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Effectiveness of Phytoremediation on Groundwater Contaminated with Cadmium Around Talang Gulo Landfill in Jambi Province

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Abstract. The Talang Gulo landfill site in Jambi City does not yet receive clean water services from PDAM, so the community uses dug wells to get water needs. The aim of this research is to analyze the heavy metal content in the well water of residents around the Talang Gulo landfill (TPA) and determine the effectiveness of using water hyacinth plants (*Eichhornia crassipes*) in reducing the heavy metal Cadmium (Cd) content in the well water of residents around the TPA. This research is experimental research and analysis of heavy metal concentrations using Atomic Absorption Spectrophotometry (AAS). Based on the research results, the metal concentrations of Cd, Fe, Cr and Cu in residents' well water were respectively 0.054 mg/L; 1.023 mg/L; 0.062 mg/L; and 0.509 mg/L. The level of contamination/pollution of Cd metal is in the highly polluted category, the highest compared to Fe, Cr and Cu metals. After phytoremediation was carried out using water hyacinth plants for 7, 14, 21 and 28 days, the highest level of effectiveness of water hyacinth plants in reducing Cd metal was obtained on the 21st day, namely 93.61%. So, it can be concluded that water hyacinth plants are very effective in reducing the concentration of Cd metal in well water.

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1. Introduction

The presence of heavy metals in landfills is very dangerous to the environment around the landfill because these heavy metals are toxic. Heavy metals from leachate have the potential to leach into the soil and later contaminate groundwater. The presence of heavy metal contaminants in groundwater will contaminate the groundwater and the aquifers within it cannot be relied upon for domestic water supply and other uses (Rajkumar et al., 2012), especially for residents who live around the landfill and use well water for their daily needs.

The process of waste disposal in open landfills and sanitary landfills generates wastewater in the form of leachate. This type of waste disposal can cause surface water pollution due to mismanagement of leachate and uncontrolled material flow (Navarro & Toretta, 2019).

Leachate is defined as a solution (e.g., rainwater) exposed to waste deposits, some of which percolates into the soil to mix with groundwater and some of which flows on the soil surface. This leachate carries suspended and dissolved solids that represent waste degradation. The composition of leachate is influenced by factors such as the type of waste deposited, the amount of rainfall in the landfill area, and site-specific conditions. Heavy metals commonly found in leachate are lead (Pb) and mercury (Hg) (Maramis et al., 2006). In addition, according to Rosita (2003), leachate also contains heavy metals and other contaminants, namely nitrite (NO^{2-}), manganese (Mn), iron (Fe), chromium (Cr), copper (Cu), and others. Leachate, which has toxic properties, can affect the quality of the surrounding well water, so it is necessary to control it properly to avoid groundwater contamination. According to Siddiqua et al. (2022), in an effort to prevent forms of environmental pollution, ways can be designed to prevent or minimize any impact through proper disposal and/or burial of waste.

TPA Talang Gulo is one of the landfills in Jambi City, originally built using an open dumping waste management system in 1997 and is no longer in operation, this is because TPA Talang Gulo has been operated to a waste processing system using a sanitary landfill system in 2022. However, the land used as a landfill has been in operation for decades, so it is suspected that the surrounding soil and groundwater have been polluted by leachate.

The Talang Gulo open dump is surrounded by homes, most of which use groundwater as a source of clean water. Groundwater is extracted through dug wells of varying depths in each resident's house. Leachate and rainwater in the landfill seep through the soil pores and flow by gravity to the aquifer and are stored as groundwater. Examining this water journey and looking at the characteristics and symptoms in communities that use well water, where well water smells, has a brownish color, and is often itchy, it is assumed that the well water has been contaminated. Groundwater pollution is caused by heavy metal contamination, which can degrade water quality but also poison people. One way to reduce water pollution from heavy metals is to use water hyacinth (*Eichhornia crassipes*), which works to reduce heavy metal levels of lead (Pb) and mercury (Hg) in water. Water hyacinth (*Eichhornia crassipes*) is a hyperaccumulator plant that absorbs heavy metals in water. One of the heavy metals, namely lead (Pb) and mercury (Hg) in waters can be absorbed by these plants (Faisal, 2015).

Phytoremediation is an alternative solution for reducing heavy metal levels in water. The application of this method uses hyperaccumulator plants, which are considered capable of restoring the function of polluted water. The selection of plants is more resistant than microorganisms at high contaminant concentrations, plants also absorb and reduce contaminant toxicity much faster (Widyasari, 2021).

The purpose of this study is to analyze the heavy metal content in the well water of residents near the Talang Gulo dump site and to determine the effectiveness of using water hyacinth (*Eichhornia crassipes*) in reducing the heavy metal content of cadmium in the well water of residents near the Talang Gulo dump site.

2. The Methods

The site of this research is the residential areas around the Talang Gulo landfill, Jambi Province. The sample for measuring the weight content, namely well water that will be measured using AAS. The sampling method is purposive sampling. This research was conducted for 7 months, namely in April - October 2023.

The tools used in this study are GPS (Global Position System), AAS (Shimadzu AA-7000), oven (Galemp Camp), 200 mesh sieve, mortar, hot plate, analytical balance, flask, desiccator, Whatman No. 42 filter paper, and glassware commonly used in laboratories. The materials used are well water samples, water hyacinth, HNO_3 (p) 65% p.a., HCl (p) 37% p.a., Aqua DM, and heavy metal standard solution.

The stages of the research carried out are bellow

1) Well water sampling (Hadi, 2015)
   Well water samples were taken up to 2 liters using a simple tool, namely a glass bottle. They were then placed in the container provided.
2) Sample preparation and measurement of heavy metal content (Murtini, Hastuti & Gunawan, 2009)
   a. A total of 50 mL samples were taken using a dropping pipette.
   b. The sample was placed in a 100 mL beaker and 5 mL of HNO_3 solution (nitric acid) was added. The purpose of adding nitric acid is to separate out other minerals, such as oil and sulfate content, so that what is read on the AAS instrument is only heavy metals.
   c. The solution was heated on a hot plate until the sample volume reached 15-20 mL.
   d. The solution was transferred to a 50 mL volumetric flask and distilled water was added until the line of the volumetric flask was reached.
   e. The sample from the 50 mL volumetric flask was then transferred to a plastic bottle that was tightly sealed.
   f. The sample-filled plastic bottles were placed in the Atomic Absorption Spectroscopy (AAS) to read the desired heavy metal content.
   g. Data analysis using SPSS and Microsoft Excel software.

3. Result and Discussion

3.1. Heavy Metal Content

Measurements of the heavy metals cadmium, iron, chromium, and copper in the well water were performed using atomic absorption spectrophotometry (AAS). Measurements of pH and temperature were made in the field at the time of sampling. The results of the measurement of physical parameters in the well water, namely pH and temperature, are presented in Table 1 below.

Table 1. Results of pH and Temperature Measurements of Well Water

No.	Distance of Sampling Points (m)	pH	Temperature (℃)
1.	70	7,1	29
2.	230	5,64	29
3.	300	5,51	29

The measurement results show that at a distance of 70 m, 230 m and 300 m, the temperature is the same at 29 ^{0}C. The state of water temperature at each sampling location is relatively the same and is classified as normal or stable. The effect of temperature in normal conditions in water does not really affect the quality of clean water, if the temperature increases and is not normal, it will affect the increase of metal solubility in well water. According to Sukoasih and Widiyanto (2017), the increase in temperature in water will increase the accumulation and toxicity of heavy metals due to the increased metabolism of aquatic organisms. Sukoasih & Widiyanto (2017) also stated that at high temperatures, heavy metals will precipitate in sediments, while at low temperatures, heavy metals will dissolve in water. Metal particles will move faster under high ambient temperature conditions.

pH or acidity is one of the physical parameters of water that indicates the alkaline or acidic nature of the water. In addition, pH has an important influence on the mobility of heavy metals. Measurement of well water pH is also used to ensure the safety of water use. The measurement results shown in Table 1 show that at a distance of 70 m from the open dump the pH value is 7.10, at a distance of 230 m it is 5.64, and at a distance of 300 m it is 5.51. According to Indonesia MoH Regulation No. 02/2023 (Permenkes No. 02/2023), the pH value of the water has an average value of 6-8.5, if the pH value is above the value range, the water is alkaline, while if the pH value is below the value range, it is acidic and corrosive. At a distance of 70 m the pH value is still in the normal category and at a distance of 230 m and 300 m in the near normal category. In Table 1 above, the pH of the well water decreases with the distance of sampling, but is still in the normal category.

The low acidity (pH) of well water is due to contamination by pollutants. The pH of rainwater generally falls on land will increase the acidity of the soil (Singkam et al., 2021). According to Sukoasih and Widiyanto (2017), pH is used to control the solubility of metals in water. The increase in pH will decrease the solubility of metals in water because the high pH will change the stability of the carbonate form to hydroxide, thus forming a particle bond in water that will settle to form sludge. At a pH close to normal, metal solubility tends to stabilize and bind with anions, which then form organic and inorganic compounds that settle to the bottom of the water.

The results of cadmium, iron, chromium, and copper metal measurements in the well water were obtained using AAS to determine the concentration of heavy metals. The results were then compared with the quality standards for groundwater and clean water to see the concentration levels of heavy metals (Table 2).

Table 2. Concentrations of Cd, Fe, Cr, and Cu heavy metals in well water samples from residents near the Talang Gulo landfill.

Distance of Sampling Points (m)	Concentration (mg/L)			
	Cadmium (Cd)	Iron (Fe)	Chromium (Cr)	Copper (Cu)
70	0.054	1.023	0.062	0.509
230	0.043	0.663	0.046	0.316
300	0.021	0.387	0.038	0.111
Threshold Value[a]	0.004	0.3	0.07	1.3
Threshold Value[b]	0.003	0.2	0.05	2

Notes: [a]New Jersey Administrative Code 7:9C Ground Water Quality Standards (2020), [b] Indonesia Ministry of Health Regulation No. 02 of 2023

Table 2 shows that the concentration of cadmium was 0.054 mg/L at the 70 m sampling point from the open dump, 0.043 mg/L at the 230 m sampling point, and 0.021 mg/L at the 300 m sampling point. Referring to Figure 1 below, the cadmium at the 70, 230, and 300 m distances has concentrations exceeding the quality standards of New Jersey Administrative Code 7:9C (N.J.A.C) 7:9C N.J.A.C and Permenkes No. 02/2023. Cadmium has the highest concentration value compared to other metals when compared to the quality standards used. The high concentration of cadmium metal found in dug well water around the landfill is also consistent with the research conducted by Nasution and Silaban (2017) on dug wells around Muara Fajar landfill, where the obtained heavy metal cadmium content was 0.21 mg/L, which is much higher when compared to the quality standard of cadmium by Permenkes RI No. 907/MENKES/VII/2002, which is 0.003 mg/L.

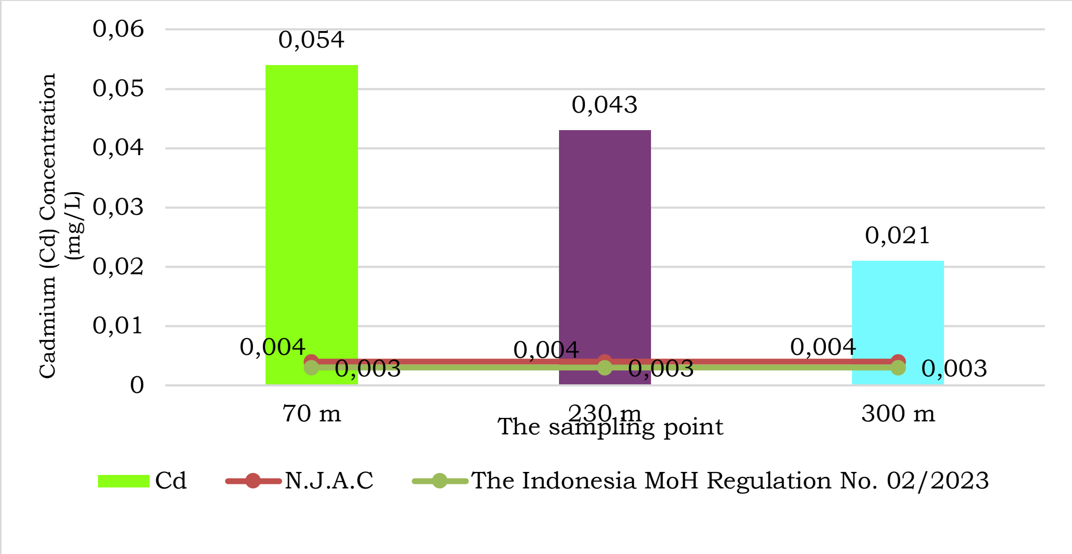

Figure 1. Concentration of Cadmium in Residents' Well Water Near Talang Gulo Landfill, Jambi City

In this study, cadmium content was found to be the highest compared to other metals in the well water of residents who were used as sampling points. Cadmium is a metal with a high toxicity value. Leachate that seeps into the wells of residents can lead to a decrease in the quality of well water. If the water is used for cooking, washing and bathing needs, it will have an impact on human health. Not only that, if the well water containing the metal is used for agricultural purposes, it will be accumulated by the plants and also contaminate the soil. If the cadmium metal is consumed by humans every day, more heavy metals will enter the body and exceed the threshold value. In the long run, this will have a negative effect on human health and cause dangerous diseases such as cancer, kidney, bone, and other diseases (Siswoyo & Habibi, 2018).

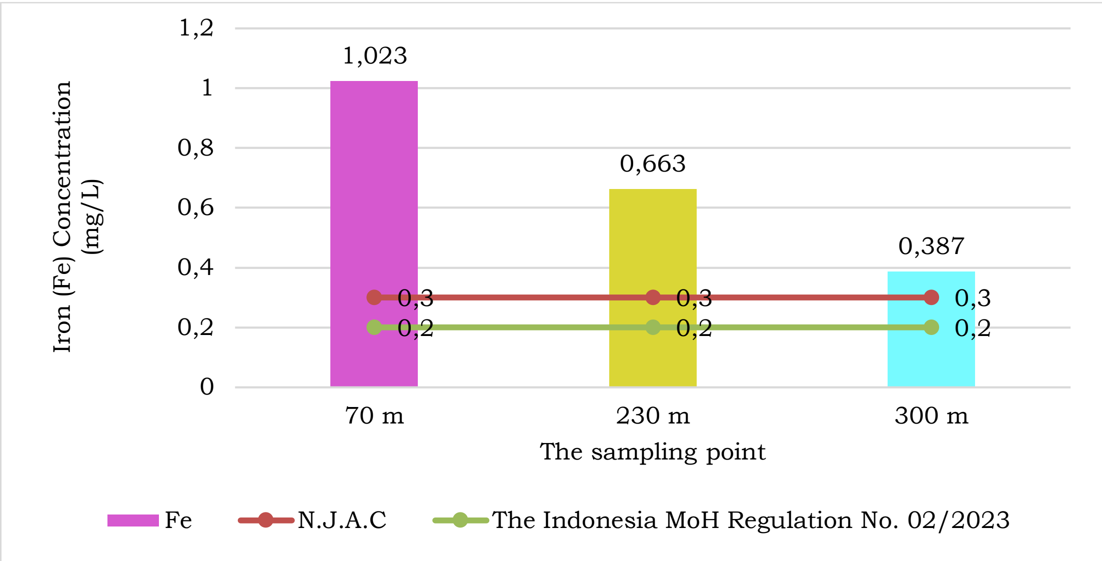

Figure 2. Concentration of Iron in Residents' Well Water Around Talang Gulo Landfill, Jambi City

Iron metal is commonly found in water and soil. Iron is an essential metal that is needed by the human body in small amounts, if in large amounts this metal will become toxic to the human body. In addition to the body, this heavy metal can damage aesthetic value because it can cause black or yellow stains on clothing. Water contaminated with excessive iron metal will show a very high color intensity in water, such as yellowish color and even brownish red color. While in the sense of taste, water containing heavy metal iron has an acidic and concentrated taste. According to Mashadi et al. (2018), excessive consumption of water containing high iron metal will cause several diseases such as heart attack, tooth decay, vascular diseases and even liver cancer.

The iron concentrations obtained were 1.023 mg/L at 70 m, 0.663 mg/L at 230 m, and 0.378 mg/L at 300 m, as shown in Table 2 above. As shown in Figure 2, the concentration of iron metal obtained in the test exceeded both the N.J.A.C. groundwater quality standard for iron metal content and the Permenkes No. 02/2023 clean water quality standard of 0.3 mg/L. Referring to other research conducted by Rosita (2023) on groundwater in Tangerang landfill, the value of iron was obtained with a high concentration of 0.02-1.16 mg/L, which has exceeded the quality standard threshold of Permenkes No. 416 of 1990 which is 1 mg/L. Another parallel study conducted by Nasution (2012) around Muara Fajar landfill, the results of well water research with the highest iron content of 0.65-2.17 mg/L which has exceeded the quality standard value of Permenkes RI No. 907/MENKES/SK/VII/2002 which is 0.3 mg/L.

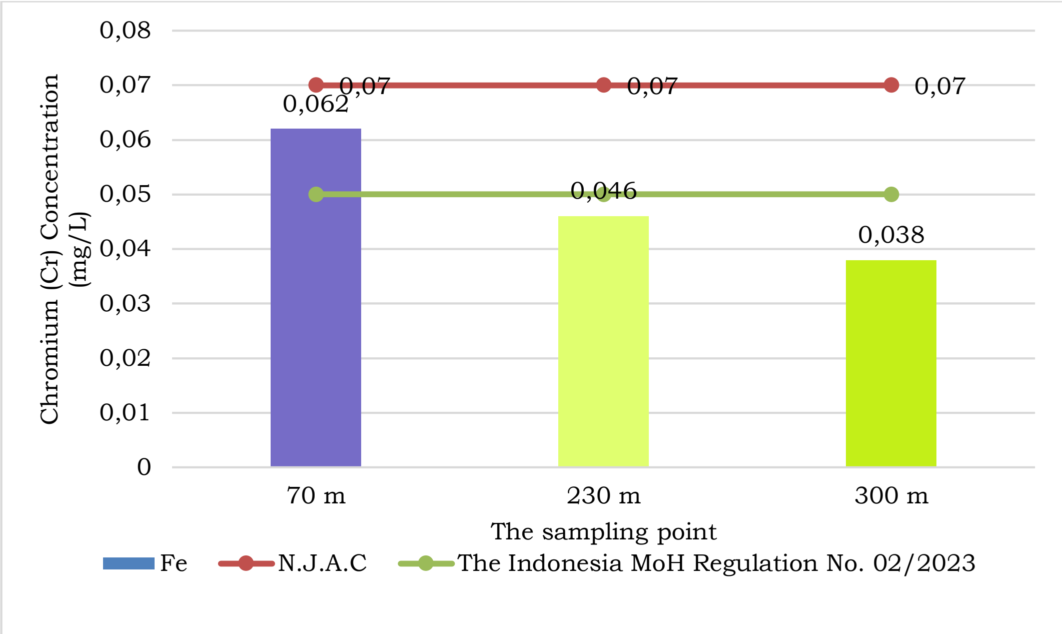

Figure 3. Concentration of Chromium in Residents' Well Water Around Talang Gulo Landfill in Jambi City

The concentration of the heavy metal of chromium was 0.062 mg/L at 70 meters, 0.046 mg/L at 230 meters, and 0.038 mg/L at 300 meters. Chromium has a concentration below the N.J.A.C. Groundwater Quality Standard, while at the Permenkes No. 02/2023 Clean Water Quality Standard at a distance of 70 m the concentration of this metal is above the quality standard and at a distance of 230 m and 300 m it is still below the quality standard as can be seen in Figure 3. This shows that the results obtained at the three distances differ only slightly. The chromium found in the dug well water of the residents around the landfill is still below the groundwater quality standard based on the N.J.A.C which is 0.07 mg/L, when compared to Permenkes No. 02 of 2023, it exceeds the drinking water quality standard at a distance of 70m. Similar research conducted by Taufik et al. (2013) on well water around Namobintang landfill, where the concentration of chromium was 0.00065-0.04345 mg/L. These results show that chromium is still below the quality standard of Permenkes No. 492/Per/IV/2010 on drinking water quality requirements, which is 0.05 mg/L.

Chromium metal enters water through natural and non-natural means. According to Poa et al. (2021), the low chromium in water is caused by physical and chemical factors. Normal temperature indicates low chromium toxicity, the higher the water temperature, the higher the toxicity of chromium. In addition to temperature, another factor is pH, where the lower the pH, the greater the toxicity of chromium metal. Groundwater can become contaminated with chromium when it comes into contact with soil, which adsorbs chromium through a process called desorption. Chromium is classified as a carcinogenic metal and can interfere with the body's metabolism.

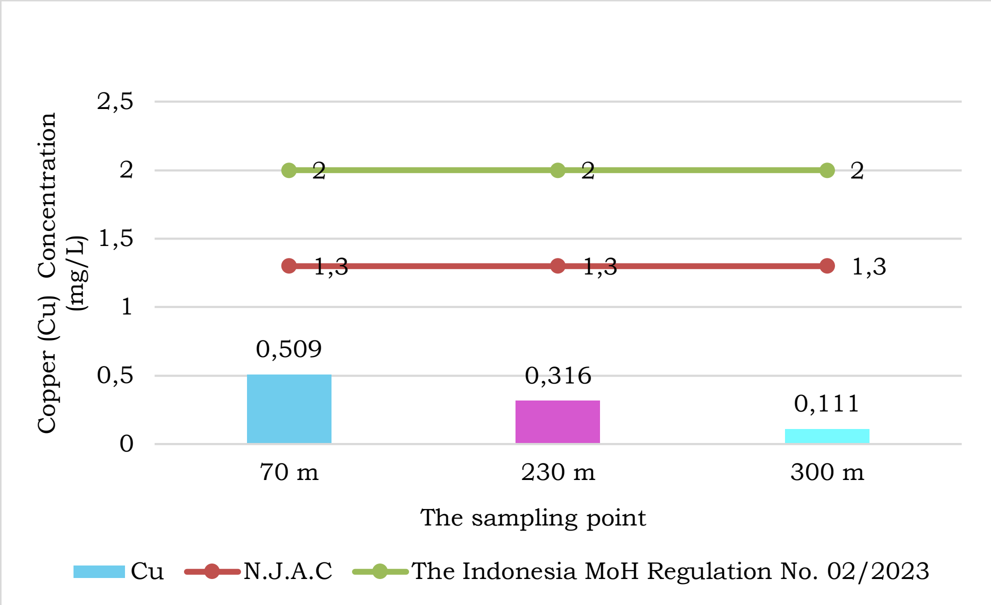

Figure 4. Concentration of Copper in Residents' Well Water Around Talang Gulo Landfill in Jambi City

The results of the copper tests in this study were 0.509 mg/L at 70 meters, 0.316 mg/L at 230 meters, and 0.111 mg/L at 300 meters. The concentration of copper obtained does not exceed the quality standards of N.J.A.C. and Permenkes No. 02 of 2023 as shown in Figure 4. These results indicate that dug well water contains very little copper as opposed to cadmium, iron and chromium. In accordance with the research conducted by Komala et al. (2008) on the well water of the residents of the Cold Water Landfill, the concentration of copper in well water is 0.0063-0.0107 mg/L, these results are still below the quality standard of PP RI No. 82 of 2001 for copper of 0.02 mg/L. Referring to the research conducted by Wahyuni et al. (2010) on the well water of the residents of Rawa Kucing Landfill, where the results of copper concentrations were found to be 0.046-0.002 mg/L, which showed that it is still below the quality standard based on Permenkes RI No. 492/Menkes/Per/IV/2010 concerning water quality requirements, which is 2 mg/L.

The element copper is widely distributed in nature in the form of metal. Copper is found in water, soil and air in the form of compounds and ions. Copper is an essential metal, where in small amounts copper is needed by organisms as a coenzyme in the body's metabolism, but in high concentrations it becomes toxic (Harahap & Simatupang, 2021). High and low concentrations of copper in dug well water because copper can form $Cu(OH)_2$ precipitates at pH 6-8 (Wahyuni et al., 2010). In addition, according to Komala et al. (2008) that what affects the concentration of copper in groundwater is copper salts such as copper carbonate ($CuCO_3$), copper silicide (CuS) and copper hydroxide ($Cu(OH)_2$), which have insoluble properties in water. Phytoplankton will die because the concentration of 0.01 mg/L inhibits the process of metabolic enzymes during phytoplankton cell division. Copper metal at a concentration of 0.01 mg/L phytoplankton will die because copper inhibits the process of metabolizing enzymes in phytoplankton cell division. At concentrations of 2.5-3.0 mg/L in water, it can cause death in fish (Harahap & Simatupang, 2021).

2.2. Effectiveness of Using Water Hyacinth (*Eichhornia crassipes*) as a Phytoremediation Agent

Referring to Table 2, the results of measuring well water samples of residents around the Talang Gulo landfill where the concentration of Cd, Fe, Cr and Cu heavy metals has exceeded the quality standards of N.J.A.C and Permenkes No. 2/2023. In this study, only the effectiveness of using water hyacinth plants (*Eichhornia crassipes*) to reduce the heavy metal levels of Cd was observed, because Cd is included in the toxic metals and is a global health that affects many organs and in some cases can cause death (Rahimzadeh et al., 2017). Cd is a toxic non-essential transition metal that poses health risks to humans and animals and accumulates in plants and animals with a long half-life of about 25-30 years (Genchi et al, 2020), while Fe is included in the class of non-essential toxic metals. According to Ika et al (2012), Fe belongs to the group of transition metals needed by the body for the formation of hemoglobin and the levels in natural water are 0.05-0.2 mg/L.

The effectiveness of using water hyacinth (*Eichhornia crassipes*) in reducing Cd heavy metal levels can be known after laboratory testing. Two types of samples are tested, namely the initial Cd heavy metal concentration before and after the phytoremediation test. The phytoremediation test uses an abatch system, which is a glass tub filled with well water samples dug by residents around the Talang Gulo landfill. Water hyacinth (*Eichhornia crassipes*) plants were placed in the batch and monitored in a time variation of 7 days, 14 days, 21 days and 28 days.

Table 3. Concentration of Cadmium after Phytoremediation with Hyacinth

No.	Detention Time (Days)	Concentration of Cd Metal (mg/L)	Threshold Value	
			N.J.A.C	Ministry of Health Regulation No. 2 Year 2023
1.	7	0.023	0.004 mg/L	0.003 mg/L
2.	14	0.012	0.004 mg/L	0.003 mg/L
3.	21	0.003	0.004 mg/L	0.003 mg/L
4.	28	0.012	0.004 mg/L	0.003 mg/L

Based on Table 3 above, there is a decrease in heavy metal levels with each retention time, where the lowest decrease in heavy metal levels and has reached the quality standards on the 21st day, namely 0.003 mg/L. The effectiveness of cadmium (Cd) reduction in water hyacinth plants refers to the ability of water hyacinth to absorb cadmium (Cd) content in community dug well water. Based on Equation 1 of the formula Effectiveness (EF) = $\frac{(Co - Ct)}{Co} \times 100\%$, the effectiveness of water hyacinth plants is obtained in Table 4 below.

Table 4. Effectiveness of Water Hyacinth Plants in Reducing Cd Concentration in Residents' Well Water

No.	Detention Time (Days)	Initial Concentration of Cd (mg/L)	Final Concentration of Cd (mg/L)	EF (%)
1.	7	0.047	0.023	51.06
2.	14	0.047	0.012	74.47
3.	21	0.047	0.003	93.62
4.	28	0.047	0.012	74.47

Based on Table 4 above, it is known that water hyacinth plants are very effective in reducing cadmium metal, especially with a retention time of 21 days with an effectiveness of 93.62%. On the 28th day, the water hyacinth plants were saturated and the cadmium metal absorbed by the plants was released. The effectiveness of reducing the cadmium (Cd) in well water dug by the community in TPA

Talang Gulo area, Jambi City by using water hyacinth (*Eichhornia crassipes*) plants planted directly in the well water is more optimal than adding water hyacinth (*Eichhornia crassipes*) powder to the dug well water. Based on research (Lestari, 2012) states that the calculation of the effectiveness of cadmium after adding water hyacinth powder is the highest at 33.72% with the initial level of heavy metal cadmium (Cd) in community well water in Namo Bintang village before filtering is 0.00685 mg/L which exceeds the quality standards, so researchers reduce it by adding adsorbents in the form of water hyacinth powder (*Eichhornia crassipes*).

4. Conclusion

The results obtained for cadmium and iron heavy metal concentrations at a distance of 70 m, 230 m, and 300 m exceeded the quality standards of N.J.A.C. and Permenkes No. 02/2023. The value of chromium concentration has exceeded the N.J.A.C. standard at a distance of 70 m, 230 m and 300 m. While based on the quality standard of Permenkes No. 02/2023, the concentration of chromium at a distance of 70 m exceeds the quality standard and the distance of 230 m and 300 m is still below the quality standard. The copper metal concentration values obtained at 70 m, 230 m and 300 m are still below the N.J.A.C. quality standard. Water hyacinth plants are very effective in reducing heavy metal cadmium, especially with a detention time of 21 days with an effectiveness of 93.62%.

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