Heavy metals in groundwater surrounding industrial areas: a case study in Leuwigajah, Cimahi

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Abstract. Living things need groundwater as an alternative source of clean water. If contaminated, it will harm to living things and the surrounding environment. One of groundwater contamination is caused by heavy metals from industrial activity. Leuwigajah is an area in Cimahi city with high industrial action. This paper describes the potential heavy metal contamination to groundwater in Leuwigajah industrial area using the heavy metal pollution index (HPI). Groundwater samples were taken from 26 locations in April 2021, September 2020, and 2021. The heavy metals were analyzed using atomic absorption spectrophotometer for Fe, Mn, Zn, Cu. Cr, and Cd. The results showed that Fe, Mn, Zn, and Cu were found in groundwater around Leuwigajah industrial area. HPI in April is 59.04, and HPI in September is 61.53.

Keywords: groundwater, heavy metal pollution index, heavy metal, Leuwigajah industrial area.

1. Introduction

Groundwater is a source of clean water that is used by living things because it's unsusceptible to contamination compared with surface water. Groundwater has a slow renewal rate, so it's challenging to eliminate the contamination [1]. However, groundwater contamination is harmful to living things and causes an environmental problem, and heavy metal is one source of contamination even at low concentrations [2, 3]. In addition, the occurrence of heavy metals in groundwater can be natural or anthropogenic [4, 5], like industrial activities [6, 7] or irrigation agriculture [7, 8].

The present study investigates heavy metals in groundwater surrounding the industrial area of Leuwigajah Cimahi. Water quality in the study area is evaluated using the heavy metal pollution index (HPI) that the method assesses the influence of heavy metal concentration in groundwater at the study area [3, 6]

2. Material and Methods

Leuwigajah industrial area is located in the south Cimahi District, Cimahi City. The industrial zone in Cimahi city is 459 hectares and one of which is situated in Leuwigajah [9]. Groundwater samples were collected in April 2021, September 2020, and 2021 from a shallow well in the Leuwigajah industrial area. The number of samples contained is 26 (13 samples were taken in April, and 13 samples were taken in September) that the location is W01, W02, W03, W04, W07, W09, W10, W11, W12, W13, W14, W15, and W16 that was showing in figure 1. Sampling location was recorded using GPS Garmin.

For heavy metal analysis, groundwater is collected in polypropylene bottles and acidified with nitric acid immediately after the collection to a pH below 2 to minimize precipitation and adsorption on container walls [10]. Heavy metal concentrations (Fe, Mn, Zn, Cu, Cr, and Cd) were measured using Atomic Absorption Spectrophotometer (AAS) Shimadzu AA-7000 in the National Research and Innovation Agency (BRIN) laboratory. Sample analysis was based on standard methods for the examination water and wastewater [10]. The analysis is carried out for each metal using a standard with a certain concentration based on the procedure of the standard method and using a sample blank. Repeated sample measurements with AAS were carried out a triple.

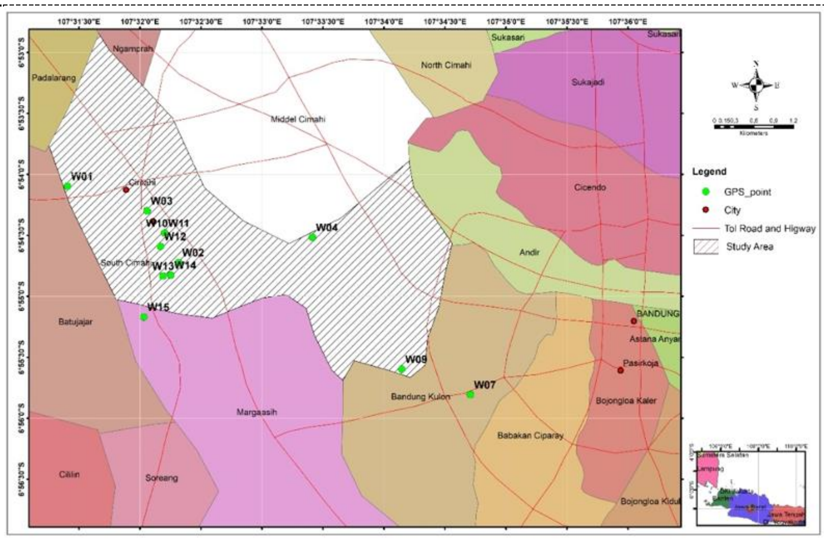

Figure 1. Study area and samples location map.

Heavy metals stay for a long time due to non-degradability after being released from the Earth's crust [11, 12] and are persistent in the natural environment [13]. Some have toxicological effects on animals, plants, and humans [13, 14, 15], while others don't. Cadmium (Cd), chromium (Cr), arsenic (As), and lead (Pb) are toxic heavy metals [16], there are very harmful even at low concentrations [17]. Meanwhile, iron (Fe), manganese (Mn), copper (Cu), zinc (Zn), cobalt (Co), and molybdenum (Mo) are essential for human metabolism and also for various biomolecules at low concentrations [15, 18]. Still, if their concentration exceeds a specific limit, it may be harmful to humans [19]. Generally, high concentrations of all heavy metals cause toxic effects [15].

HPI combined the influence of overall heavy metals to determine water quality [20], based on the weighted arithmetic quality mean method [1]. HPI is an effective method of rating and ascertaining the water quality concerning heavy metals. HPI has been developed and formulated [21] as:

$$HPI = \frac{\sum_{i=1}^{n} QiWi}{\sum_{i=1}^{n} Wi} \quad \text{......(1)}$$

Where Qi is the sub index of the ith parameter, Wi is the unit weight of the ith parameters, n is the number of parameters considered. The unit weight (Wi) has been found out using formula:

$$W_i = \frac{K}{S_i} \quad \text{......(2)}$$

K is the proportionality constant, and Si is the standard permissible value of the ith parameter. The sub-index of (Qi) of the parameter is calculated by:

$$Q_i = \sum_{i=1}^{i=n} \frac{|M_i - I_i|}{S_i - I_i} x\ 100 \quad \text{......(3)}$$

Where Mi is the monitored value of the heavy metal of the ith parameter, Ii is the ideal value of the ith parameter, Si is the standard value of the ith parameter.

The higher HPI value causes more significant damage to the health. Generally, the critical heavy metal pollution index value is 100. Therefore, the evaluation of heavy metal pollution is shown in table 1.

Table 1. Evaluation of heavy metal pollution, HPI value [22].

Degree of pollution	HPI Value
Low heavy metal pollution	< 100
Heavy metal pollution on the threshold risk	=100
High heavy metal pollution	>100

3. Result and Discussion

In the present study, metals such as Fe, Mn, Zn, Cu, Cr, and Cd were considered. Heavy metal concentration in groundwater and a summary of descriptive statistics of the metal concentration of groundwater, and the guideline values as specified maximum concentration limit defined by Government Regulation of the Republic of Indonesia, no 22/2021 about "Protection and Management Environment" are summarized in table 2 and table 3.

The HPI for the study area is determined by incorporating the mean concentration values of recorded heavy metals. The calculation of HPI of groundwater is shown in table 4 and table 5

Table 2. Laboratory analysis results in September compared with allowable limits (in mg/L).

Heavy metal	Minimum	Maximum	Mean	Government Regulation of Indonesia no 22/2021
Fe	< 0.0200	8.1160	1.2126	0.3
Mn	< 0.0100	1.1693	0.3500	0.1
Zn	< 0.0050	0.0748	0.0244	0.05
Cu	< 0.0100	0.0199	0.0124	0.02
Cr	< 0.0200	0.0218	0.0201	0.05
Cd	< 0.0020	0,0077	0.0028	0.01

Table 3. Laboratory analysis result in April compare with allowable limits (in mg/L).

Heavy metal	Minimum	Maximum	Mean	Government Regulation of Indonesia no 22/2021
Fe	< 0.0200	7.8972	1.0264	0.3
Mn	< 0.0100	0.9182	0.3004	0.1
Zn	< 0.0050	0.0994	0.0276	0.05
Cu	< 0.0100	0.0258	0.0145	0.02
Cr	< 0.0200	0.0491	0.0222	0.05
Cd	< 0.0020	0,0052	0.0022	0.01

Table 4. Calculation for HPI from groundwater sample (September) in Leuwigajah industrial area

Heavy metal	Monitored value in mg/L *Mi*	Standard value in mg/L *Si*	Unit weight *Wi*	Sub index *Qi*	*WiQi*	HPI Σ*WiQi*/Σ*Wi*
Fe	1.2126	0.3	3.3333	404.2128	1347.376	
Mn	0.3499	0.1	10	349.9923	3499.923	
Zn	0.0243	0.05	20	48.7692	975.3846	
Cu	0.0124	0.02	50	62.1153	3105.769	
Cr	0.0201	0.05	20	40.2769	805.5385	
Cd	0.0027	0.01	100	27.7692	2776.923	
			Σ*Wi*=203.333		Σ*WiQi*=1251.91	61.5291

Table 5. Calculation for HPI from groundwater sample (April) in Leuwigajah industrial area

Heavy metal	Monitored value in mg/L *Mi*	Standard value in mg/L *Si*	Unit weight *Wi*	Sub index *Qi*	*WiQi*	HPI Σ*WiQi*/Σ*Wi*
Fe	1.0264	0.3	3.3333	342.1359	1140.453	
Mn	0.3004	0.1	10	300.4154	3004.154	
Zn	0.0276	0.05	20	55.2769	1105.538	
Cu	0.0144	0.02	50	72.3461	3617.308	
Cr	0.0222	0.05	20	44.4769	889.5385	
Cd	0.0022	0.01	100	22.4615	2246.154	
			Σ*Wi*=203.333		Σ*WiQi*=12003.15	59.0319

Concentration heavy metals exceeding the standard in September are Fe in 5 location samples (W07, W09, W10, and W14), Mn in 8 location samples (W02, W04, W07, W09, W10, W11, W15, and W16), Zn in one location (W10). Meanwhile, from the sample that was taken in April, in 5 places, we found Fe (W03, W04, W07, W10, W11), Mn in 8 locations (W02, W03, W04, W07, W10, W11, W15, W16), Zn in one place (W13), and Cu in two locations (W10 and W14). Cr and Cd are found in minor concentrations in all samples locations.

Some samples have a high concentration in April, but in September, it is reverse. The heavy metal found is probably local, but in some locations that consistently found heavy metal in April and September, heavy metal concentration is permanent in that area. However, groundwater from the two places has no heavy metal inside W01 and W12.

In Cimahi City, generally in Indonesia, April is the rainy season, and September is the dry season; this will result in differences in heavy metal concentrations in groundwater samples influenced by dilution factors. This can be seen from the September HPI value, which is higher than the April HPI value.

Fe in groundwater can come from the disposal of industrial and domestic waste that does not treat first through corroded iron pipes and waste from vehicle repair shops in the surrounding area [23]. Geological conditions can cause Fe and Mn to be found in groundwater. The presence of Cu and Zn in waters can be sourced from industrial locations in the area around the river. Also, it may be attributed to domestic sewage water and runoff from extensively farmed areas.

4. Conclusion

The study reveals that the HPI based on the mean concentration value of (Fe, Mn, Zn, Cu, Cr, and Cd) was found to be 61.5291 in September and 59.0319 in April, which means that HPI in the study area is below the critical pollution index value of 100. However, the HPI value is close to 100, so further monitoring of heavy metals is needed. The heavy metal concentration was Fe, Mn, Cu, and Zn over the quality standards. Therefore, considering increasing economic activity in the research area, it is necessary to coordinate with the government to anticipate an increase in HPI value.

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