4. Conclusion

The average of waste that came into the MRF is 0.954 ton/day or 348.46 ton/year with the volume average of 1449.20 l/day. As for the density of the MRF waste intake is 0.65 kg/l, the waste in the MRF can fall into two categories, which are organic and non-organic waste with the rate of 93.4% and 6.4% respectively, during the separation process there is a change in the mass of waste before and after separation as much as 0.2%. the average of the non-organic waste consists of clear plastics (35.47%), coloured plastics (30.64%), sachets (15.29%), hygiene products (1.97%), plastic cups (5.44%), Styrofoam (6.94%), and duplex/papers (2.59%). The characteristics of the leachate on the pH, temperature, BOD, COD parameter didn’t pass the required standards that has been stated in the Ministry of The Living Environment Regulation No. 59 year 2016 which are the average for pH is 2.86, temperature is 33.4, BOD > 4000 mg/l, COD 176310.6 mg/l, and for Nitrite, Nitrate, Ammonia, and the organic substance are 0.026 mg/l, 85 mg/l, 12.17 mg/l, 117754.5 mg/l respectively, which showed that the organic substance inside the leachate is very high and the iron concentration rate is 1.88 mg/l.

Based on the results and discussion regarding the shallow groundwater quality around the MRF, it is shown that the pH, BOD, COD, and Nitrate parameters exceeded the required standards, and the rest of the parameters is exactly in the required standards as stated in the Government Regulation No. 82 Year 2001 regarding Water Quality Management and Pollution Control. As for the correlation between the groundwater quality with the distance variation from the MRF showed that the highest correlation is in the point B pH parameter with 76.04% rate and the lowest is in the point A of iron parameter with 0.00% rate and the groundwater pollution levels based on the Pollution Index mostly fall into the 1 to 5 index values. This means that the groundwater fell into the Lightly Contaminated category. The highest Pollution Index value with the severely contaminated category is the 90 m point AA with the value of 6.91 and the lowest is the 75 m point B with the value of 3.17.

5. Acknowledgments

The authors thanks to Universitas Indonesia as the sponsor for the financial support to this research under the PITTA 2017 grant as shown in the Assignment Agreement Letter from the Directorate of Research and Community Service UI Number: 2418 / UN2.R3.1 / HKP.05.00 / 2018

6. References

[1]. Pemerintah Kota Depok. (2011). Badan Pusat Statistika Kota Depok. Depok: Pemerintah Kota Depok.
[2]. Sawyer, et. al. (2003). Chemistry for Environmental Engineering and Science fifth edition. New York: Mc Graw-hill.

[3]. Republik Indonesia. (2001). Peraturan Pemerintah Nomor.82 Tahun 2001 tentang Pengelolaan Kualitas Air dan Pengendalian Pencemaran Air. Jakarta: Sekretariat Negara.

[4]. Pemerintah Kota Depok. (2011). Buku Putih dan Sanitasi Kota Depok. Depok: Pemerintah Kota Depok.

[5]. Tchobanoglous, et. al. (1993). Integrated Solid Waste Management Engineering Principles and Management Issues. new york: Mc. graw-hill.

[6]. Tchobanoglous, et. al. (1993). Integrated Solid Waste Management Engineering Principles and Management Issues. new york: Mc. graw-hill.

[7]. Menteri Lingkungan Hidup dan Kehutanan Republik Indonesia. (2003). Keputusan Menteri Negara Lingkungan Hidup Nomor.115 tahun 2003 tentang Pedoman Penentuan Status Mutu Air.