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Research Article

A Brief of Water and Soil Pollution Management (Recent Trend and Economic Perspective)

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Abstract

Soil and water pollution are the most crucial issues in the world. Various reports have informed that pollution has had long-term adverse effects on environmental sustainability and human health. Several methods have been reported to be effective in reducing pollutant parameters in water and soil. The methods often used in water and soil remediation are bioremediation (land-vetting, bio-cell. Bio cell, Phytoremediation, Land venting, Composite, Bio venting, Bio slurry), Adsorption, Pretreatment (Ultrasonic), Microwave, Electrokinetic disintegration, High-Pressure Homogenization/HPH, Thermal Hydrolysis, Acid hydrolysis (HCl, H_2SO_4, H_3PO_4, and HNO_3), Ozonation, Fenton Oxidation, Fe (II) - activated persulfate, Protease, amylase, lipase. This paper will explain water and soil pollution and the methods used to overcome them. Information collection is carried out using secondary data; internationally reputable journals and accredited national journals are used to obtain information about the effectiveness and costs incurred. This paper will provide a holistic comparison of prices, effectiveness, and information on various remediating water and soil pollution methods around the world. Based on the NPV and IRR analysis, the water treatment method using the adsorption method is an economically feasible method with an IRR value of 51%.

***Keywords**:* economic analysis; soil; water; wastewater; wastewater treatment

1. Introduction

Environmental pollution has been reported in various countries around the world (Landrigan and Fuller, 2015). The decline in water and soil quality is a crucial issue and is the most widely discussed in various scientific articles. World Water Congress reports that water pollution has occurred in various cities worldwide, including Aqaba, Bangkok, Beijing, Chennai, Durban, Kampala, Lima, and Manila. This international congress reports that the decrease in water quantity and quality is caused by human activities, including agriculture, mining, industrial manufacturing, infrastructure development, and other human activities (International Water Association, 2018). Other studies have also reported that a decrease in water quality has occurred in Southeast Asian countries such as Indonesia, Thailand, Malaysia, Myanmar, Cambodia, Vietnam, Philippines (Anh et al., 2007; Ferrer et al., 2012; Watanabe et al., 2016). The decline in water quality in various countries includes a decrease or increase in pH so that water is acidic or alkaline, high metal ion content, high BOD, COD and TSS concentrations, and dye content and other parameters. Apart from water, the soil has also been reported as a part of the environment that has experienced a decline in quality. Soil pollution also occurs due to human activities; a recent study reports that China's agricultural activities have caused soil contamination. This area has been contaminated with Cd, Cr, Hg, As, Pb, Cu, Zn, and Ni above the safety standards of the Ministry of Ecology and Environment of the People's Republic of China and State Administration for Market Regulation (GB 15618-2018) (Huang et al., 2019).

The number of reports on water and soil pollution worldwide has led various researchers to make innovations related to water and soil pollution management. Some of the methods that are often used in reducing water pollution are adsorption (Naswir et al., 2020a, 2019), flotation (Rubio et al., 2002), coagulation (Teh et al., 2016), filtration (Hube et al., 2020), disinfection (Bond et al., 2011), fluoridation (Ochoa-Herrera et al., 2009), and various other methods. Unfortunately, the various methods used only report on their effectiveness and novelty. It is sporadic to find articles reporting methods of water and soil treatment from an economic perspective. In addition to the lack of information on the costs involved in managing water and soil, various widely reported methods also use high technology. They can only be produced on a small scale (laboratory scale). A study reported water treatment with the bioremediation method entitled "Development of Peroxidase Enzyme Immobilized Magnetic Nanoparticles for Bioremediation of Textile Wastewater Dye", this study says that magnetic nanoparticles successfully reduce pollutant parameters in textile waste (Darwesh et al., 2019);. However, this method has succeeded in reducing the parameters of textile waste pollutants, and there is no information stating the costs that must be incurred if this material is used to reduce polluting parameters in textile wastewater.

Other studies also reported that the adsorption method using biochar successfully reduced the pollutant parameters of wastewater generated from agricultural activities. This study also said that biochar was able to reduce heavy metal content in agricultural soils. Biochar succeeded in reducing Fe, Pb, and Zn concentrations in a variation of 0 to 73 days. Unfortunately, this research also still uses high technology and is carried out in the laboratory (Nzediegwu et al., 2019); besides that, the absence of information on the cost of biochar production also informs that studies related to material production costs in reducing pollutant parameters are still minimal. Apart from water treatment, information on soil remediation has also been carried out using various methods. One method often used to reduce soil pollutant parameters is the Electrokinetic Soil Flushing (EKSF) method. This method is one of the methods that is reported to effectively reduce the parameters of soil pollutants such as heavy metals. There is no published article in popular indexing such as Google Scholar, Springer, Nature, and Elsevier informed the review of comparison method including the economic analysis.

The EKSF method is effective in a relatively long period. Research shows that the EKSF method used is effective in reducing pollutant parameters (pesticides) within 300-1000 hours (12.5-41.6 days) (Risco et al., 2016). The EKSF method is also widely used in reducing pollutant parameters in sediment, soil, and sludge (Ramadan et al., 2021). Like water treatment, the methods used in land remediation also rarely inform the economic aspect. The economic side is an essential aspect and becomes a consideration in determining the method to be used in remediation. Many economic considerations are used in deciding the method to be used in environmental remediation. This article aims to discuss water and soil treatment methods in detail, including the economic analysis.

2. Method

2.1 Narrative Review Preparation

This paper used IMRDC (Introduction, Methods, Result and Discussion, and Conclusion). The narrative review has been using in this paper. This paper using more than 30 papers from reputable and accredited journals has been using as a reference. The main feature of this research is to describe the method and result of soil and water remediation from various sources. Generate table and discuss the previous study about soil and water remediation. Generally, this paper describes and rationale content, discusses and evaluates, summarizes the related topic, and connects with the research needed.

2.2 Data collection

The method was chosen using the Google Scholar search engine with keywords: heavy metals sorption, adsorption, wastewater treatment, soil remediation, EKSF, environmental cost, and bioremediation for wastewater treatment. The articles chosen for these keywords are articles from reputable international journals (Elsevier, Nature, Springer, Willey, IWA, and other publishers). Besides that, this paper also looks for books or book chapters as references obtained from reputable publishers. International journals used as references are accredited national journals that have been screened for the validity of the data and the methods used. Pricing and economic analysis are carried out by looking for references from official government agencies, marketplaces, and field surveys.

2.3 Economics Analysis

Economic analysis is carried out by comparing the remediation costs of each method. Data on remediation costs are obtained from various sources such as scientific articles, field surveys, personal experiences, and international and national institutions that standardize water and land treatment prices. Another analysis used to obtain economic value is benefit-cost analysis. This analysis is used to assess the cost-benefit of using water management technology systematically. The analysis used in this study is the calculation of the benefit-cost ratio in the adsorption method. The criteria used to determine the benefit-cost ratio is the analysis of the net present value (NPV) using the equation (Ji et al., 2018):

$$NPV = \sum_{t=0}^{n} \frac{Bt-Ct}{(1+i)^t} \quad (1)$$

Bt is the gross social benefit of the adsorption method in year t, Ct is the gross cost, n is the economic life of the adsorption method, and i is the economic discount rate. The NPV value will be compared with zero (NPV> 0 = useful and NPV <0 = fail / not useful). This study also calculates the value of the Internal Rate of Return (IRR) by following the equation (Magni, 2010) :

$$\sum_{t=0}^{n} \frac{Bt-Ct}{(1+i)^t} = 0 \quad (2)$$

3. Result And Discussion

3.1 An Overview of Wastewater Treatment Methods

Various studies have reported many successful methods of reducing pollutant parameters in polluted water. One method that is widely used in bioremediation. The bioremediation method utilizes biological processes in reducing pollutant parameters in water. Some of the bioremediation techniques carried out are biofilters, bioreactors, bio-venting, composting, landfarming or land treatment, prepared bed bioreactors, bio-piling, bioaugmentation, and bio-stimulation. A recent study informs that the biofilter method requires a new approach to improve the ability to reduce polluted water parameters. The biofilter method is considered ineffective and still requires high costs in its utilization; studies of biofilter utilization in the aquaculture industry (fish and shrimp ponds) reportedly require innovations such as active suspension ponds (Avnimelech, 2006). Various attempts have been made to develop technologies in the bioremediation process; bioremediation methods have been reported to have been widely used and reduced pollutant parameters in polluted water. A recent article even reported that some bacteria such as Nitrobacter, yeast, and Bacillus subtilis effectively reduced nitrogen by up to 99.4% and were able to reduce phosphate up to 62.78% (Rosanti et al., 2020).

Another method that is often used in reducing pollutant parameters in polluted water is adsorption. This method utilizes the pollutant trapping process in the pores of the material used. Various materials are continuously being developed to obtain new materials with maximum adsorption capacity. Some of the materials commonly used in the adsorption process are activated carbon and biochar made from coconut shells. Activated carbon and biochar are two potential materials and are often used in reducing pollutant parameters, both of which have almost the same characteristics as high -COO-; OH; -CO, -R-OH groups (the hydroxyl functional group), high pH, high surface area, high porosity, high surface charge, and high water holding capacity (Wibowo et al., 2019). Apart from coconut shells, another material that has been reported to reduce water pollutant parameters is a rubber fruit shell. Rubber fruit shell is one of the solid wastes that is rarely used. A recent study reported that an adsorbent could be made from a rubber fruit shell and effectively reduces Fe with the Freundlich isotherm model (Naswir et al., 2020b).

The adsorbent can not only be made from carbon-based materials. A recent study also reported that clay could also be used to reduce pollutant parameters in polluted water. A recent study reported that bentonite is one type of clay that effectively reduces pollutant parameters (Hg) in water. Even though the research was carried out on artificial solutions, the environmental conditions and processes that were made vary according to field conditions. Bentonite was reported to reduce Hg by up to 86% after 30 minutes of treatment (Naswir et al., 2020a). Unfortunately, this study did not carry out further testing until the bentonite was saturated entirely to determine the maximum capacity of the adsorption capacity of the bentonite.

Another method that can be used to solve the problem of water pollution is disinfection. Disinfection is widely used in the management of polluted water. Unlike bioremediation and adsorption methods that can reduce pollutant parameters in water, disinfection methods remove bacteria and viruses from contaminated water. A recent study informed that one of the effective disinfectants used in the disinfection process is peracetic acid. Peracetic acid is a disinfectant that can effectively remove bacteria and viruses. Peracetic acid has bactericidal, virucidal, fungicidal properties. Peracetic acid is a disinfectant that is cheaper when compared to chlorine; this reason is one of the reasons that peracetic acid is often used in the industry as a competitive advantage of chlorine (Kitis, 2004). Other studies have reported that the disinfection method is the method that must be used after the primary treatment (adsorption or bioremediation) of municipal wastewater. Apart from using peracetic acid, UV and Ozone methods are recommended methods for use after primary treatment. Secondary treatment (peracetic acid, UV, and ozone) is intended to remove bacteria and viruses from the wastewater after reducing the pollutant parameters.

3.2 Soil Remediation Methods

Soil washing is a process of volume reduction or waste minimization. Soil particles containing the majority of contaminants are separated from the bulk fraction of the soil. The contaminants are removed from the soil by chemical solutions and recovered from the solution in a solid substrate. Various studies have reported that the soil washing method has successfully reduced pollutant parameters in the soil. A study said that remediation of contaminated soil using Surfactant-Aided. The study reported that surfactant-aided soil washing successfully reduced the content of hydrophobic organic compounds in contaminated soil (Chu, 2003). A study from Japan informed that soil washing had been used to reduce cadmium (Cd) levels from contaminated soil. A sample of paddy soils was collected from Toyama, Nagano, and Hyogo. Soil sample preparation is carried out by placing the sample in a room with a temperature of 25 C with a relative humidity value of approximately 60% and a sieve at a size of 2 mm. This method succeeded in reducing the Cd content in the Hyogo area from 0.16 to 0.02 mg/kg, while for the Hyogo region, the Cd content was successfully reduced from 0.6 to 0.1 mg/kg and was able to reduce the Cd content from 0.20 to 0.14 mg/kg in the Toyama region (Makino et al., 2006)

A recent study also informed that the soil washing method reduced the Zn, Pb, and Cd content at one time. This research was conducted using samples of Zn-Pb mining soil in the Hanyuan region, Sichuan, China (29 ° 24′N, 102 ° 37′E). Soil samples used are soil with a height of 0-20 cm from the surface. The washing soils used in this study were ethylenediamine tetra (methylene phosphonic acid) (EDTMP) and polyacrylic acid (PAA). The highest reduction effectiveness level decreased Cd content which reached 70% after 120 minutes at pH 4. The result of the reduction in Cd, Pb, and Zn content was also corrected using. The statistical approach is used to predict the maximum value of the rate in effect, the interaction factor with a specific range using equations

$$E(y) = \beta o + \sum_{j=1}^{p} \beta j.\chi j + \sum_{j=1}^{p} \beta jj, x^2 j + \sum_{j=1}^{p} \beta ij.\chi j.xj \quad (3)$$

where E(y) is the theoretical value, P is the number of variables, βo is a constant of the equation, βj, βij, and βjj are the linear, quadratic and interactive coefficients of the model, respectively; P is the number of variables, and Xi and Xj are the coded independent variables

Another method that can be used to reduce pollutant parameters on the soil is Electrokinetic Soil Flushing (EKSF). Electrokinetic soil remediation is an up-and-coming technology for removing organic contaminants in the soil. Its efficiency can be increased by using surfactants as solvents because most organic contaminants have low solubility in water. An improved electrokinetic process was carried out in this study to remove n-hexadecane and anthracene from soil samples. Both contaminants are hydrophobic and do not have an electric charge. Therefore removal can only be carried out by electroosmosis using surfactants to increase the solubility of the contaminants. Experiments were carried out to determine the efficiency of removing n-hexadecane and anthracene by enhanced electrokinetic using one surfactant/combination of two surfactants with different electrochemical properties. Three surfactants were used, namely: sodium dodecyl sulfate (SDS), Tween 80 (T80), and Triton X100 (TX100). T80 and TX100 are neutral compounds added to the anolyte for transport to the soil by electroosmosis. SDS is an anionic surfactant, added to the catholyte and transported to the soil by electromigration. The effectiveness of surfactants for removing n-hexadecane or anthracene is SDS> Tween 80> Triton X100. Simultaneous SDS use in the cathode chamber and Tween 80 in the anode chamber improved the removal of n-hexadecane (69%) and anthracene (59%). The combination of SDS in the catholyte and Tween 80 in the anolyte increase the remediation result. However, it is advisable to avoid very acidic pH to increase the two surfactants' remediation results. The combination of surfactants T80 and SDS is suggested as a new approach for large-scale applications. Overall, combining surfactants can be a good approach to eliminate soil contamination by hydrophobic organic compounds (Boulakradeche et al., 2015).

Another study confirmed that four plants spiked with four herbicides (2,4-Dichlorophenoxyacetic acid (2,4-D), oxyfluorfen, chlorsulfuron and atrazine) underwent treatment, namely Electro Kinetic Soil Flushing (EKSF). The results showed that the efficiency of EXFF depends on the chemical properties of the pesticide used. The amount of pesticide collected in the anode chamber was more significant than that collected in the cathode chamber, suggesting that electromigration is much more critical than electroosmotic flux drainage. After 15 days of treatment, pesticide 2,4-D was the most efficient to remove (95% removed), whereas chlorsulfuron was the pesticide that was more resistant to treatment. The volatility (evaporation rate) of chlorsulfuron is much lower than other pesticides during the electro remediation test. Besides, volatilization was a significant process in applying electrokinetic techniques to herbicide-contaminated soils. Therefore, this process needs to be considered for design on a large scale in the future. It can be concluded that soil decontamination with EKSF is a viable process for repairing contaminated soil using polar and non-polar pesticides. EKSF technology can remove more than 80% of pollution by electrokinetic and flux evaporation for 15 days. Side processes, such as electrochemical oxidation of pesticides, are not expected because electrodes are being used. Synthesis soil is used to prevent by-products of processes, such as adsorption or biological oxidation. The electroosmotic flux in all cases was stable, about 1 mL cm-2 d-1 after more than ten days of treatment. In the electrokinetic remediation process, the pesticide flows to the anode by the process of electromigration, which depends on the pesticide properties (i.e., ionization, pKa). Significant pesticide concentrations can be detected at the cathode during the electroosmosis process (Risco et al., 2016)

Soils from former chemical factories that were contaminated by Organochlorine (OC) compounds from old pesticide residues underwent surfactant-assisted Electrokinetic Remediation (EKR). Organic surfactants increase OC's availability, while electrokinetic remediation (EKR) will increase the transferability of the surfactant-oxidant mixture and OC throughout the soil. Tween 80 (TW80) and N, N-Dicarboxymethyl glutamic acid tetrasodium (GLDA) surfactants increased OC availability and increased soil oxidation efficiency EKR process. TW80 is a surfactant often used as a solvent because of its low cost, low polarity, low toxicity, and high dissolving capacity. The results showed that flushing the soil with TW80 increased OC's continuous removal from the soil, with a removal efficiency of 40% -80%.

Furthermore, the combination of TW80 with sodium persulfate significantly caused advanced oxidation and removed 60% –82% OC for ten days. Compared to the control treatment, the addition of TW80 increased the EKR by 20% –30%. This increase is associated with the ability of TW80 to dissolve compounds that are difficult to dissolve and the ability to maintain the activation of persulfate ion (S2O82–) by dissolving metal ions in the soil to stimulate the production of sulfate radicals (SO42-) and thus degradation of pollutants (if there is no nZVI reactive barrier).). In contrast to TW80, the capacity of GLDA to dissolve and extract OC from the soil is much slower and less reliable, averaging about 10% compared to 60% removal of OC when using TW80. Although GLDA is not a reliable solvent for reducing OC in the soil, its ability to dissolve and maintain solution divalent ions plays an essential role in maintaining the Fenton reaction. Its participation increases pollutant removal by an average of 50% - 60%. These findings suggest that the combination of TW80 with EKR and advanced oxidation coupled with an nZVI reactive barrier is the best in situ approach to recovering OC-contaminated soil from industrial process chemical wastes (Suanon et al., 2020).

A literature review suggests that investigations regarding the removal of anthracene from contaminated soil are relatively rare. Therefore, this study aimed to investigate electrokinetics' application in rinsing soil with the ionic surfactant Tween 80 to remove anthracene in contaminated clay. The results were analyzed and compared with a reference test. Tween 80 surfactant was fed to the anode reservoir, and the tests were carried out at a voltage of 1.5 V / cm and at different times (3, 7, and 10 days). The reference test was carried out using distilled water at the anode at a 1.5 V / cm voltage for seven days. Each time a pH test is performed, the EC (electrical conductivity) and the outflow volume are also measured. At the end of each test, several soil samples were extracted from various anode distances, and the anthracene removal rate from the samples was measured using HPLC (High-Performance Liquid Chromatography).

The results showed that distilled water was not effective in removing anthracene from contaminated soil. The addition of Tween 80 surfactant to the anode reservoir increases the fluid effluent from the cathode. By using Tween 80 anthracene, removal was increased. Besides, by increasing the treatment duration to 7 days, the elimination was also increased. However, after seven days, the increased anthracene removal rate was not significant (Estabragh et al., 2019). Several methods are also reported in soil remediation, such as soil vapour extraction. This method is known as vacuum extraction or soil venting. This method used air stripping and groundwater pumping for treating the contaminated groundwater. This method is used in homogenous and permeable soil. The soil must be covered with an impermeable surface layer to reduce infiltration and short-circuiting. This method is not recommended for petroleum contamination (Khan et al., 2004). The most successful method for petroleum treatment is landfarming, but this method is not recommended for soil contaminated more than 1.5 m (Khan et al., 2004)

3.3 A Brief of Economic Analysis of Soil and Wastewater Methods

Economic analysis was carried out to obtain price comparisons for each method used. One method widely used in water treatment is bioremediation; based on information obtained from the Ministry of Environment and Forestry, the bioremediation method costs 25-75 USD (accessed at http://sib3pop.menlhk.go.id/index.php/articles/view?slug=teknologi-bioremidiasi-untuk-pengolahan-pops).

Tabel 1. Economic price of several remediation methods

No	Methods	Price	Reference
1	Bio cell	52.3 -$627.8 USD/ m³	(Sasongko et al., 2017)
2	Phytoremediation	21.3-75.35 USD/m³	(Sasongko et al., 2017)
3	Land venting	50-70 USD/ m³	(Sasongko et al., 2017)
4	Composite	250 USD/m³	(Sasongko et al., 2017)
5	Bioventing	79-109 USD/ m³	(Sasongko et al., 2017)
6	Bio slurry	160-210 USD/ m³	(Sasongko et al., 2017)
7	Bioremediation	25-27 USD/m³	SIB3POP MENLHK
8	Adsorption	0.68 USD/kg	Marketplace
9	Oxidase Fenton	5.3 USD/kg	(Murti et al., 2019)
10	Oxidase Fenton	5.3 USD/kg	(Murti et al., 2019)
11	Fe(II)-activated persulfate	0.00064 USD/g	(Murti et al., 2019)
12	Pretreatment (Ultrasonic)	110 USD/day	(Murti et al., 2019)
13	Microwave	1524 USD/day	(Murti et al., 2019)
14	Disintegration electrokinetic	561 USD/day	(Murti et al., 2019)
15	High pressure Homogenization/ HPH	229 USD/day	(Murti et al., 2019)
16	Hydrolysis thermal	758 USD/day	(Murti et al., 2019)
17	Hydrolysis of acid (HCl, H_2SO_4, H_3PO_4 and HNO_3)	No information	(Murti et al., 2019)
18	Ozonation	186 USD/day	(Murti et al., 2019)
19	Protease, amylase, lipase	712 USD/day	(Murti et al., 2019)

Some of the methods above are often used in the remediation of polluted soil and water. Based on Table 1, several methods can be innovative such as green synthesis. For example, the green synthesis from the materials in the adsorption method has been reporting (Ali et al., 2016). Although the Ministry of Environment and Forestry has published the cost of bioremediation, Republic of Indonesia, unfortunately, there is no detailed information about the types of remediation methods used on the Ministry of Environment SIB3POP. And Forestry of the Republic of Indonesia. Based on Sasongko's research results, the most economical bioremediation methods are the Vito remediation and Land Venting methods. Each method has advantages and disadvantages and has specific specifications. Several methods may effectively reduce the parameters of one type of polluted water but are not effective in reducing the parameters of contaminated water for other types.

3.4 NPV and IRR Analysis

NPV and IRR were analyzed by software (Microsoft Excel). The IRR value is obtained by an algorithm (=IRR(NPV value)). Cost analysis related to the feasibility analysis uses the base price of coconut shell as the material most widely used in the water treatment adsorption process. The price of coconut shells is obtained from the marketplace in Indonesia. The coconut shell price is IDR 250.000/10 kg, equal to 17.53 USD/10 kg. An investment is infeasible if the resulting IRR is less than the applied interest rate. The results of the IRR analysis inform that the adsorption method using coconut shells is economically feasible.

$$NPV = \sum Cash\ flow\ xDCF \quad (4)$$

Where the DCF is:

$$DCF = \frac{1}{(1+IR)^{period}} \tag{5}$$

Table 1. NPV and IRR value

Interest Rate 20%	Cash flow (USD)	DCF	NPV
Investment Month 0	173	1	-173
Investment Month 1	150	0,833333	125
Investment Month 2	120	0,694444	83,33333
Investment Month 3	100	0,578704	57,87037
Investment Month 4	80	0,482253	38,58025
Investment Month 5	60	0,401878	24,11265
Investment Month 6	40	0,334898	13,39592
Investment Month 7	20	0,279082	5,581633
Net Present Value			**174,8742**
IRR			**39%**

4. Conclusion

The soil and water treatment has been explained in detail, including the economic analysis. Environmental pollution has become the focus of various international organizations. Water and soil pollution are two of the most widely discussed environmental pollution. Water pollution has caused various health problems and deaths for aquatic biota. Soil pollution is also widely reported to be bad for the environment. Various reports state that industrial activities are the leading cause of pollution. Various efforts have been made to reduce the pollution that has occurred; various methods are also being developed. Several methods that are often used to reduce pollutant parameters are bioremediation (land-venting, bio-cell. Bio cell, Phytoremediation, Land venting, Composite, Bio venting, Bio slurry), Adsorption, Pretreatment (Ultrasonic), Microwave, Electrokinetic disintegration, High-Pressure Homogenization/HPH, Thermal Hydrolysis, Acid hydrolysis (HCl, H_2SO_4, H_3PO_4, and HNO_3), Ozonation, Fenton Oxidation, Fe (II) -activated persulfate, Protease, amylase, lipase and each of these methods cost 21.3 to 1524 USD/day. Based on the NPV and IRR analysis, the water treatment method using the adsorption method is an economically feasible method with an IRR value of 39%.

Reference

Ali, I., AL-Othman, Z.A., Alwarthan, A., 2016. Green synthesis of functionalized iron nano particles and molecular liquid phase adsorption of ametryn from water. J. Mol. Liq. 221, 1168–1174.

Anh, V.T., Tram, N.T., Klank, L.T., Cam, P.D., Dalsgaard, A., 2007. Faecal and protozoan parasite contamination of water spinach (Ipomoea aquatica) cultivated in urban wastewater in Phnom Penh, Cambodia. Trop. Med. Int. Heal. 12, 73–81.

Avnimelech, Y., 2006. Bio-filters: The need for an new comprehensive approach. Aquac. Eng. 34, 172–178.

Bond, T., Huang, J., Templeton, M.R., Graham, N., 2011. Occurrence and control of nitrogenous disinfection by-products in drinking water - A review. Water Res. 45, 4341–4354.

Boulakradeche, M.O., Akretche, D.E., Cameselle, C., Hamidi, N., 2015. Enhanced Electrokinetic Remediation of Hydrophobic Organics ontaminated Soils by the Combinations of Non-Ionic and Ionic Surfactants. Electrochim. Acta 174, 1057–1066.

Chu, W., 2003. Remediation of contaminated soils by surfactant-aided soil washing. Pract. Period. Hazardous, Toxic, Radioact. Waste Manag. 7, 19–24.

Darwesh, O.M., Matter, I.A., Eida, M.F., 2019. Development of peroxidase enzyme immobilized magnetic nanoparticles for bioremediation of textile wastewater dye. J. Environ. Chem. Eng. 7.

Estabragh, A.R., Lahoori, M., Javadi, A.A., Abdollahi, J., 2019. Effect of a surfactant on enhancing

efficiency of the electrokinetic method in removing anthracene from a clay soil. J. Environ. Chem. Eng. 7, 103298.
Ferrer, A., Nguyen-Viet, H., Zinsstag, J., 2012. Quantification of diarrhea risk related to wastewater contact in Thailand. Ecohealth 9, 49–59.
Huang, Y., Wang, L., Wang, W., Li, T., He, Z., Yang, X., 2019. Current status of agricultural soil pollution by heavy metals in China: A meta-analysis. Sci. Total Environ. 651, 3034–3042.
Hube, S., Eskafi, M., Hrafnkelsdóttir, K.F., Bjarnadóttir, B., Bjarnadóttir, M.Á., Axelsdóttir, S., Wu, B., 2020. Direct membrane filtration for wastewater treatment and resource recovery: A review. Sci. Total Environ. 710, 1–22.
International Water Association, 2018. Wastewater Report 2018, IWA The International Water Association.
Ji, C., Cheng, K., Nayak, D., Pan, G., 2018. Environmental and economic assessment of crop residue competitive utilization for biochar, briquette fuel and combined heat and power generation. J. Clean. Prod. 192, 916–923.
Khan, F.I., Husain, T., Hejazi, R., 2004. An overview and analysis of site remediation technologies. J. Environ. Manage. 71, 95–122.
Kitis, M., 2004. Disinfection of wastewater with peracetic acid: A review. Environ. Int. 30, 47–55.
Landrigan, P.J., Fuller, R., 2015. Global health and environmental pollution. Int. J. Public Health 60, 761–762.
Magni, C.A., 2010. Average Internal Rate of Return and Investment Decisions: A New Perspective. Eng. Econ. 55, 37–41.
Makino, T., Sugahara, K., Sakurai, Y., Takano, H., Kamiya, T., Sasaki, K., Itou, T., Sekiya, N., 2006. Remediation of cadmium contamination in paddy soils by washing with chemicals: Selection of washing chemicals. Environ. Pollut. 144, 2–10.
Murti, G.W., Pertiwi, A., Masfuri, I., Juwita, A.R., Adiprabowo, A.B., Dwimansyah, R., Senda, S.P., Prasetyo, D.H., 2019. Ulasan Teknologi Pretreatment Terkini Limbah Cair POME Sebagai Umpan Digester Biogas. JTERA (Jurnal Teknol. Rekayasa) 4, 17.
Naswir, M., Desfaurnatalia, Y., Septiarini, L., Gusti Wibowo, Y., 2019. Activated Bentonite: Low Cost Adsorbent to Reduce Mercury Content in A Solution. Res. J. Appl. Sci. 14, 243–249.
Naswir, M., Natalia, D., Arita, S., Wibowo, Y.G., 2020a. Adsorption of Mercury Using Different Types of Activated Bentonite : A Study of Sorption , Kinetics , and Isotherm Models. J. Rekayasa Kim. dan Lingkung. (Journal Chem. Eng. Environ. 15, 123–131.
Naswir, M., Rahima, S., Wibowo, Y.G., 2020b. Rubber fruit shell : agricultural waste material as a potential sustainable production for wastewater treatment. In: TALENTA CEST II. IOP Conferense Series: Material Science and Engineering, pp. 1–9.
Nzediegwu, C., Prasher, S., Elsayed, E., Dhiman, J., Mawof, A., Patel, R., 2019. Effect of biochar on heavy metal accumulation in potatoes from wastewater irrigation. J. Environ. Manage. 232, 153–164.
Ochoa-Herrera, V., Banihani, Q., León, G., Khatri, C., Field, J.A., Sierra-Alvarez, R., 2009. Toxicity of fluoride to microorganisms in biological wastewater treatment systems. Water Res. 43, 3177–3186.
Ramadan, B.S., Wulandari, M., Wibowo, Y.G., Ikhlas, N., Nurseta, D.Y., 2021. Removing Ionic and Nonionic Pollutants from Soil, Sludge, and Sediment Using Ultrasound-Assisted Electrokinetic Treatment. In: Electrokinetic Remediation for Environmental Security and Sustainability.
Risco, C., López-Vizcaíno, R., Sáez, C., Yustres, A., Cañizares, P., Navarro, V., Rodrigo, M.A., 2016. Remediation of soils polluted with 2,4-D by electrokinetic soil flushing with facing rows of electrodes: A case study in a pilot plant. Chem. Eng. J. 285, 128–136.
Rosanti, D., Wibowo, Y.G., Safri, M., Maryani, A.T., 2020. Bioremediations Technologies on Wastewater Treatment : Opportunities , Challenges and Economic Perspective. Sainmatika J. Ilm. Mat. dan Ilmu Pengetah. Alam 17, 142–156.
Rubio, J., Souza, M.L., Smith, R.W., 2002. Overview of flotation as a wastewater treatment technique. Miner. Eng. 15, 139–155.
Sasongko, N.A., Agustiani, R., Khotimal, K., 2017. Analisis Biaya Manfaat Berbagai Jenis Teknik Remediasi Air Terproduksi dari Kegiatan Industri Minyak dan Gas Bumi. J. Energi dan Lingkung. 13, 79–86.
Suanon, F., Tang, L., Sheng, H., Fu, Y., Xiang, L., Herzberger, A., Jiang, X., Mama, D., Wang, F., 2020. TW80 and GLDA-enhanced oxidation under electrokinetic remediation for aged contaminated-soil: Does it worth? Chem. Eng. J. 385, 123934.
Teh, C.Y., Budiman, P.M., Shak, K.P.Y., Wu, T.Y., 2016. Recent Advancement of Coagulation-

Flocculation and Its Application in Wastewater Treatment. Ind. Eng. Chem. Res. 55, 4363–4389.

Watanabe, Y., Bach, L.T., Van Dinh, P., Prudente, M., Aguja, S., Phay, N., Nakata, H., 2016. Ubiquitous Detection of Artificial Sweeteners and Iodinated X-ray Contrast Media in Aquatic Environmental and Wastewater Treatment Plant Samples from Vietnam, the Philippines, and Myanmar. Arch. Environ. Contam. Toxicol. 70, 671–681.

Wibowo, Y.G., Ramadan, B.S., Andriansyah, M., 2019. Simple Technology to Convert Coconut Shell Waste into Biochar; A Green Leap Towards Achieving Environmental Sustainability. J. Presipitasi Media Komun. dan Pengemb. Tek. Lingkung. 16, 58.