J-PAL, Vol. 14, No. 1, 2023
DOI: 10.21776/ub.jpal.2023.014.01.02

ISSN: 2087-3522
E-ISSN: 2338-1671

Diversity and Biotic Index of Wild Pioneer Plants as Potential Bioindicators of Crude Oil-Contaminated Soil in Siak Regency, Riau Province, Indonesia

Dodi Dwi Risaundi[1*], Suwondo[2], Endang Arisoesilaningsih[1]

[1*]Department of Biology, Faculty of Mathematics and Natural Sciences, Universitas Brawijaya, Malang, East Java, Indonesia.
[2]Study Program of Biology Education, Department of Science, Faculty of Teacher Training and Education, Universitas Riau, Pekanbaru, Riau, Indonesia.

Abstract

This study aims to determine the spatial variations in the diversity of wild pioneer plants along the gradation of crude oil-polluted soils and to analyze their biotic potential as a bioindicator of crude oil-contaminated soils in Siak Regency. Sampling was done in three oil wells using a purposive sampling method (center, edge, far from the well) measuring 1 x 1 m^2. The soil at each contamination gradation was composited and analyzed for Total Petroleum Hydrocarbon (TPH) content. Vegetation data were analyzed using biotic indices such as density, Shannon-Wiener distribution index, species richness, rate of endemism, and importance value index. Potential bioindicator was analyzed by regression analysis, biplot, and IndVal. The results showed spatial variations in colonization, diversity, and structure of pioneer plants along the gradation of oil contamination. Species from the Cyperaceae, notably Scleria sumatrensis, Cyperus rotundus, and Fimbristylis ovata, were found in the center of the contamination areaand resistant to oil contamination. The regression and biplot analysis revealed that along with the increasing soil TPH, the species richness and diversity index tended to decline, but the rate of endemism increased. IndVal analysis showed that C. rotundus and S. sumatrensis showed a potential bioindicators of oil-contaminated soils with TPH content of 2,700 to 3,300 ppm, while F. ovata, Panicum repens, and Imperata cylindrica was potential for TPH 692 to 851 ppm. Mimosa pudica was a sensitive plant and found on the soil TPH 73 ppm.

Keywords: bioindicator, crude oil-contamination, diversity, pioneer plants

INTRODUCTION

Riau Province has long been known as an area rich in oil and gas. Riau is the largest contributor to Indonesia's national oil production, with the Rokan Block as its main buffer. Rokan Block in Riau Province accounts for up to 40% of total national oil production [1] The activity covers the upstream to the downstream industry, which includes the exploration stage (covering geological investigations, seismic activities, and drilling to search for oil and gas sources), the exploitation stage (oil extraction and oil and gas production stages), as well as downstream industrial activities such as the processing stage at refineries, transportation, storage, and marketing. All of these mining processes have the risk of producing oil spills and disturbing the environment through contamination of crude oil and its processing [2]. Mining activities have positive and negative impacts, such as increasing people's welfare and reducing unemployment as a positive impact, but also have negative impacts such as health problems, environmental degradation such as soil degradation [3]. Oil exploration and exploitation activities carried out in Minas, and Sabak Auh Districts in Siak Regency are part of the upstream oil industry. The soil around the well experienced mild, moderate to severe contamination due to industrial activities carried out. This contamination has caused soil degradation and decreased soil productivity. The findings of research on permanent plots for 12 years in soil contaminated with crude oil showed that grasses and sedges had grown as pioneer plants in the succession process. In addition, bio- and phytoremediation, restored natural vegetation and reduced the level of oil contamination by 55% to 90% [4].

In the upstream oil area in Riau Province, the ground cover has grown on crude oil-contaminated soil at mild, moderate to severe levels. The diversity profile and structure of the vegetation cover on degraded or contaminated land are interesting to be studied because it will provide basic information for monitoring and oil-contaminated soil management. Vegetation grown on polluted or contaminated soil has the potential to be a bioindicator of environmental

Correspondence address:
Dodi Dwi Risaundi
Email : dodidwi12@student.ub.ac.id
Address : Department of Biology, Faculty of Mathematics and Natural Sciences, Universitas Brawijaya, Malang, East Java, Indonesia.

change or a phytoremediator [5]; [6]. Bioindicators are biological processes at either the species or community level and are used as a biological measure of environmental quality and how it changes. All species or communities that are tolerant or sensitive to environmental changes can function as bioindicators and can be used to assess the condition of an environment using the "biotic index" being analyzed. In general, there are three main functions of bioindicators: 1. to monitor the environment (physical and/or chemical changes), 2. to monitor ecological processes, or 3. to monitor biodiversity [7]. In some cases of environmental change, plants are often used as bioindicators. Tolerant pioneer plants have the potential as phytoremediators to reduce contaminant levels in the environment [8]; [9]. Grass is a type of pioneer plant that improves and increases soil quality and fertility so that the productivity of other plants increases [10]. Meanwhile, several species showed sensitive characteristics, so this plant showed the potential for a contaminant bioindicator. The crude oil-contaminated soil needs to be treated by using bioremediation and/or phytoremediation as part of an easy, inexpensive, and ecofriendly technology[11]. The identification of various pioneer plants is necessary to accelerate and increase the efficiency of the phytoremediation process. However, information on pioneer plants on crude oil-contaminated soils in Siak Regency has not been widely published. Therefore, this research aimed to determine the spatial variations in the diversity and structure of the wild pioneer plants along the gradations of crude oil contamination and to analyze its biotic indices as potential bioindicators.

MATERIAL AND METHOD

This research was conducted from October 2020 to November 2021 in three different oil wells of Minas and Sabak Auh Districts in Siak Regency, Riau Province (Figure 1; sites 1, 2, and 3).

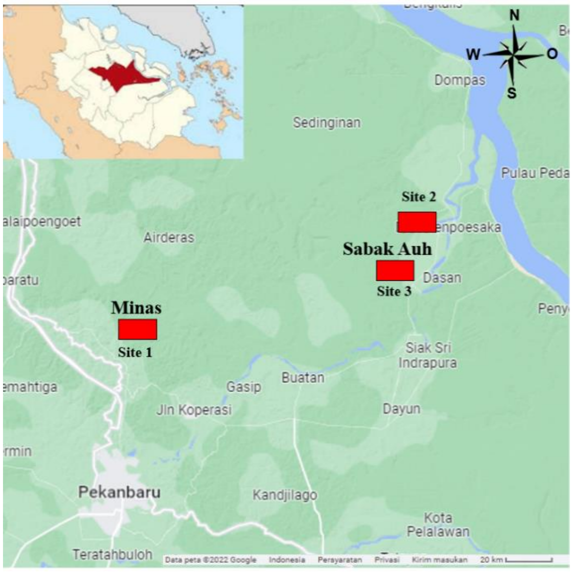

Figure 1. Research site map. Site 1= Minas Regency (C1, E1, F1), Site 2= Sabak Auh District (C2, E2, F2), Site 3= Sabak Auh District (C3, E3, F3).

1.1 Study area description

The first well is in Minas District and is included in the Rokan Block. The second and third wells are oil sources in Sabak Auh District and are included in the Pekanbaru Coastal Plan Block. However, the three active wells are included in the Siak Regency, Riau Province, with an elevation of 83 to 110 m asl. Crude oil spills were found in the area surrounding the well, with contamination levels ranging from low to high. Sometimes, the dark brown oil looks on the compacted soil surface, where it is naturally a yellow compacted clay. The distance and area of oil contamination vary depending on the intensity of exploitation activities.

1.2 Soil and vegetation analysis

In each oil well, there were three observation points (center of contamination (C), edge of contamination (E), beyond the contamination area (F), so there were nine observation sites. Pioneer plants at each observation site were purposively sampled using a squared plot of 1 x 1 m^2 (Figure 2). The pioneer plants observed were all types of wild pioneer plants, such as grasses, sedges, herbs, shrubs, and ferns. In each plot, species, densities and abundance of wild pioneer plants found were recorded. The soil color was observed visually, and the smell of the soil was evaluated organoleptically. Soil samples were collected to analyze soil moisture, pH, electric conductivity and soil TPH (Total Petroleum Hydrocarbon) values.

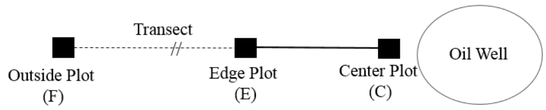

Figure 2. Research sampling plots design.

1.3 Data analysis

Some biotic indices were analyzed by determining relative density, relative frequency, importance value index, Shannon-Wiener species diversity index, species richness, and rate of endemism using the following formula:

1. Density = number of individual species / area of the plot.
2. Relative Density (RD) = (density of a species / density of all species) x 100%.
3. Frequency = number of plot occupied by a species / total number of plots.
4. Relative Frequency (RF) = (frequency of a species / frequency of all species) x 100%.
5. Important Value Index (IVI) = RD + RF

[12].

6. Shannon-Wiener species diversity index (H') = $H' = -\sum P_i \times \ln P_i$, $P_i = n_i/N$

H'= Species diversity index
ni = Important value index of a species
N = Total number of important value Index
ln = Natural log
[13].

Species richness was recorded by counting the number of species found. Plant species were grouped into local or endemic species and exotic or introduced species based on the natural distribution of the Malesiana phytoregion. The degree of endemism was determined by the equation: (density of local or endemic species / total species density) x 100% [14]. The diversity index between two sites was compared by the diversity t-test. Data on plant density at each location were then analyzed using indicator value analysis (IndVal) PAST 4.05 software to identify the potential species as bioindicators. Furthermore, the software was also used to analyze the interaction between biotic index, soil character and crude oil contamination by regression analysis and biplot.

RESULT AND DISCUSSION

1.1 Spatial variation of soil characteristics and TPH contamination

The characteristics of crude oil-contaminated soil varied along the gradient of contamination, especially in color, odor, and TPH concentration (Table 1). It can be seen that the soil at the center of contamination (C) had a black color, a strong oil smell, and the highest TPH value, followed by the edges area (E) and even beyond the visual contamination site. Soil contaminated by petroleum spills tends to be darker in color than soil that is not contaminated by petroleum [15]. However, the contamination in well 3 (C3) was much higher than in the other two wells (Table 1).

Table 1. Properties of crude oil contaminated soil.

Sites	Plots	pH	Color	Smell	EC	TPH
Center	C1	4.3	Black	Strong	1.0	851
	C2	4.6	Black	Strong	2.0	692
	C3	4.7	Black	Strong	1.0	3300
Edge	E1	4.7	Dark brown	Medium	1.0	751
	E2	4.6	Dark brown	Medium	2.0	493
	E3	4.6	Dark brown	Medium	3.0	2700
Far	F1	4.9	Brown	Slight	2.0	504
	F2	6.8	Light brown	Odorless	6.0	73
	F3	5.8	Brown	Slight	5.0	638

Notes : Sites (Center, Edge, Far or beyond the contamination area), Plots of 1st , 2nd, 3rd wells, Color (black, dark brown, brown, light brown), Smell (strong, medium, slight, odorless), EC = Electric Conductivity (μS cm^{-1}), TPH (Total Petroleum Hydrocarbon, ppm).

The minimum limit for soil TPH is 0.5% or 5000 ppm [16]. The government also continues to enforce to decrease of this threshold to lesser than 2000 ppm, so that the land can be remedied into productive land. Many oil companies in Indonesia used the bioremediation method to manage waste oil spills on the ground and set a TPH of less than 2000 ppm as a reference [17]. Soil TPH < 1000ppm is the safe limit for hydrocarbon contamination [18]. Based on Table 1, there were two plots: C3 and E3 with TPH of 3,300 ppm and 2,700 ppm, respectively, that exceeded the standard. Soil pH and EC conditions did not show high variation and ranged between 4.3 to 6.8 and 1.0 to 6.0 μS cm^{-1}, respectively.

There is a big indication that if the soil pH is too acidic, the pollutant content in the soil will also increase [19]. Soil TPH values appeared to correlate with soil pH values (Figure 3). Soil pH values were reported to have a negative correlation with soil TPH values [20].

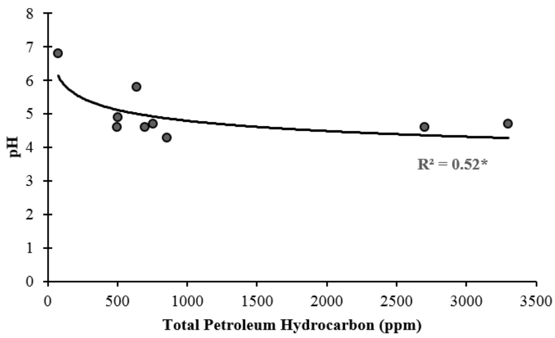

Figure 3. Relation between TPH value and pH value based on regression analysis. ***=** Significant (p < 0.05)

1.2 Spatial variation of wild pioneer plants diversity and structure along the gradation of crude oil contamination

Twenty-one species of pioneer plants belonging 10 families were found from the vegetation analysis. The majority of the plants were exotic and opportunistic, and only eight species were native or local. There were spatial variations in pioneer plants diversity and vegetation structure along with the gradation of oil contamination in the soil around the active wells. Regression analysis showed that plant species richness and diversity index decreased significantly with increasing TPH concentration toward the center of the contamination site (Figure 4). Species richness and diversity index are two important biotic indicators of this wild pioneer plants colonization. Based on the regression analysis, around 61.2 to 67.7% of soil TPH affected the plant diversity or species richness index. It means that the hydrocarbon compounds contained in the oil were very toxic so plants were very difficult to survive in the area [21]. The presence of oil contamination in soil affected the abundance of organisms, including microbial communities or plants [22]. The presence of stress caused by toxic pollutants differently leads to growth responses in each species due to different adaptation mechanisms to pollutants [23]. If the TPH level in a soil exceeds the plant's tolerance value, several species of plants show structural damage and dying [24]. Petroleum hydrocarbon molecules damage cell membranes and penetrate cells [25], interfere with the absorption of nutrients in the soil and inhibit plant growth [26]. Due to the toxicity of these hydrocarbon compounds, some plant species were sensitive. Thus, only resistant or tolerant species were able to grow in these conditions.

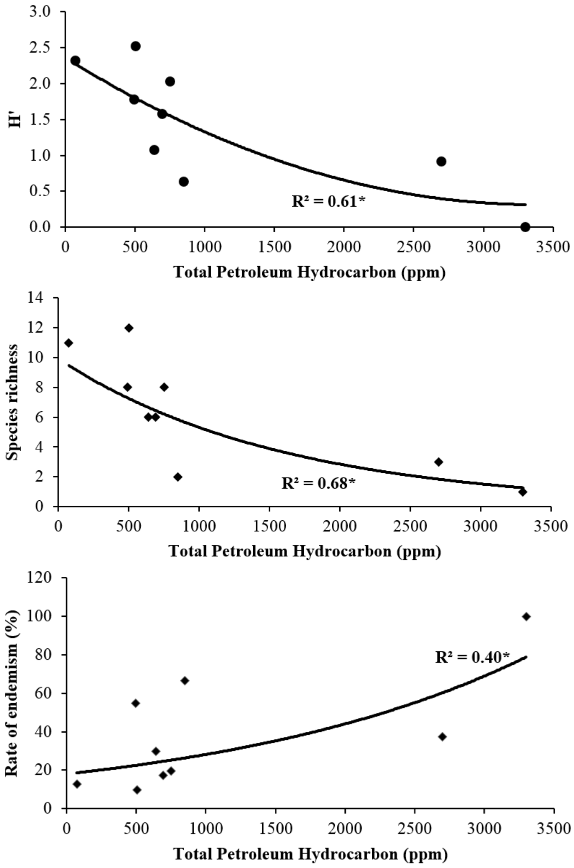

Figure 4. Relation between of TPH value and some biotic indices based on regression analysis. H'= Diversity Index, ***=** Significant (p < 0.05)

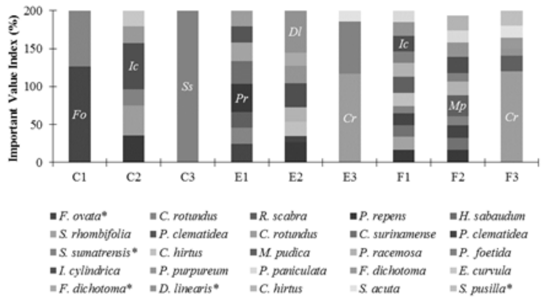

Figure 5. Variation of pioneer plant species across gradations of petroleum contamination. *= Native Species, C= Center of contamination, E= Edge area, F= Beyond the contamination area, *Fo= Fimbristylis ovata*, *Ic= Imperata cylindrica*, *Ss= Scleria sumatrensis*, *Pr= Panicum repens*, *Dl= Dicranopteris linearis*, *Cr= Cyperus rotundus*, *Mp= Mimosa pudica*

Furthermore, Figure 4 illustrates a significant and positive correlation between soil TPH and the rate of endemism. Therefore, the local plant species such as *Scleria sumatrensis*, and *Fimbristylis ovata* were abundantly found in some higher TPH contaminated plots. On the contrary, the exotic or opportunistic species such as *I. cylindrica, P. repens,* and *C. rotundus* were more sensitive and were found in the lesser TPH-contaminated plots. This finding revealed that some local species were resistant and had the potential as pioneers of the early step of succession as well as of phytoremediation. Natural colonization of local species on contaminated soil could be used as an example of success and spontaneous phytoremediation. Efforts to rehabilitate degraded land require local species so that the results are more optimal and do not cause new problems, such as a decrease in the quality of diversity and ecological services due to colonization of invasive species. Besides has great potential as a phytoremediator for polluted soils [27], local species are usually also easy to plant and adapt well to local conditions [28]. Therefore, it is very important to explore the local plant species before carrying out phytoremediation. Plants that are able to grow in these contaminated conditions, especially at sites C and E, were possibly utilized as phytoremediation agents for crude oil-contaminated soils.

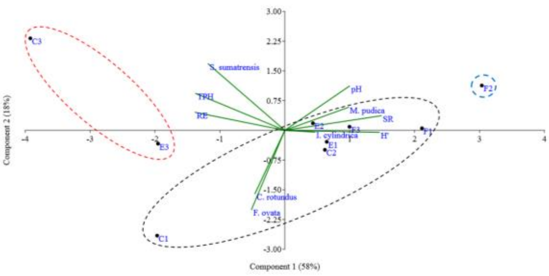

Figure 6. Relation between soil quality and biotic index and pioneer plant species based on PCA analysis. TPH = Total Petroleum Hydrocarbons, RE = Rate of Endemism, H' = Diversity Index.

According to Figure 5, in general the species *F. ovata, S. sumatrensis,* and *C. rotundus* were dominant sedges having high IVI values in all of the observed plots. This demonstrated that these species showed a higher chance of surviving in oil-contaminated environments. Species *S. sumatrensis* is a typical species found in almost all sites, especially in contaminated areas by oil spills. In Malaysia, *S. sumatrensis* was reported to be a pioneer sedge, had fast growth and formed a large coverage in swamps after forest fires [29]. Fast growing and resistance to crude oil toxicity are important requirements for effective phytoremediation agents. The wild and fast growing plants in the degraded areas were reported to be very effective pioneers in a rehabilitation program [30]. Furthermore, sedge *F. ovata* had a high level of resistance to several pollutants and grew well on serpentine soils [31], and is often used as a phytoremediation agent of contaminated or degraded soil. The species *F. ovata* and *S. sumatrensis* were also known as ~~t~~he pioneer plant species [32]. Unlike the two previous sedges, *C. rotundus* was the dominant exotic species found in high IVI values on edge plots. This indicated that *C. rotundus* was also a resistant species to hydrocarbon pollutants and utilized in fluoride phytoremediation in water [33]. However, this sedge had the potential risk of becoming an invasive species [34].

Principal Component Analysis (PCA) and biplot showed that the rate of endemism and density of *S. sumatrensis* was positively correlated with TPH soil contamination around the third well. TPH score was negative correlations with low density of species *I. cylindrica*, and *M. pudica*, diversity index values (H'), pH and species richness (Figure 6). The soil pH was low in the higher soil TPH value. However microorganisms that degraded contaminating oil increased soil pH toward neutral [35]. Changes in soil pH were the important factors influencing the changes in plant communities' structure and composition [36].

The use of several indices simultaneously is recommended for the study of species indicators [37]. Therefore, the data were then analyzed by the indicator value (IndVal). The results showed that the density of *S. sumatrensis* was confirmed significantly characterized by C3 plots with IndVal 100% (Table 2) and the highest soil TPH of 3,300 ppm.

Table 2. IndVal of species indicators grown along the gradation of petroleum contamination.

	IndVal (%) of Plots								
Species	**C1**	**C2**	**C3**	**E1**	**E2**	**E3**	**F1**	**F2**	**F3**
Fo	**65**	0	0	0	0	0	0	0	0
Ic	0	**40**	0	0	16	0	**14**	13	0
Ss	0	9	**100**	11	8	38	4	6	0
Pr	0	16	0	**21**	11	0	7	7	0
Dl	0	0	0	0	**40**	0	0	0	0
Cr	35	19	0	10	0	**50**	0	0	**30**
Mp	0	0	0	0	0	0	12	**19**	20

Notes : Bold value indicates a signifcant indVal for p<0.05. *Fo= Fimbristylis ovata, Ic= Imperata cylindrica, Ss= Scleria* *sumatrensis, Pr= Panicum repens, Dl= Dicranopteris linearis, Cr= Cyperus rotundus, Mp= Mimosa pudica.*

Sedge *S. sumatrensis* was found in several post-coal mining degraded lands [38]. This sedge had a high survival rate, allowing it to grow in the degraded soils caused by various contaminants. Meanwhile, the E3 plot was characterized by the density of *C. rotundus* with a soil TPH of 2700 ppm. Therefore, it is shown that both species were potential as soil bioindicators with TPH of 2700 to 3300 ppm. Furthermore, *F. ovata, P. repens,* and *I. cylindrica* also showed potential bioindicators with soil TPH values of 692 to 851 ppm. In addition, *Dicranopteris linearis* became an indicator in the E2 plot with a TPH of 493 ppm. Whereas *M. pudica* was more sensitive, becoming a potential indicator in soil with a TPH of 73 ppm. These results can become basic data in determining subsequent policies regarding sustainable management in the oil mining sector. Bioindicators summarize information on biological, physical and chemical aspects that manifest as benchmarks for the quality of the organisms present in them and the processes of the ecosystem. From an environmental management perspective, bioindicators inform the basis for sustainable and biologically unsustainable actions [39].

CONCLUSION

There are spatial variations in the diversity of wild pioneer plants found along the gradation of soil contaminated with crude oil. Spatial variation is shown in some biotic indices. Based on the regression and PCA analysis, we recorded the negative correlations between soil TPH concentrations and several biotic indices such as species richness and diversity index. In comparison, a positive correlation was found between soil TPH concentrations and a rate of endemism. Based on IndVal analysis, species from the Cyperaceae family, especially *S. sumatrensis, C. rotundus* and *F. ovata*, were found in the center and on the edges of the contamination area, indicating their resistance to crude oil. The results of IndVal's analysis also explained that *S. sumatrensis* and *C. rotundus* species are potential as bio-indicators of crude oil-contaminated soil with a TPH above 2700 ppm followed by *F. ovata, P. repens,* and *I. cylindrica* showing potential soil bioindicators with TPH values below 851 ppm, followed by *Dicranopteris linearis* which also had the potential to become a bioindicator of soils with lower TPH values, while species *M. pudica* was more sensitive and unable to grow in soil contaminated by crude oil. TPH toxicity reduced the growth of wild pioneer plants, but *S. sumatrensis, C. rotundus* and *F. ovata* survived in oil-contaminated soils. These species had potential as bioindicators and or phytoremediation agents for crude oil-contaminated soils.

ACKNOWLEDGEMENT

Alhamdulillah, praise and thanks to Allah Almighty for His blessings, guidance and provision of the research grant so the field work finished. The author also thanks the colleagues in the Biology Education Laboratory, the University of Riau, who assisted in collecting field work data. The authors also thank the anonymous reviewer, colleagues and members of the Conservation Biology Working Group for Sustainable Tropical Ecosystems in the Department of Biology, Faculty of Mathematics and Natural Sciences, Universitas Brawijaya, for providing feedback, support and constructive input. Besides, we also thank Durrotul Inayah, who assisted with the soil sample analysis.

REFERENCES

[1]. Bayu, A.W, Heriyanto, M. and Darwin, A.N. 2020. Forest Conversion in Upstream Oil and Gas Industry Area. *International Journal of Science, Technology and Management* 1(3):256-264, doi:10.46729/ijstm.v1i3.46.

[2]. Sulistyono. 2013. The impact of oil spills in marine waters on oil and gas industry activities and methods of handling them. *Forum Teknologi* 3(01):49-57. (in Indonesian).

[3]. Anggraini, D., Soemarno, & H. Riniwati. 2019. The Effect of Traditional Gold Mining toward the Socio-Economic and Environmental Aspect in Sepauk District Sintang Regency. *J-PAL* 10(1): 51-57.

[4]. Novakovskiy, A., Kahev, V.A. and Markarova, M.Y. 2021. Long-term dynamic of plant communities after biological remediation of soil-contaminated soils in far north. *Scientific Report* 11(1):1-13, doi:10.1038/s41598-021-84226-5.

[5]. Rishikesh, S., Sagar, R., Srivastava, P., Singh, P. and Singh, J.S. 2017. Herbaceous Species Diversity and Soil Attributes Along a Forest Savanna-Grassland Continuum in a Dry Tropical Region. *Ecological Engineering* 103:

226–235, doi:10.1016/j.ecoleng.2017.04.020.

[6]. Marta J., Grobelak, A. and Vandenbulcke, F. 2020. Modeling assisted phytoremediation of soils contaminated with heavy metals e Main opportunities, limitations, decision making and future prospects. *Chemosphere* 249: 1-15, doi:10.1016/j.chemosphere.2021.130062.

[7]. Holt, E. A., and Miller, S. W. 2010. Bioindicators: Using Organisms to Measure Environmental Impacts. *Nature Education Knowledge* 3(10):8.

[8]. David, N D. and Sharon, L.D. 2009. Improving Phytoremediation Through Biotechnology. *Current Opinion in Biotechnology* 20:1-3, doi:10.1016/j.copbio.2009.03.007.

[9]. Widyati, E. 2011. Potential of Undergrowth as Heavy Metal Accumulator to Help Rehabilitate Mine Land. Forest Productivity Research Center. *Jurnal Mitra Hutan Tanaman* 6(2): 37-55. (in Indonesian).

[10]. Umer, S., Aticho, A. and Kiss, E. 2018. Effects of integrated use of grass strip and soil bund on soil properties, Southern Ethiopia. *Journal of Degraded and Mining Lands Management* 6(2):1569-1578, doi:10.15243/jdmlm.2019.062.1569.

[11]. Kumar, B.M. 2013. Mining waste contaminated lands: and uphill battle for improving crop productivity. *Journal of Degraded and Mining Lands Management* 1(1):43-50.

[12]. Muhakka, M., Suwignyo, R.A.,, Budianta, D. and Yakup, Y. 2019. Vegetation analysis of non-tidal swampland in South Sumatra, Indonesia and its carrying capacity for Pampangan buffalo pasture. *Biodiversitas* 20(4):1077-1086, doi:10.13057/biodiv/d200420.

[13]. Tamartash, R. and Ehsani, S.M. 2021. The effect of earthworms on plant diversity and soil properties under different landuses. *Acta Ecologica Sinica* 41:171-176, doi:10.1016/j.chnaes.2020.06.008.

[14]. Rahma, A.F. and Arisoesilaingsih, E. 2017. Threatening of Invasive Alien Species (IAS) on Vegetation Structure and Aerial Arthropod Diversity in Protection Area of UB Forest. *Indonesia Journal of Environment and Suistainable Development* 8(2):89-92, doi:10.21776/ub.jpal.2017.008.02.05.

[15]. Gogoi, B.K., Goswami, N.N. and Mohan, P.K. 2003. A case study of bioremediation of petroleum-hydrocarbon contaminated soil at a crude oil spill site. *Advances in Environmental Research* 7 (4): 767-782, doi:10.1016/S1093-0191(02)00029-1.

[16]. Regulation of the Minister of Environment and Forestry of the Republic of Indonesia Number 6 of 2021 concerning Procedures and Requirements for the Management of Hazardous and Toxic Waste. (in Indonesian).

[17]. Hendrawati, D. 2022. Management of Heavy Oil-Type Contaminated Soil Using Phytoremediation Techniques. Thesis. Environmental science, Riau University, Pekanbaru. Thesis (in Indonesia)

[18]. Decree of the State Minister for the Environment Number 128 of 2003 concerning Procedures and Requirements for the Management of Biological Oil and Soil Contaminated Oil Waste.

[19]. Karamina, H., T. Wardiyati, & D. Maghfoer. 2017. Use of Phytoremediation Technology to Increase the Growth and Yield of Aloe Chinensis Varieties. *J-PAL* 8(1): 9-12. (in Indonesian).

[20]. Aliyanta, B., Sumarlin, L.O. and Mujab, A.S. 2011. Use of Biocompost in Polluted Land Bioremediation Petroleum Waste. *Valensi* 2(3):430-442, doi:10.15408/jkv.v2i3.114 (in Indonesian).

[21]. Mutairi, N.A., Bufarsan, A. and Al Rukaibi, F. 2005. Ecorisk Evaluation and Treatability Potential of Soils Contaminated with Petroleum Hydrocarbon-Based Fuels. *Chemosphere* 74:142–148, doi:10.1016/j.chemosphere.2008.08.020.

[22]. Li, C., Quan, Q., Gan, Y., Dong, J., Fang, J., Wang, L. and Liu, J. 2020. Effects of heavy metals on microbial communities in sediments and establishment of bioindicators based on microbial taxa and function for environmental monitoring and management. *Science of the Total Environment* 729:1-9, doi:10.1016/j.scitotenv.2020.141555.

[23]. Grifoni, M., Rosellini, I., Angelini, P., Petruzzeli, G. and Pezzarossa, B. 2020. The Effect of Residual Hydrocarbons in Soil Following Oil Spillages on the Growth of Zea Mays Plants. *Environmental Pollution* 265:1-8, doi:10.1016/j.envpol.2020.114950.

[24]. Jingchun T., Min, W., Fei, W., Qing, S. and Qixing, Z. 2011. Eco-Toxicity of Petroleum

Hydrocarbon Contaminated Soil. *Journal of Environmental Sciences* 23(5): 845–851, doi:10.1016/S1001-0742(10)60517-7.

[25]. Fadhliah, S. and Suryati, T. 2014. Phytoremediation of Petroleum Contaminated Soils Using Four Species of Grass. *Jurnal Riset Industri* 8(2):123– 128. (in Indonesian).

[26]. Khan, M.A.I., Biswas, B., Smith, E., Naidu, R. and Mengharaj, M. 2018. Toxicity assessment of fresh and weathered petroleum hydrocarbons in contaminated soil a review. *Chemosphere* 212:755-767, doi:10.1016/j.chemosphere.2018.08.094.

[27]. Teresa, S. and Kluk, D. 2020. Application of Festuca Arundinacea in phytoremediation of Soils Contaminated with Pb, Ni, Cd and Petroleum Hydrocarbon. *Ecotoxicology and Environmental Safety* 194:1-12, doi:10.1016/j.ecoenv.2020.110409.

[28]. Adelaide, C., Ana, M., Graca, O., Maria, A., Martin, L. and and Otilia, C. 2016. Effect of Hydroseeding Components on The Germination of Mediterranean Native Plant Species. *Journal of Arid Environments* 125:68-72, doi:10.1016/j.jaridenv.2015.09.017.

[29]. Ulok, G., Nuruddin, A.A., Go, R. and Tahir, P.M. 2016. Leaves Calorific Values of Selected Species in Burnt Tropical Peat Swamp Forest in Selangor, Malaysia. *American Journal of Environmental Sciences* 12 (2): 63-67, doi:10.3844/ajessp.2016.63.67

[30]. Anshari, M.F., Boedianto, E., Fernandes, A.A.R. and Arisoesilaningsih, E. 2018. Hydroseeding application using pioneer local plant seeds for coal postmining soil in Tanah Laut Regency, South Kalimantan. *Journal of Degraded and Mining Lands Management* 5(4):1335-1345, doi:10.15243/jdmlm.2018.054.1335.

[31]. Chathuranga, P.A.D., Dharmasena, P.D., Rajakaruna, N. and Iqbal, M.C.M. 2015. Growth and Nickel Uptake by Serpentine and nonserpentine populations of *Fimbristylis ovata* from Srilangka. *Australian Journal of Botany* 63(2) 128-133, doi:10.1071/BT14232.

[32]. Rishikesh, S., Sagar, R., Srivastava, P., Singh, P. and Singh, J.S. 2017. Herbaceous Species Diversity and Soil Attributes Along a Forest Savanna-Grassland Continuum in a Dry Tropical Region. *Ecological Engineering* 103: 226–235, doi:10.1016/j.ecoleng.2017.04.020.

[33]. Khandare, R.V., Watharkar, A.D., Pawar, P.K., Jagtap, A.A. and Desai, N.S. 2020. Hydrophytic plants Canna indica, Epipremnum aureum, Cyperus alternifolius and Cyperus rotundus for phytoremediation of fluoride from water. *Environmental Technology and Innovation*21:101234, doi: 10.1016/j.eti.2020.101234.

[34]. Sutomo, S. and Fardila, D. 2015. Autecology of Invasive Species *Cyperus rotundus* L. in Forest Edge of Pohen Mountain, Batukahu Nature Reserve, Bali, Indonesia. Metamorfosa: *Journal of Biological Sciences* 2(2): 50-57.

[35]. Luge, R., Zheng, X., Oba, B.T., Shen. C., Wang, X., Wang, H., Liao, Q. and Sun, L. 2021. Activating Soil Microbial Community Using Bacillus and Rhamnolipid Toremediate TPH Contaminated Soil. *Chemosphere* 275:1-10, doi:10.1016/j.chemosphere.2021.130062.

[36]. Chao, Y. and and Sun, J. 2021. Impact of Soil Degradation on Plant Communities in An Overgrazed Tibetan Alpine Meadow *Journal of Arid Environment*.193:1-7, doi:10.1016/j.jaridenv.2021.104586.

[37]. Podania, J. and Csányib, B. 2010. Detecting indicator species: Some extensions of the IndVal measure. *Ecological Indicators* 10 (6): 1119-1124, doi:10.1016/j.ecolind.2010.03.010.

[38]. Vivi, N., Choesin, D.N., Iskandar, D.T. and Suprayogo, D. 2017. Plant Species from Coal Mine Overburden Dumping Site in Satui, South Kalimantan, Indonesia. *Journal of Degraded and Minings Land Management* 4(4):927-936, doi:10.15243/jdmlm.2017.044.927.

[39]. Holt, E. A., and Miller, S. W. 2010. Bioindicators: Using Organisms to Measure Environmental Impacts. *Nature Education Knowledge* 3(10):8.