INNSPUB

International Journal of Biosciences | IJB |
ISSN: 2220-6655 (Print), 2222-5234 (Online)
http://www.innspub.net
Vol. 22, No. 1, p. 18-26, 2023

RESEARCH PAPER OPEN ACCESS

Removal of Fe in well water using surface flow constructed wetland system with *Eichhornia crassipes* and *Pistia stratiotes* L.

Nopi Stiyati Prihatini*, **Muhammad Firmansyah, Indah Nirtha, Chairul Abdi, Andi Suryanata**

Environmental Engineering Study Program, Faculty of Engineering, Universitas Lambung Mangkurat, Jl. A. Yani Km. 36, Banjarbaru, South Kalimantan, 70714, Indonesia

Key words: Fe, Well Water, Surface Flow Constructed Wetlands (SF-CW), *Pistia stratiotes* L., *Eichhornia crassipes*

http://dx.doi.org/10.12692/ijb/22.1.18-26 Article published on January 02, 2023

Abstract

Research on water Fe removal by *Eichhornia crassipes* and *Pistia stratiotes* L. on the Constructed Wetland (CW) system was carried out to know the efficiency of Fe removal on the Surface Flow Constructed Wetland (SF-CW) system. The research was conducted on well water in Selat Makmur Village, Beruntung Baru District, Banjar Regency, South Kalimantan Province, Indonesia. Fe concentration in existing well water is 2.24 mg / L; compared to the Regulation of the Minister of Health of the Republic of Indonesia No. 32 of 2017 concerning water health requirements for sanitary hygiene purposes, the well water exceeds the predetermined quality standards. This study used six reactors where two reactors contained Pistia *stratiotes* L.; two reactors had *Eichhornia crassipes* and two other reactors without vegetation as control reactors. The dimensions of each reactor are 90cm x 30cm x 45cm, operated for 20 days with a residence time of 5 days. The density of *P.stratiotes* L. and *E.crassipes* used was 540g/108L wet-weight. The highest Fe removal efficiency of SF-CW with *P.stratiotes* L. vegetation occurred on the 15th day at 85.11%, and SF-CW with *E.crassipes* on the 10th day at 89.32%. The results of this study show that both vegetation with the SF-CW system can be considered for use by the surrounding community because this vegetation can remove Fe.

* **Corresponding Author:** Nopi Stiyati Prihatini ✉ ns.prihatini@ulm.ac.id

Introduction

Gambut Subdistrict has the characteristics of marsh and peat soil, so the water in this area has high levels of heavy metals such as Iron (Fe). Based on data from the Banjar Regency Health Office, South Kalimantan Province, Indonesia, the majority of the population in the Gambut Subdistrict still depends on well water to meet their basic needs. The water used has a yellow color and smells; this indicates that water contains heavy metals such as high iron (Fe) content (I. Nirtha *et al.*, 2021; Nurlina *et al.*, 2016; Prihatini *et al.*, 2022). This water problem will cause health problems for the community is used continuously without any treatment. Based on previous research that has carried out the results of analysis on the well water, which has a Fe concentration of 101.54 mg/L, the water exceeds the maximum allowable level of 1 mg/L based on Minister of Health RI No. 32 of 2017 concerning Water Health Quality Standards for Sanitation Hygiene Needs, Swimming Pools, Solus Per Aqua, and Public Baths. Therefore, technology is needed to treat Fe in the well water so that the well water is fit for use by the community.

The method that can be used to solve the problem of water containing heavy metals that are easy, inexpensive, and effective in its application is constructed wetlands (Kadlec & Wallace, 2008; Prihatini *et al.*, 2022; Yunus & Prihatini, 2018). Constructed wetlands are planned or controlled treatment systems designed and built using natural processes involving vegetation, media, and microorganisms to treat wastewater (Prihatini, 2015; Prihatini, Khair, *et al.*, 2020). Constructed wetlands have good performance characteristics and minimum operating and investment costs and are highly economical and beneficial to society in wastewater treatment. Pollutant removal mechanisms are an essential basis in the engineering design of constructed wetlands and can provide reliability in engineering design and operation (Prihatini *et al.*, 2015). In this study, we will use Surface Flow Constructed Wetlands (SF-CW) with the flow and plant types that differ from previous studies. Previous studies using Vertical Subsurface Flow Constructed Wetlands (VSSF-CW) (Prihatini *et al.*, 2016; Prihatini, Khair, *et al.*, 2020) with Jeringau (*Acorus calamus*) and Purun tikus (*Eleocharis dulcis*) were effective in removing Fe with fairly good efficiency (76,72 % - 85.68%) (Prihatini *et al.*, 2022), it's just that the concentration of iron after being processed in the VSSF-CW reactor for 40 days is not meet the quality standard required by Regulation of the Minister of Health of the Republic of Indonesia Number 32 of 2017. This study will use *Eichhornia crassipes* and *Pistia stratiotes* L., which are local plants in Kalimantan. The two plant species that will be used in the constructed wetlands are capable of treating and degrading water containing heavy metals. In Yunus & Prihatini's research (2018), the performance efficiency of CW using *E.crassipes* in removing Fe was 87.11% - 95.28%, and Mn was 70.08 - 79.84%. The research by Nurlina *et al.* (2016) stated that the *P.stratiotes* L. plant was proven to be able to P.stratiotes is proven to be able to absorb Fe with an absorption capacity of 249.5807 mg/kg/day.

Pistia stratiotes L., or what we usually call water lettuce, are floating plants that belong to the *Araceae* family. *P.stratiotes* L. plants have roots that hang submerged under leaves that float on the surface (Dipu *et al.*, 2011).

The Constructed wetland system in this study applies surface *flow* (SF) which means a condition where the water level is above the ground level; vegetation rooted above the water surface, significantly above the ground. *Surface flow* is used because *P.stratiotes* L. and *E.crassipes* are plants that do not require media to live and only rely on water (Yunus & Prihatini, 2018). The *constructed wetlands* method can lower Fe concentrations and increase pH (I. Nirtha *et al.*, 2021; Prihatini, Abdi, *et al.*, 2020; Prihatini *et al.*, 2015, 2016, 2022; Prihatini & Soemarno, 2021, 2017; Yunus & Prihatini, 2018). The result of metal removal is partly due to the metal sedimentation process with the natural shrinkage of sulfates and some with the help of plants, using plants absorbing a small part of the metal (Yunus & Prihatini, 2018).

Research methodology

In this study, *P.stratiotes* L. and *E.crassipess* 5 g/L wet weight were used, with fresh green color leaves and medium height stem medium height stems with habitat around the study site. The SF-CW reactor is 90 cm x 30 cm x 45 cm. Figure 1 illustrates the reactor in this study; figure 1. a show the whole constructed wetland system, two reactors planted with *P.stratiotes* L., two reactors (Figure 1. b) are planted with *E.crassipes* and the last two reactors (Figure 1. c) without plant and will be used as control reactors (Figure 1.d). Sampling in this study will be conducted for 20 days with a residence time of every five days. Samples were taken on the influent and effluent from each reactor of as much as 600 mL.

Data analysis to determine the efficiency of removal Fe used the following equation (Hedin & Nairn, 1990) :

$$E = \frac{C_o - C_e}{C_o} \times 100\% \quad (1)$$

Annotation :

E = Fe removal efficiency (%)

C_o = Initial concentration of iron (mg/L)

C_e = Final concentration of iron (mg/L)

Data analysis will be carried out after the data collection process. The study was conducted on a laboratory scale. The data obtained was then used to determine the SF-CW system using two types of plant, *P.stratiotes* L. and *E.crassipess*, which were the most efficient in removing iron (Fe) in well water. The data obtained from the research results will be analyzed properly, the data will be presented in tables or graphs as a basis for decision-making, and descriptive data analysis will be carried out.

Results and discussion

Characteristics of Fe well water

Heavy metals contained in the well water of The Selat Makmur Village, such as Fe and Mn, are derived from marshlands and pictorial. The physical characteristics of well water include a brownish-yellow color and a metallic smell. The high concentration of iron exceeds the threshold value of the Minister of Health of the Republic of Indonesia No. 32 Th 2017 on water health requirements for sanitary hygiene purposes causing well water to be unusable for clean water needs by residents of Selat Makmur Village. Before processing with the surface flow constructed wetland system, the well water sample of The Selat Makmur Village is analyzed first to determine the concentration of pollutants. The results of the preliminary analysis of the well water characteristics of Selat Makmur Village, Beruntung Baru District, Banjar Regency, are presented in Table 1.

Table 1. Characteristics of Well Water in Selat Makmur Village, Beruntung Baru District, Banjar Regency.

Parameter	Unit	Value	Quality Standards
Temperature	^oC	-	air temperature ± 3
pH	-	6,99	6,5 – 8,5
Fe	mg/L	2,24	1
Mn	mg/L	0,7	0,5
TDS	mg/L	189	1000
Total Coliform	NPM/s	3,6	50

Based on Table 1, it can be seen that there are some parameters whose values still exceed the quality standards of the Minister of Health of the Republic of Indonesia No. 32 th 2017 on water health requirements for sanitary hygiene purposes, such as Fe with a value of 2.24 mg / L and Mn with a value of 0.7 mg / L. In comparison, other parameters such as pH, temperature, TDS, and total coliform have reached the quality standard values. Efforts can be made to maintain individual hygiene such as MCK and washing food, tableware and clothing with the help of the SF-CW system using vegetation *P.stratiotes* L. and *E.crassipess* so that the well water of The Selat Makmur Village can be used safely and comfortably.

Efficiency analysis of Surface Flow Constructed Wetlands (SF-CW) system

The concentration of Fe in the well water of The Selat Makmur Village before being treated with a surface flow constructed wetland system is 4.1 mg/L. Based on the Minister of Health of the Republic of Indonesia No.32 of 2017 concerning water health requirements for sanitary hygiene purposes, it doesn't meet the quality standard of 1.0 mg / L. High concentrations of Fe can have an impact on the health of living things. The iron found in the water can come from rock water that feeds Fe compounds such as pyrite.

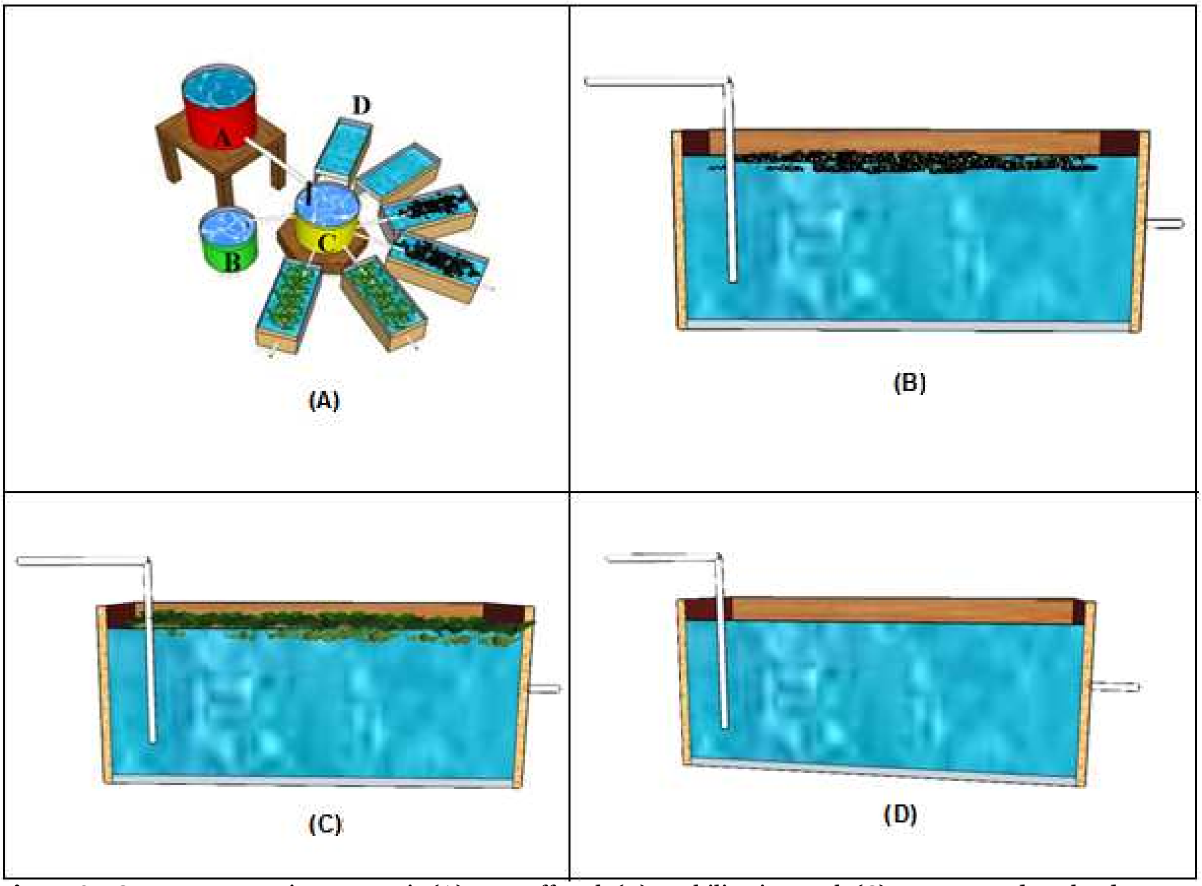

Fig. 1. SF-CW Reactor Design reservoir (A); run-off tank (B); stabilization tank (C); constructed wetland reactor (D).

This study utilized the Surface Flow Constructed Wetlands System with a continuous operating procedure; samples were taken per five days for 20 days. The sample was taken on day 0 to determine the initial concentration before the water goes through the process in the SF-CW system on days fifth, 10th, 15^{th}, and 20th to determine concentration removal or efficiency in each reactor. The number of reactors used is six pieces, with the reactor size being 90cm x 30cm x 40cm. The dimensions of this reactor are the same as the previous study by Prihatini *et al.* (Prihatini *et al.*, 2022). Two SF-CW are used for *P.stratiotes* L. plants, two for the *E.crassipess* plants, and the other two are used for the repetition of the control reactor (without plants) aimed at minimizing errors while the research is ongoing.

The results of measurements of Fe concentrations in the *effluent* of the Surface Flow Constructed Wetland system can be seen in Figure 2 as follows. In this study, the average pH in the reactor was 6.65 – 7.75 while the water temperature was 27.15°C – 30.5°C. According to the Minister of Health of the Republic of Indonesia No. 32 of 2017, the optimum condition of the pH of the water used in the phytoremediation test of 6.5 – 8.5 showed that in this study, the pH of the water had met the quality standards. Under these conditions of temperature and pH, plants can grow well, and simultaneously, the phytoremediation process can run well. **Figure 2** explains that Fe concentrations during the 20 days of study for all reactors decreased significantly after being processed in SF-CW systems compared to Fe concentrations before passing through SF-CW systems. Reactors containing *P.stratiotes* L. plants have the lowest Fe concentration value, namely, on day 15, which is worth 0.78 mg / L, and the *E.crassipes* reactor on day 10 has the lowest concentration value of 0.425 mg / L.

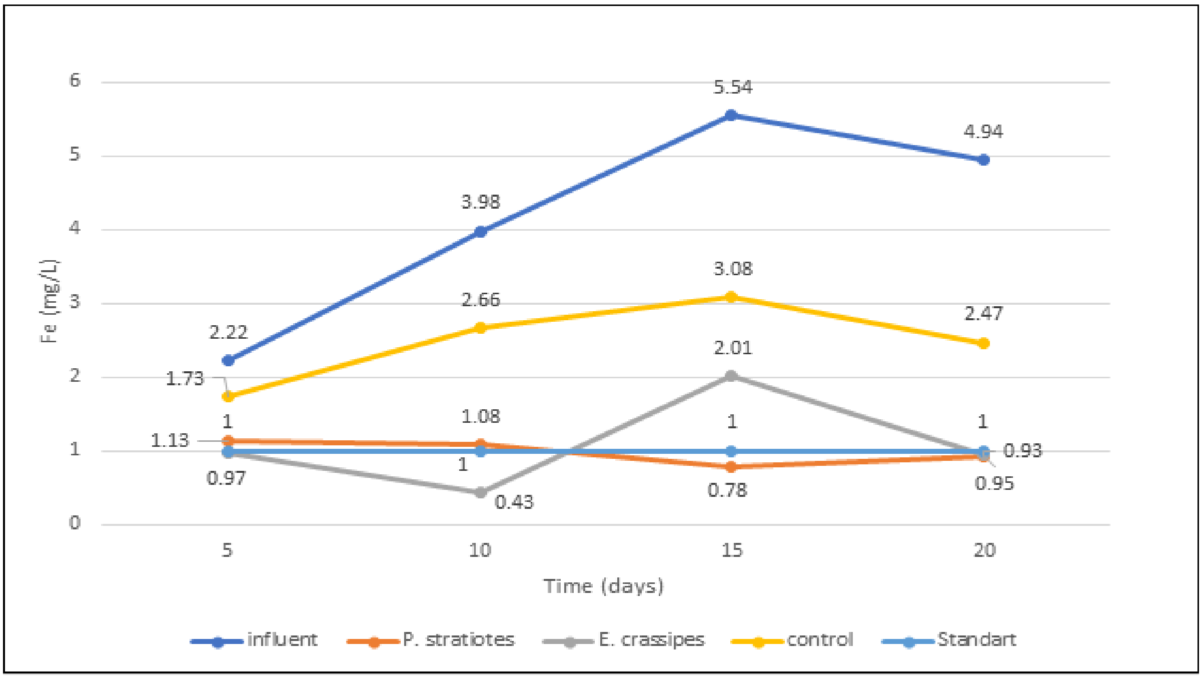

Fig. 2. Fe Concentration in SF-CW.

Figure 2 shows that the concentration of Fe in reactors with *P.stratiotes* L. plants undergoes fluctuating changes. The decline started from the fifth to the 15th day, with 1.13 mg / L on the fifth day, 1.08 mg / L on day 10, and 0.78 mg / L on day 15, respectively. On the 15th day, the Fe content met the quality standard values specified in the Minister of Health of the Republic of Indonesia No. 32 th 2017. However, the Fe concentrations on the fifth and tenth days still needed to meet these standards. Although the value of the Fe concentration decreased when compared to the Fe concentration in the influent. Fe concentration increases by 0.15 mg / L on the 20th day compared to Fe concentration on the 15th. The increase in engagement on day 20 is still within reasonable limits when referring to quality standards because these values are still <1 mg/L. The value of Fe concentration in each SF-CW with *P.stratiotes* L. indicates a decrease in Fe concentration far below the influent value. Because *P. stratiote* L. is a phytoremediator plant that can absorb harmful metals and organic and inorganic substances (Audiyanti *et al.*, 2019), including Fe.

Fe concentrations in SF-CW with *E.crassipess* showed more fluctuating changes than Sf-CW with *P.stratiotes* L. The decline occurred from day 5 to day 10 of 0.97 mg / L and 0.425 mg / L, respectively. In this research, it can be seen that on the fifth day, Fe concentration met the requirements of the Minister of Health of the Republic of Indonesia No. 32th 2017 because Fe values were < 1 mg/L. Not only that, but on the next sampling day (day 10), the Fe concentration value decreased. However, on the 15th day, there was a significant increase to 2.01 mg / L, and the return dropped on the 20th day, which was 0.95 mg /L. Although there was a change in the fluctuation of Fe concentrations in *E.crassipess* reactors, the value has decreased compared to the *influent* value. Fe concentrations SF-CW with

E.crassipess on day 15 increase. This can be caused by the metabolism process in plants that are getting used to plants' excessive absorption of heavy metals, which results in plants becoming saturated (Nurlina *et al.*, 2016; Wandana & Laksmono, 2013). Saturated plants cannot absorb heavy iron metals, which releases heavy metals into the environment. Metal absorption by plants is affected by exposure time. When plants no longer absorb during a certain period of exposure, it indicates that the plant has reached a saturation point. The saturation point is the maximum time limit for tolerating plant-absorbing contaminants. The saturation point of plants is defined as changes in plant physiology and morphology. Symptoms of chlorosis and necrosis in plants appear due to exposure to metals that are too long past the plant's saturation point (Nurlina *et al.*, 2016).

The value of Fe concentration in the Sf-CW without plant (control reactor) also fluctuates with each time interval. In contrast to the *P.stratiotes* L. and *E.crassipess* reactors, the control reactors experienced an increase in Fe concentration from day 5 to day 15 of 1.73 mg / L, 2.65 mg / L, and 3.08 mg / L, respectively. While on day 20, there was a decrease in the value of Fe concentration to 2.47 mg / L. Nevertheless, the value of Fe concentration in the control reactor decreased compared to the influent.

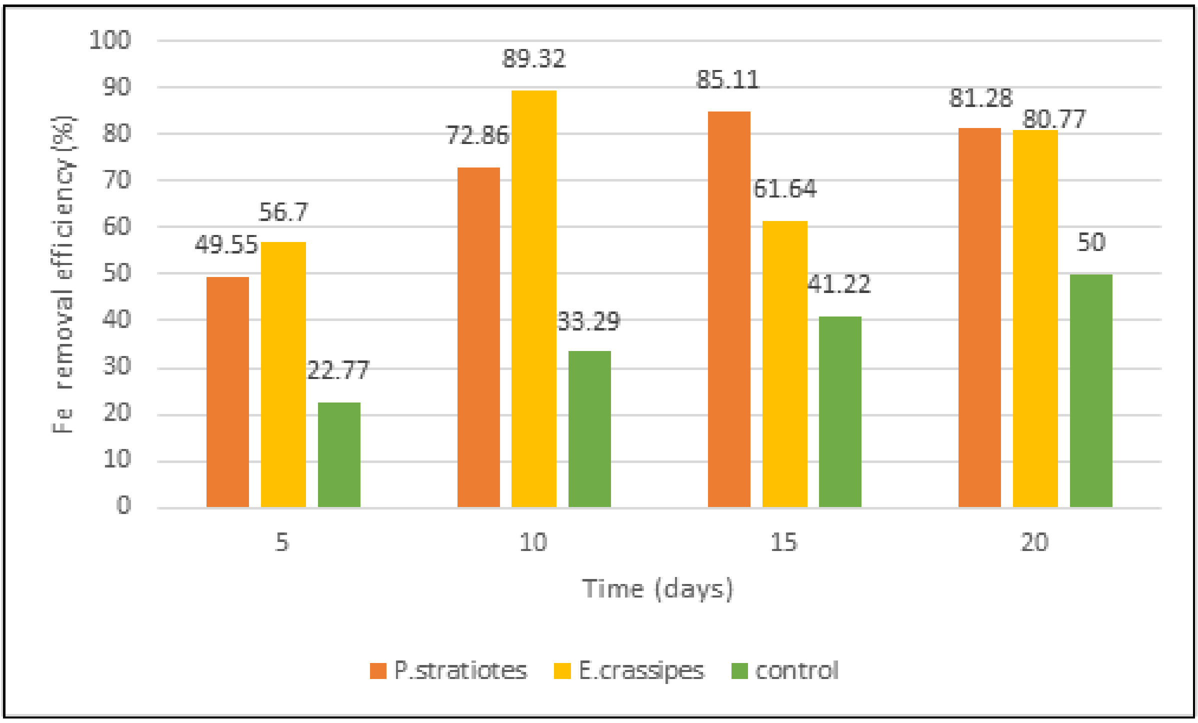

Fig. 3. Fe removal Efficiency.

Fe removal efficiency in the SF-CW system

The efficiency of removing Fe in well water by the SF-CW system was determined by comparing influent Fe concentration and Fe effluent concentration with calculation equation 1. The results of the calculations are presented in Figure 3.

Based on the study's result, the efficiency of Fe removal from SF-CW with *P.stratiotes* L. increased on the fifth to the 15th day. The fifth day of elimination efficiency was 49.55%, the 10th day was 72.86%, and the 15th day was 85.11%. The decrease in the efficiency of *P.stratiotes* L. occurs on the 20th day due to the low absorption of Fe concentration by *P.stratiotes* L. Meanwhile, SF-CW with *E.crassipess* experienced an increase in the efficiency of Fe elimination on day five and day 10. The efficiency on the fifth day was 56.70% and on the 10th day was 89.32%. Based on Figure 3**.** on day five and day 10, the higher efficiency was *E.crassipess* compared to *P.stratiotes* L. The efficiency of SF-CW with *E.crassipess* decreased on the 15th day to 61.64% due to the low absorption of Fe concentrations by *E.crassipess* plants. On day 20, the efficiency of Fe absorption decreased to 80.77%. The efficiency in the control increased continuously during the fifth day, day 10, day 15, and day 20, respectively, by 22.77%, 33.29 %, 41.22%, and 50%.

Figure 3 shows the efficiency of Fe removal from SF-CW with P.stratiotes, E.crassipes, and control (without plants). The highest efficiency on the tenth day was in the SF-CW reactor with E.crassipes (89.32%). Meanwhile, the control reactor had the lowest elimination efficiency on the fifth day (22.77%). The average efficiency of Fe removal by the SF-CW system with *P.stratiotes, E.crassipes*, and control was 72.2%; 72.1%; 36.82%, respectively. Reduction of Fe in the control reactor still occurs even with low efficiency. Plants show a significant influence on increasing the efficiency of the SF-CW system. With the presence of plants, there is an increase in system efficiency up to approximately twofold. Plants absorb Fe in water and are used for growing purposes. The results of previous studies also showed results similar to this study, that VSSF-CW with Eleocharis dulcis plants showed greater efficiency (85.68%) than VSSF-CW without plants (59.37%) in removing Fe in water (Prihatini *et al.*, 2022).

Yunus and Prihatini's research (2018) results show that E.crassipes has a Bioconcentration Factor for Fe of 1701.12. The high FBK value of Fe indicated that E.crassipes was a Fe hyperaccumulator plant. E.crassipes requires a longer time to environmental conditions (especially at low pH conditions), but the process of transport and translocation of Fe takes less time (Yunus & Prihatini, 2018).

The most efficient plant type in Fe removal at SF-CW

This study utilizes two different types of plants; this intends to determine the capacity of plants to influence the efficiency of Surface Flow Constructed Wetlands Systems against the Fe removal in well water. The two types of plants showed the no different ability to remove Fe from well water. This is demonstrated by the average elimination efficiency, which is only a difference of 0.1%. However, SF-CW with E.crassipes can absorb Fe faster than P.stratiotes. This can be seen from the elimination efficiency on the fifth day, which reached 56.7%; on the tenth day, it went 89.32%, while SF_CW with P.stratiotes only got 85.11% efficiency on the fifteenth day. Although belonging to two different genera, the two plants have the same fibrous roots. The number of plant roots affects the amount of dissolved Fe absorption (Sudiro and Ayuningtyas, 2013), so the relatively large number of E.crassipes and P.stratiotes roots causes a large amount of absorption of dissolved Fe in water.

Conclusion

The characteristics of the Selat Makmur Village well water in the Fe parameters do not meet the quality standards of the Minister of Health No. 32 of 2017, so it can be treated with the Surface Flow Constructed Wetland system. Plants show a significant influence on increasing the efficiency of the SF-CW system. The highest Fe removal efficiency of SF-CW with *P.stratiotes* L. vegetation occurred on the 15th day at 85.11%, and SF-CW with *E.crassipes* on the 10th day at 89.32%. The results of this study show that both vegetation with the SF-CW system can be considered for use by the surrounding community because this vegetation can remove Fe.

Acknowledgment

Thank you to the Lambung Mangkurat University Research and Community Service Institute for funding this research with DIPA funds from Lambung Mangkurat University 2021 Number: SP DIPA-023.17.2.677518/2022 November 17, 2020; Lambung Mangkurat University, Ministry of Education and Culture, by the Decree of the Chancellor of Lambung Mangkurat University Number:458/UN8/PG/2022, March 28, 2022.

Reference

Audiyanti S, Hasan Z, Hamdani H, Herawati, H. 2019. Efektivitas Eceng Gondok (Eichhornia crassipes) dan Kayu Apu (Pistia stratiotes) sebagai Agen Fitoremediasi limbah Sungai Citarum . *Jurnal Perikanan Dan Kelautan*, **10(1),** 111–116.

Dipu S, Kumar AA, Thanga VSG. 2011. Phytoremediation of dairy effluent by constructed wetland technology. The Environmentalist **31(3),** 263–278. https://doi.org/10.1007/s10669-011-9331-z

Hedin RS, Nairn RW. 1990. April 23). Sizing and Performance of Constructed Wetlands: Case Studies 1. Mining and Reclamation Conference and Exhibition.

Kadlec RH, Wallace S. 2008. *Treatment Wetlands*. CRC Press. https://doi.org/10.1201/9781420012514

Nirtha I., Prihatini NS, Pronawati L. 2021. Penggunaan Lahan Basah Buatan Aliran Vertikal Bawah Permukaan dengan Tanaman Typha latifolia dan Cyperus papyrus dalam Menyisihkan Besi (Fe) dan Mengan(Mn) Pada Air Sumur Bor. Jukung (Jurnal Teknik Lingkungan*)*, *7***(1),** 95–102. https://doi.org/10.20527/jukung.v7i1.10820

Nurlina N, Suhadiyah S, Umar MR. 2016. Akumulasi Logam Berat Besi (Fe) Pada Kiapu Pistia stratiotes L. dari Air Sumur Sekitar Workshop Unhas. Prosiding Seminar Nasional From Basic Science to Comprehensive Education, 151–155. https://doi.org/https://doi.org/10.24252/psb.v2i1.3327

Prihatini NS. 2015. A Study of Iron (Fe) Uptake by Purun Tikus (Eleocharis dulcis) Grown on Acid Mine Drainage at a Subsurface Flow Constructed Wetland. Proceedings of International Conference on NAMES 62–66.

Prihatini NS, Abdi C, Pratama YA, Noor I. 2020. Efisiensi Sistem Lahan Basah Buatan Aliran Permukaan Dengan Variasi Debit Dalam Menyisihkan Mangan Pada Air Asam TAMBANG. Jukung Jurnal Teknik Lingkungan **6(1),** 77–85. https://ppjp.ulm.ac.id/journa/index.php/jukung/issue/view/838/showToc

Prihatini NS, Khair RM, Nirtha RI, Tanjung, RF. 2020. Effectiveness of Sub Surface Flow Constructed Wetland Planted With Equisetum hyemale And Iris pseudacorus to Remove Iron (Fe) And Manganese (Mn) From Ground Water. In *Prosiding Seminar Nasional Lingkungan Lahan Basah* (Vol. 5, Issue April).

Prihatini NS, Nirtha I., Khair RM, Nahdah A. 2022. Study of Variation of Plant Types of Vertical SubSurface Constructed Wetland Treating Groundwater Contaminated with Iron (Fe). International Journal of Research and Review **9(1),** 635–641. https://doi.org/10.52403/ijrr.20220174

Prihatini NS, Priatmadi BJ, Masrevaniah A, Soemarno S. 2015. Performance of the Horizontal Subsurface-Flow Constructed Wetland with Different Operational Procedures. International Journal of Advances in Engineering & Technology **7(6),** 1620–1629.

Prihatini NS, Priatmadi BJ, Masrevaniah A, Soemarno S. 2016. Effects of the Purun Tikus (Eleocharis dulcis (Burm. F.) Trin. ex Hensch) Planted in the Horizontal Subsurface Flow-Constructed Wetlands (HSSF-CW) on Iron (Fe) Concentration of the Acid Mine Drainage. Journal of Applied Environmental and Biological Sciences **6(1),** 258–264. www.textroad.com

Prihatini NS, Soemarno. 2021. Potential of Purun tikus (Eleocharis dulcis (Burm. F.) Trin. ex Hensch) to restore the Iron (Fe) contaminated acid mine drainage by using constructed wetland. In K. Bauddh, J. Korstad, & P. Sharma (Eds.), Phytorestoration of Abandoned Mining and Oil Drilling Sites. Elsevier. https://doi.org/10.1016/B978-0-12-821200-4.00015-7

Prihatini NS, Soemarno S. 2017. Iron (Fe) bio-concentration in purun tikus (Eleocharis dulcis) planted on the constructed wetland treating the coal acid mine drainage. International Journal of Biosciences (IJB), **11(3),** 69–75. https://doi.org/10.12692/ijb/11.3.69-75

Wandana R, Laksmono R. 2013. Penggunaan Tanaman Kayu Api (Pistia stratiotes) untuk Pengolahan Air Limbah Laundry secara Fitoremediasi. Jurnal Ilmiah Teknik Lingkungan, **5(2),** 60–64.

Yunus R, Prihatini NS. 2018. Fe and Mn phytoremediation of acid coal mine drainage using water hyacinth (Eichornia crassipes) and chinese water chestnut (Eleocharis dulcis) on the constructed wetland system. International Journal of Biosciences (IJB), **12(4),** 273–282. https://doi.org/10.12692/ijb/12.4.273-282