Control of Chromium Hexavalent (Cr -VI) Pollution on Waste Water in Nickel Ore Extraction Industry with Phytoremediation Technology

Erikha Maurizka Mayzarah[1,*], *Setyo Sarwanto* Moersidik[2], and *Lana* Saria[3]

[1]School of Environmental Science, Universitas Indonesia, Indonesia
[2]Environmental Engineering Program, Faculty of Engineering, Universitas Indonesia, Indonesia.
[3]General Directorate of Mineral and Coal, Ministry of Energy and Mineral Resources,Indonesia

Abstract. The issue that surfaces from the digging of limonite and saprolite zones on nickel ore mining is the oxidation of chromium to chromium hexavalent. The aim of this research is to analyze the efficiency level of phytoremediation technology to reduce chromium hexavalent on waste water of nickel ore mining industry. This study was done in situ to observe the potential of Water Lettuce (*Pistia stratiotes*) using self-designed experimental devices.. This research was divided into three part, such as the variation of plant's weight of 10grams, 20grams, 30grams, 60grams, 70grams, and 150grams with interval of an hour for five hours, variation of chromium hexavalent of 0.5ppm, 1ppm, 2ppm, 5ppm, and 7ppm with interval of 4 days for 20 days, and variation HRT 1.5 hours, 2 hours, and 3 hours with interval of 24 hours for 16 days. The result of this research shows the average of efficiency on observation one, two and three are 18.5%, 89%, and 28%. The usage of phytoremediation technology shows the potential to reduce chromium hexavalent pollutant.*Keywords: Phytoremediation,Chromium hexavalent, Pollution Control, Pistia stratiotes, Waste water*

1 Introduction

The high level of damage and pollution to living environment has become one of the addressed debates and issues in every occasion in many parts of the world, including Indonesia. Pollution and environmental damage that originate from human's activities contribute substantially to the decrease of quality and function of environment to support humans' and other living creatures' live [1]. Industrial sector is one of the humans' activities that contribute to the environmental damage due to excessive usage of natural resources, as well as produce waste and pollution [2].

*Corresponding author: ssarwanto@eng.ui.ac.id

PT Vale Indonesia Tbk is a company that operates on extraction of nickel ore mining. On 2017, PT Vale Indonesia Tbk has produced nickel matte of 76.807 ton. Other than producing nickel matte, the mining activities also produce waste product such as solid, liquid and gas waste. The main issue faced by PT Vale is the chromium hexavalent content that becomes the pollutant on waste water,which the content is approximately 0.1 – 6.28 ppm [3]. Metal Cr (VI) may induce toxic effect and dangerous for humans and animals [4] Chromium hexavalent pollutant cannot be degraded in a short time and has to be extracted from the polluted location [5].

Some of the traditional methods of waste water treatment to reduce chromium hexavalent pollutant are adsorption and coagulation, chemical deposition, membrane filtration and ion exchange [6]. These methods have deficiencies such as incomplete reduction, needs huge energy, and produces toxic mud [7]

Phytoremediation is a technology that utilizes plants to mitigate, transfer, stabilize or degrade pollutants present on soil, sediment and water [8] This method is considered as environmentally and economically friendly technology. Furthermore, it is also considered as one of the technology to manage water pollution caused by heavy metal [9] Phytoremediation consists of phytoextraction, phytodegradation, phytostabilization, and phytofiltration. The success of phytoremediation mainly depends on the photosynthesis activity and the growing rate of the plant used. According to [5], water lettuce (*Pistia stratiotes*) can be a phyoremediator for waste water that has heavy metal content.

This paper will discuss the efficiency rate of chromium hexavalent on waste water of nickel ore mining industry with phytoremediation technology. Moreover, this paper will also analyze the content of chromium hexavalent on water lettuce (*Pistia stratiotes*) used in this technology.

2 Materials and Methods

This research was done in PT Vale Indonesia, Tbk, Nuha Sub-district, East Luwu District, South Sulawesi, Indonesia (Figure 1). The type of plant used in the phytore mediation method is water lettuce (*Pistia stratiotes*) The first observation consisted of waste water with the chromium hexavalent content of 2 ppm, placed in 6 container, each contains 3 liters. The variation of plant weight was 10 grams, 20 grams, 30 grams, 60 grams, 70 grams, and 150 grams. The measurement was taken for every 1 hour for 5 hours. The second observation consisted of waste water with the chromium hexavalent content of 0.5 ppm, 1 ppm, 2 ppm, 5 ppm and 7 ppm. This observation used water lettuce (*Pistia stratiotes*) weighed 20gr/liter where every sample used 5 liters of artificial solution. The measurement of chromium hexavalent content was taken for every 4 days for 20 days. The third observation was the waste water in Lorraine pond which flowed to core box with capacity of 45 liters and the weight of the plant used was 20grams/liter. This research used HRT variation of 1 hour, 1.5 hours, and 3 hours. The measurement of chromium hexavalent content was taken in 24 hours interval for 16 days.

This research used Repeated Measures plan.The water sample analysis was performed with APHA-3120-2012 method. The sample of plant's leaf was analyzed with Flame Atomic Spectroscopy (FAAS) method. The efficiency rate of phytoremediation technology was analyzed with formula below [6]:

$$\text{Removal } \% = \frac{C_o - C_e}{C_o} x\ 100\% \quad (1)$$

Where,
C_o = Concentration of chromium hexavalent on inlet
C_e = Concentration of chromium hexavalent on outlet

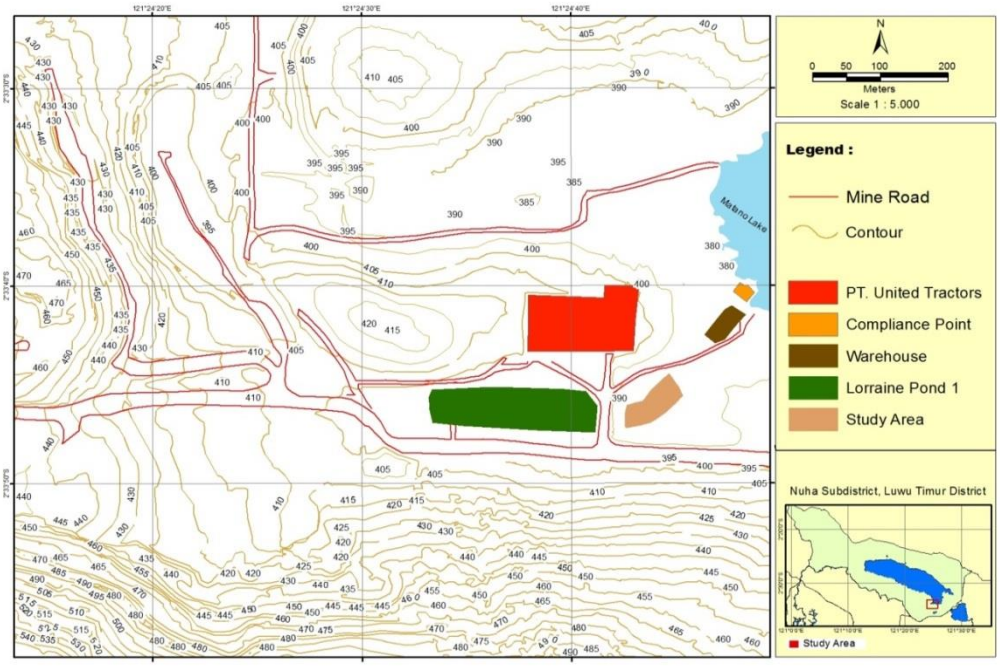


Fig. 1. Research Location

3 Results and Discussions

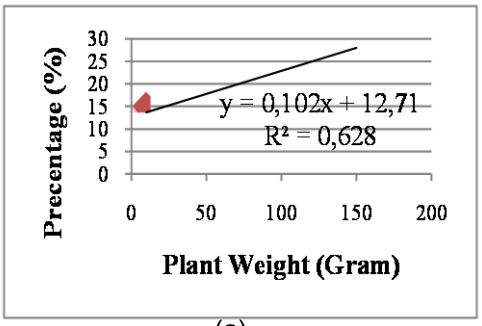
This research was performed on Lorraine Pond where this pond is the setup point of PT Vale Indonesia Tbkset by Ministry of Environment and Forestry. Lorraine pond is directly connected with Matano Lake as the water body. Technology used was phytofiltration which is a part of phytoremediation. The research's result shows the various efficiency rate of chromium hexavalent reduction (Table 1).

Table 1. The maximum, minimum, average and standard deviation of Chromium Hexavalent Reduction Test with Phytoremediation Technology

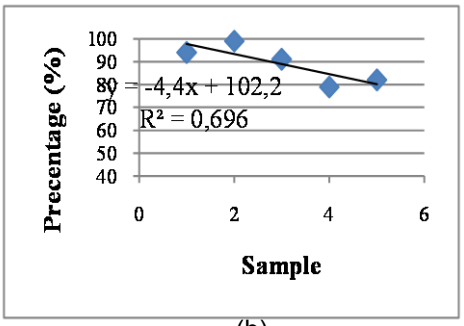
Observation	Min (%)	Max(%)	Average(%)	Dev. Std
1	11	27	19	6
2	79	99	89	7
3a	5	59	30	8
3b	2	61	28	5
3c	5	59	27	6

Based on Table 1, the highest and lowest minimum values were 79% and 2%. This happened due to rizospheric system or saturated plant's root. The highest and lowest maximum values were 99% and 27%. This indicated that the plant's absorption has not been maximized if it is measured per hour. The average of the efficiency rate of chromium hexavalent was in range of 19-89%. Where the highest and lowest maximum values were 89% and 19%. Standard deviation for the three tests were approximately 6-8. Figure 2 elaborates the results in detail.

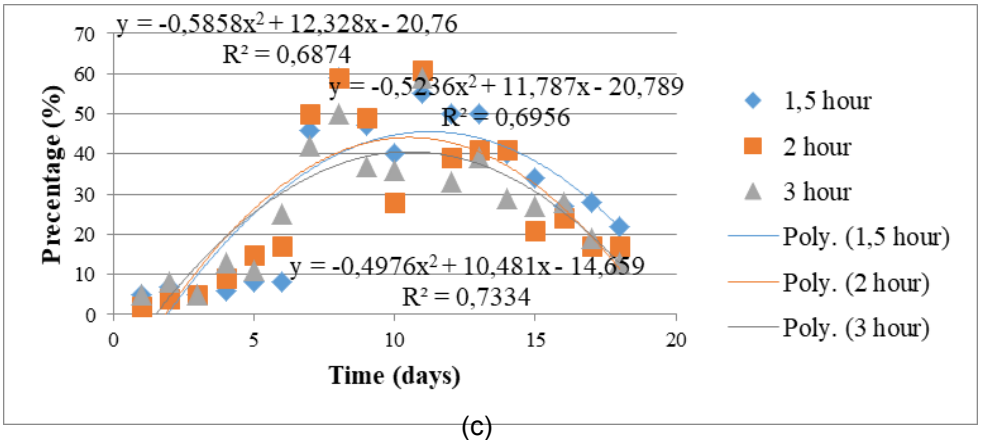
According to Figure 2, the reduction of chromium hexavalent on test one, two and three have $R^2$of 0.62, 0.69, and 0.73. The average efficiency rate on test one, two and three were 18%, 89%, and 28%. Figure 2a indicates that the weight of the plant used is directly proportional to the efficiency rate of chromium hexavalent reduction. The highest and lowest efficiency rates on this observation were 27% and 11%. Figure 2b shows that the concentration of chromium hexavalent in water is inversely proportional to the efficiency rate of chromium hexavalent reduction by *Pistia stratiotes* plant. The highest and lowest efficiency rates on this observation were 99% and 79%. Figure 2c elaborates that the efficiency rate of chromium hexavalent reduction was increased, however on the 11th day, it has reached its maximum absorption, which are 55%, 61% and 59%.



(a)



(b)



(c)

Fig. 2. The efficiency rate of phytoremediation Technology (a) Variation of water lettuce (*Pistia stratiotes*)weight on Batch Scale (b) Variation of chromium hexavalent concentration on Batch Scale (c) Variation of Hydraulic Retention Time (HRT) on Continued Scale.

This is in accordance with research by Ugya (2015) that concluded the water lettuce (*Pistia stratiotes*) is an effective agent to reduce and eliminate various heavy metal such as

Hg, Cd, Mn, Ag, Pb, Zn in Romi River, Nigeria [10]. Victor et al. (2016)[11] claimed that water lettuce (*Pistia stratiotes*) reduces lead (Pb), zinc (Zn), cadmium (Cd), copper (Cu) and chromium (Cr) for more than 50%. The potential of heavy metal reduction using water lettuce (*Pistia stratiotes*) was also reported by other researchers (12,13, 14).
Water lettuce (*Pistia stratiotes*) in phytoremediation technology is one of the solutions to control pollution. However, this technology still has its shortcoming, such as longer time needed. Currently, pollution mitigation and waste minimization are preferred compared to pollution control. However, recently industries prefer to control their waste by reducing pollutants because it is cheaper and faster [15].

4 Conclusion

Pistia stratiotes is efficient to reduce chromium hexavalent in 16 days. The result of the research shows that this plant has a good performance in reducing chromium hexavalent on observation one, two and three with value of 18.5%, 89% and 28%. This can be an alternative to control water pollution, however other factors have to be considered to reach the maximum result. Former researchers have done many research regarding the elimination of chromium from different waste water, however, a big scale research has never been done before on mining water. It is expected that in the future, bigger attention will be given to Pistia stratiotes plant to treat industry and other type of waste water.

Acknowledgments

This research was funded by HIBAH PITTA 2018 from DRPM University of Indonesia No.2583/UN2.R3.1/HKP.05.00/2018 and supported by PT Vale Indonesia Tbk.

References

1. S. Singh. J. of Env. An. Chem. **1** (2012).
2. G.T. Miller, S.E. Spoolman. *Environmental Science Fifteenth Edition*.(Cengage Learning: Boston, USA, 2016)
3. Vale Indonesia Tbk. *Geotechnical and hydrology Section Report* (Jakarta; PT. Vale Indonesia Tbk., 2017)
4. H. Qin, Z. Zhang, M. Liu, H. Liu, Y. Wang, X. Wen, Y. Zhang, S. Yan., Eco. Eng. **95**:753-762 (2016)
5. J. Yu, C. Jiang, Q.Guan, P. Ning, J.Gu, Q. Chen J. Zhang, R. Miao, Chemo. **195** (2018).
6. P. Saha, O.Shinde, S. Sarkar, Int. J.of Phyt. **19**, 1 (2017).
7. S. O. Ojoawo, G.Udayakumar, P. Naik, Aquatic Procedia**. 4** (2015).
8. D. H. K. Reddy, Wat. Pol. C. Tech. 3-22. (2017).
9. A.Y. Ugya, T.S. Imam, S.M. Tahir, J. of Env. Sci., Tox. F. Tech. **9** (2015).
10. K.K. Victor, Y. Seka, K.K. Nobert, T.A. Sanogo, A.B. Celestin, Int. J. of Phyt. **18**, 10 (2016).
11. E.J.Olguín, D.A García-López,. R.E.González-Portela, G. Sánchez-Galván.Sci. of The T. Env. **592** (2017).
12. E. Handayanto, N. Erfiana,Widianto. J. Pol. Res **36**, 4 (2017).
13. V. Kumar, J. Singh,A.K. Chopra. Int. J. of Phyt **20**, 5 (2018).
14. A.N. Modenes, A.P. de Oliveira, F.R. Espinoza-Quinones, D.E.G. Trigueros, A.D. Kroumov, R. Bergamasco. Chem **172** (2017)

15. F.w. Owa, Int. Let. of Nat. Sci **3** (2014).