PHYTOREMEDIATION OF LAUNDRY WASTE BY USING *Brassica juncea* AND *Brassica rapa*

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Abstract

Laundry waste is typically discarded directly into the environment, resulting in environmental contamination. The purpose of this investigation is to determine the efficacy of mustard plants (Brassica juncea and Brassica rapa) in reducing COD, TSS, TDS, turbidity, phosphate levels, increasing DO, and neutralizing pH in laundry waste treated with the Deep Flow Technique (DFT) system. Twenty plants in each series were exposed to each of the two plant treatments for six days. The removal efficiency of Brassica juncea for COD parameters was 94.1%, TSS was 84.8%, TDS was 69.4%, turbidity was 92.5 %, phosphate was 95.0 %, the increase in DO was between 6.2 mg/L and 7.8 mg/L, and pH values were between 8.0 and 7.1. During the treatment of *Brassica rapa,* the results indicated a decrease in COD by 88.2%, TSS by 80.3%, TDS by 65.3%, turbidity by 91.9%, phosphate by 88.9%, an increase in DO between 6.0 mg/L and 7.6 mg/L, and pH values between 8.2 and 7.2. According to the presented data, the two mustard plants (Brassica juncea and Brassica rapa) are capable and effective at reducing the concentrations of pollutant parameters in laundry waste.

Keywords: *Brassica juncea*, *Brassica rapa*, DFT *hydroponics*, laundry waste

Introduction

Laundry services are one of the many services that appear to facilitate or assist domestic activities as a result of an increase in community activity levels. Laundry business actors generate liquid waste, which has a negative impact on the aquatic environment if the waste products are not monitored and processed (Maliga et al., 2017). The increasing number of business actors who dispose of waste without processing it will have a variety of negative effects, including damage to water ecosystems, contamination of water bodies, and a crisis in pure water (Kusuma et al., 2019). The parameters Total Suspended Solid (TSS), Total Dissolved Solid (TDS), and Chemical Oxygen Demand (COD) are present in laundry waste (Utami, 2013).

Given the issue of laundry refuse water pollution, water bodies must be cleaned or restored. One of the methods that can be used to treat polluted water contamination is phytoremediation. Phytoremediation is a technique that can be used to restore a polluted environment by rehabilitating both soil and water with plants (Agustin, 2017). The phytoremediation technique utilizes the capacity of plants to assimilate contaminants or heavy metals in water (Ruhmawati et al., 2017). In-situ phytoremediation (direct treatment of polluted media) and ex-situ phytoremediation (using a reactor or an artificial reservoir) are both viable methods of phytoremediation. Phytoremediation

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is frequently employed because it is simple to operate, relatively cost-effective, environmentally friendly, and safe (Hamdan et al., 2019; 2020; 2021; Nur, 2013).

Through their roots and branches, phytoremediation plants are able to decompose or degrade certain substances or pollutant concentrations at high concentrations. This process is applicable to the phytoextraction mechanism, as plants will absorb pollutant contents through their roots and transport them to their canopy for processing (Hidayanti, 2016). In phytoremediation, plants also use their stems and foliage to degrade pollutant materials; thus, plant morphology plays a crucial role in phytoremediation. According to Menurut (Kustiyaningsih and Irawanto, 2020), the degradation of pollutant materials is also influenced by the morphology of plants. Morphology in vegetation The Brassica juncea plant has broad leaves and fibrous roots. The Brassica rapa plant has spoon-shaped, oblong leaves and a taproot. Therefore, these two plants could be utilized for phytoremediation.

Plant *B. juncea* is a hyperaccumulator plant. According to (Kasmiati et al., 2018), B. juncea plants are able to survive and grow in polluted media and are able to translocate and accumulate 80-97% of the metal pollutant Cr through their roots. According to (Susanawati et al., 2016), B. juncea is capable of surviving and thriving in gray water liquid waste with hydroponic growing media. Explanation (Sabrina et al., 2018): The use of B. juncea plants as biofilter media in carp culture water is capable of producing high-quality water because B. juncea has fiber roots that can filter pollutant levels, allowing them to absorb organic matter and reduce pollutant levels. The results (Junyo and Handayanto, 2017) also demonstrate that the B. juncea plant is a hyperaccumulator capable of absorbing 0.178 ppm of Hg from polluted soil.

In addition to plant B. juncea, plant B. rapa also possesses the potential to be a hyperaccumulator. Explanation (Baroroh, 2017) that B. rapa plants can assimilate Cu at a rate of 0.059 mg/kg/day when watered with contaminated water containing Cu. According to the findings (Qulub, 2017), B. rapa plants were able to reduce nitrite, nitrate, and ammonia levels in red tilapia detritus by 71.23 percent. The results (Junyo and Handayanto, 2017) also demonstrate that the B. rapa plant is a hyperaccumulator capable of absorbing 0.311 ppm of mercury (Hg) from contaminated soil. In addition to heavy metals, B. rapa's ability to degrade other categories of contaminants has been investigated. According to reports (Effendi et al., 2015), B. rapa was able to reduce ammonium levels by 52.16 percent and orthophosphate levels by 28.16 percent. Additionally, Effendi et al. (2015) suggested that refuse treatment must be integrated with other activities, such as agriculture and fishing. Waste treatment for ammonium and orthophosphate has been incorporated into catfish farming.

One of the systems that can be used for phytoremediation is the Deep Flow Technique (DFT) hydroponic system. In this system, 4-6 cm of plant roots are submerged in the water stratumw Technique (DFT) hydroponic system. In this system, 4-6 cm of plant roots are submerged in the water stratum. (Wirawan et al., 2014) The DFT hydroponic system functions by circulating water continuously for 24 hours, thereby minimizing the likelihood that plants will wilt and dry out.

According to previous research, no one has used B. juncea and B. rapa plants to reduce levels of phosphate, COD, TSS, DO, TDS, turbidity, and pH using the DFT hydroponic system. The treatment of laundry waste with the phytoremediation of B. juncea and B. rapa plants using the DFT hydroponic system in order to reduce levels of phosphate, COD, TSS, TDS, turbidity, increase DO levels, and neutralize pH requires further study. The purpose of this study is to assess the efficacy and capacity of B. juncea and B. rapa plants in reducing pollutant levels in laundry waste. The use of the food crops B. juncea and B. rapa in the treatment of laundry waste expands the concept of laundry waste phytoremediation that is incorporated with other economic activities such as plant cultivation.

Research Methodology

Sampling Location

The research was conducted in a number of locations, including: (i) a waste sampling location in a laundry business located at Jalan Cinta Kasih Barat 9 No. 11, Lueng Bata District, Banda Aceh City; (ii) the location of the phytoremediation experiment conducted at BPP Meuraxa, Banda Aceh City; and (iii) the location of sample measurements for the parameters COD, TSS, pH, TDS, turbidity,and EC was carried out at the UIN Ar-Raniry Banda Aceh Environmental Engineering Laboratory; (iv) measurement of phosphate parameters was carried out at the USK Environmental Quality Measurement Engineering Laboratory.

Experimental procedure

In each hydroponic series, the prepared washing waste is deposited into a holding receptacle. The acclimated plants are then placed in the provided net container. The plant's roots are inserted into the net container to a depth of approximately 2–3 centimeters of water. A hydroponic circuit using an aquarium pump. Phytoremediation was conducted by observing the efficacy of plants in treating laundry effluent under varying conditions of plant residence time. The series consists of two variations: the DFT hydroponic series with 20 B. juncea (T1) plants and the hydroponic series with 20 B. rapa (T2) plants. Each treatment takes six days, and waste control is conducted in waste control tanks for comparison with waste after phytoremediation. The waste in the control container (B) was evaluated on days 1 (D1B) and 6 (D6B). Each series also incorporates aeration, which serves to increase the oxygen levels in wastewater.

Calculation of Pollutant Reduction Effectiveness

According to Trisnawati (2019) the effectiveness of the percentage of pollutant reduction can be determined by the Eq. 1.

$$\text{Effectiveness} = \frac{a-b}{a} \times 100\% \quad (1)$$

Where a is the initial concentration before processing, and b is the pollutant concentration after processing.

Result and Discussion

The test results included the parameters shown in Table 1 for TSS, COD, DO, pH, TDS, turbidity, EC, and phosphate, as well as the results of the effectiveness analysis shown in Table 2. The standard used for these parameters are Regulation of Environmental Ministry No. 5/ 2014, Regulation of Health Minitry No. 32/ 2017 and Regulation of Indonesian Government No. 82/ 2001. Based on the results of the initial sample testing of the parameters, it was determined that the laundry waste was contaminated, which alludes to the established quality standards. The concentrations of TSS, COD, phosphate, and pH were 357 mg/L, 464.0 mg/L, 26.73 mgqa-L, and 9.7, respectively. The DO and TDS concentrations were 5.8 and 1118 mg/L, respectively. The value of turbidity is 41.08 NTU. Following the application of phytoremediation to the laundry refuse, the parameters of the laundry wastewater decreased significantly in both plant treatments. This is because the two plants are capable of reducing laundry waste water. Although not all waste parameters can be eliminated in accordance with predetermined quality standards, phytoremediation results in a decrease.

Table 1. The measurement outcomes were obtained subsequent to the application of phosphate, COD, TSS, DO, pH, TDS, turbidity, and EC parameters in conjunction with B. juncea and B. rapa mustard plants.

The various stages of treatment	**Time (day)**	**TSS (mg/L)**	**COD (mg/L)**	**DO (mg/L)**	**pH**	**TDS (mg/L)**	**Turbidity (NTU)**	**EC (mS/cm)**	**Phosphate (mg/L)**
Preliminary Evaluation	0	357	464.0	5.8	9.7	1118	41.08	6.08	26.73
	1	254	328.0	6.2	8.0	612	41.01	6.03	7.99
	2	123	246.0	6.6	7.7	586	9.04	0.83	5.13
	3	112	136.5	7.3	7.5	564	4.04	0.76	4.08
B. juncea	4	82	109.2	7.5	7.4	541	3.63	0.68	2.80
	5	69	81.9	7.7	7.4	411	3.15	0.63	2.68
	6	54	27.3	7.8	7.1	342	3.07	0.42	1.31
	1	262	355.0	6.0	8.2	618	41.05	6.06	8.52
	2	162	259.0	6.3	7.8	601	9.20	0.84	6.44
	3	126	191.1	6.8	7.7	596	4.21	0.79	5.58
B. rapa	4	98	150.2	7.0	7.5	573	3.89	0.71	3.07
	5	78	95.6	7.3	7.2	434	3.76	0.67	2.96
	6	70	54.6	7.6	7.2	387	3.29	0.52	2.95
control tank	0	357	464.0	5.8	9.7	1118	41.08	6.08	26.73
	6	286	450.0	5.7	9.1	1253	42.1	6.20	18.39

Table 2. The efficacy of waste processing can be evaluated by assessing the percentage of removal for several criteria such as TSS, COD, TDS, turbidity, and phosphate content.

The various stages of treatment	**Time (day)**	**TSS (%)**	**COD (%)**	**TDS (%)**	**Turbidity (%)**	**Phosphate (%)**
Preliminary Evaluation	0	0.00	0.00	0.0	0.0	0.0
	1	28.8	29.3	45.2	17.0	70.1
	2	65.5	46.9	47.5	77.9	80.8
	3	68.6	70.5	49.5	90.1	84.7
B. juncea	4	77.0	76.4	51.6	91.1	89.5
	5	80.6	82.3	63.2	92.3	89.9
	6	84.8	94.1	69.4	92.5	95.0
	1	26.6	23.4	44.7	7.30	68.1
	2	54.6	44.1	46.2	77.6	75.9
	3	64.7	58.8	46.6	89.7	79.1
B. rapa	4	72.5	67.6	48.7	90.5	88.5
	5	78.1	79.3	61.1	90.8	88.9
	6	80.3	88.2	65.3	91.9	88.9

COD parameters

Based on Table 1, it can be seen that the COD content of both B. juncea and B. rapa mustard plants decreased over time. The results of the straightforward linear regression test indicated that time had an effect on the reduction of COD using B. juncea and B. rapa mustard plants (respective sig values of 0.000 < probability 0.05). It is known that B. juncea and B. rapa mustard plants are effective at absorbing pollutants from laundry waste when treated with this method.

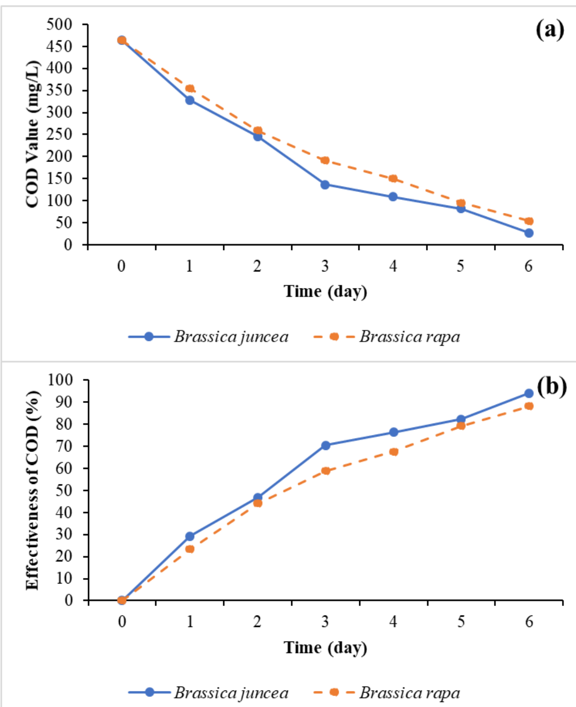

Figure 1. Graph of reduction (a) and percentage of reduction of COD (mg/L) (b) against time (days) in phytoremediation processing using B. juncea and B. rapa plants.

The root structure of each plant influences the decline in COD concentration. According to (Rahadian et al., 2017), rhizosphere microorganisms in plant roots can convert organic compounds into simpler compounds both aerobically and anaerobically. The DFT hydroponic system is utilized for laundry refuse treatment. The circulation of laundry wastewater will continue indefinitely. Each series also underwent aeration to increase the oxygen levels in the laundry discharge water. This increased oxygen content can decrease COD levels. This is supported by the assertion (Wicheisa et al., 2018) that increased oxygen can influence COD reduction.

TSS Parameters

Based on Table 1, it can be seen that the TSS content of both B. juncea and B. rapa mustard plants decreased over time. The results of a statistical test between time (days) and the TSS parameter (mg/L) indicated that there was an effect between time (days) and the TSS parameter (mg/L). The probability of employing B. juncea was (0.005 < 0.05), while that of B. rapa was (0.002 < 0.05). This indicates that plant residence time (days) has an effect on the TSS parameter (mg/L).

This occurred in the B. juncea plant on day 6 and met the quality standard with a value of 54 mg/L and a reduction percentage of 84.8%, thus meeting the predetermined quality standard. Similarly, B. rapa experienced a decline from day 0 to day 6, with the decline percentage increasing from 26.6% to 80.3%. TSS measurements on B. rapa, however, did not meet the established quality standards. This is likely due to the fact that the morphological structure of B. rapa leaves is smaller than that of B. juncea leaves. The leaves of B. rapa are round and oblong (similar to a spoon), whereas those of B. juncea are broad and undulating. So that the amount of TSS removed from B. rapa plants is not excessive. The effect of plant morphology on TSS levels is further supported by Novita et al. (2019) explanation that the decrease in TSS levels is influenced by the ability of plants to assimilate and transpire organic matter through the expansion of the plant's leaf surface.

TSS levels, which decreased in the B. juncea treatment, were also affected by the shape of the roots of the B. juncea plants, which were fibrous; these fibrous roots caused colloidal particles to adhere to plant roots when water circulated in the hydroponic circuit. This is consistent with the explanation from (Fachrurozi et al., 2010) that the decrease in TSS levels is also caused by particles in laundry residue that can settle on plant roots.

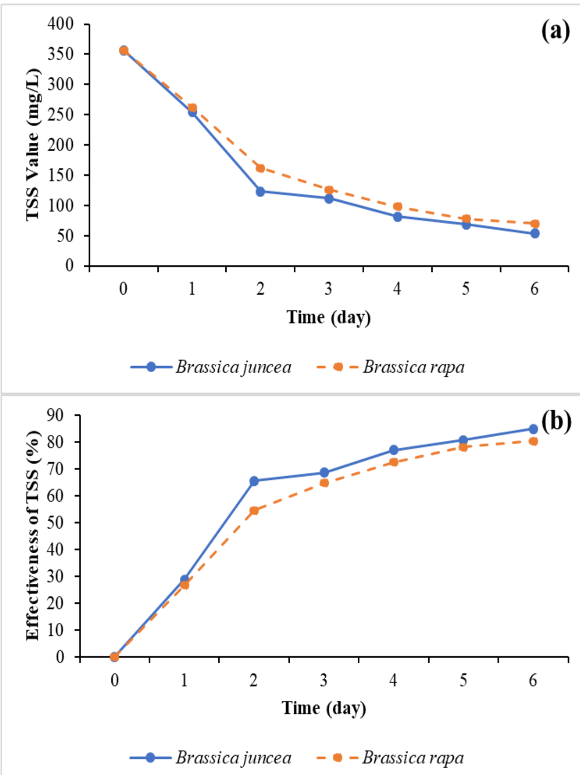

Figure 2. Graph of reduction (a) and percentage of reduction of TSS (mg/L) (b) against time (days) in phytoremediation treatment using B. juncea and B. rapa plants.

Phosphate Parameters

Using both B. juncea and B. rapa mustard plants, Table 1 demonstrates that the phosphate concentration decreased with increasing contact time. The statistical analyses between time (days) and the phosphate parameter (mg/L) revealed that there was a relationship between the two variables. The value of the probability of employing B. juncea is (0.040 < 0.05). In the meantime, the B. rapa probability value is (0.039 < 0.05). This indicates that plant residence time (days) has an effect on the phosphate parameter (mg/L).

Figure 3 illustrates the phosphate parameter of laundry wastewater before treatment, which was measured at a concentration of 29.73 mg/L. The aforementioned findings continue to surpass the prescribed quality benchmarks outlined in Regulation of the Minister of Environment of the Republic of Indonesia Number 5 of 2014, which pertains to the criteria for wastewater quality. Phosphate content decreased over time (days) following the phytoremediation treatment of laundry effluent using B. juncea and B. rapa plants. Figure 3 depicts the percentage reduction of phosphate in laundry wastewater from time (days) to time (days). The results indicate that the greatest reduction in laundry refuse treatment using B. juncea plants occurs on day 1, with a value of 7.99 mg/L and a percentage reduction of 70.1%. With a reduction value of 1.31 mg/L, processing with B. juncea met the quality standards established on the sixth day of B. juncea treatment.

The absorption of pollutants by plant roots, which in this study manifested as color changes in the roots as a result of the roots absorbing laundry waste, is also responsible for the decrease in phosphate.The study found that the roots of the plants were changing color as a result of absorbing laundry waste, which is another factor contributing to the decrease in phosphate.In accordance with (Ambardini dkk., 2020), the process of absorption of contaminants contained in waste is carried out by the extremities of the roots using meristem tissue so that water molecules in plants exert an attractive force. The xylem transports substances ingested by the roots back to the roots (Rusyani, 2014).

According to the findings of the study, B. juncea and B. rapa plants were able to adapt to and have a tolerance for phosphates in laundry refuse. This is demonstrated by the fact that the plants survived the research. Even though there were physical changes in the plants, as evidenced by the yellowing and drying of the foliage, the plants' shoots grew, as shown in the illustration. According to Figure 4, the results of the conducted research indicate that B. juncea and B. rapa plants were able to adapt to and tolerate phosphates in laundry waste. This is demonstrated by the fact that the plants survived the research. Even though there were morphological changes in the plants, as evidenced by the yellowing and drying of the leaves, the plants' shoots grew, as shown in Figure 4.

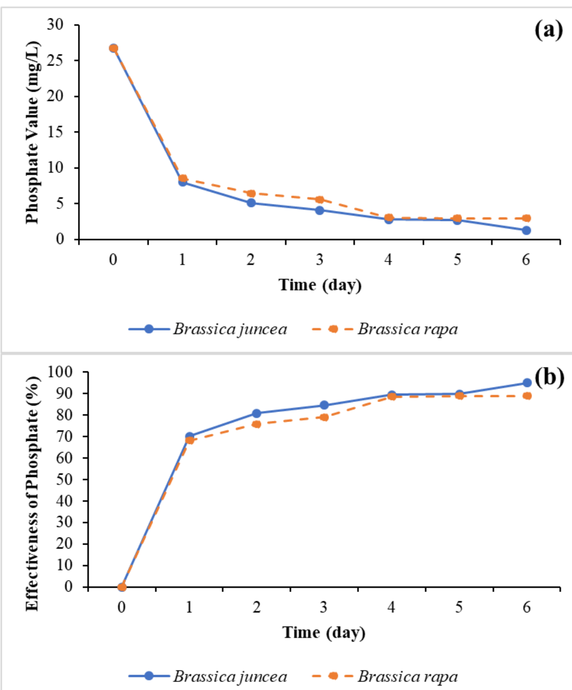

Figure 3. Graph of reduction (a) and the percentage reduction of phosphate (mg/L) (b) against time (days) in phytoremediation treatment using B. juncea and B. rapa plants.

(a) Leaf Tops of *B. juncea*

(b) Leaf Tops of *B. rapa*

Figure 4. The tops of the leaves of B. juncea and B. rapa

Value of pH Parameters

From day 1 to day 6, the pH level of the laundry effluent became neutral, as depicted in Figure 5. During the course of the investigation, the pH fluctuated between 7 and 8, which indicates that the pH is neutral and meets quality standards. The decrease in pH can also be caused by the B. juncea and B. rapa plants' decomposition of organic matter, resulting in a decrease in organic matter. Microorganisms found in plant roots degrade organic materials found in laundry waste. They assimilate organic matter, which is then incorporated into the plant's structure (Safitri et al., 2019). According to research (Retnosari and Shovitri, 2013), the decrease in pH value caused by the biodegradation of organic matter is also accurate. The statistical test results between time (days) and pH parameters revealed a correlation between the two variables. The sig probability value is less than 0.05, with the probability value for B. juncea treatment being (0.023 < 0.05) and that for B. rapa treatment being (0.011 < 0.05). This indicates that plant residence time (days) has an effect on the pH parameters of the two plant treatments.

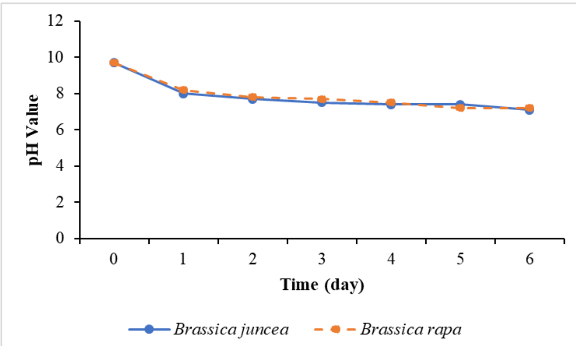

Figure 5. Graph of pH decrease with time (days) in phytoremediation treatment using B. juncea and B. rapa plants.

DO Parameters

According to the experimental data presented in Table 1, there was an increase in the levels of dissolved oxygen (DO) in the laundry wastewater during the contact period with the two plant treatments. The results of the straightforward linear regression test indicated that the variable time had an effect on increasing DO in both B. juncea and B. rapa plants (sig values of 0.000 < probability of 0.05, respectively). According to Figure 6, the DO value prior to treatment was 5.8 mg/L, which did not satisfy the quality standards. In both the B. juncea and B. rapa regimens, the DO value increased after six days of processing in both processing sequences from day to day. Both circuits' aeration contributed to the increase in dissolved oxygen levels in the laundry effluent. According to the explanation (Patang et al., 2019), this is the case. Because the aerator supplies oxygen, increasing the dissolved oxygen levels can help increase the DO value in wastewater. This is also suspected given that the DFT hydroponic circuit is used to process laundry refuse. In DFT hydroponics, water circulates continuously so that oxygen is present in the water flow and equitably distributed in the laundry waste water.

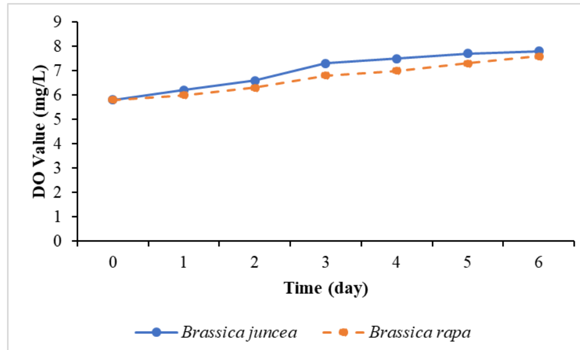

Figure 6. Graph of increase in DO (mg/L) against time (days) in processing.

TDS Parameters

Based on the experimental data presented in Table 1, TDS levels have decreased over the course of six days. The results of a simple linear regression test between time (days) and the parameter TDS (mg/L) in the data processing results also support this conclusion. The results indicate that time (days) has an effect on the TDS parameter (mg/L). The outcomes for the B. juncea treatment were (0.014 < 0.05), while the outcomes for the B. rapa treatment were (0.018 < 0.05).

It is believed that the morphology of plant roots accelerates the degradation of TDS levels, resulting in a decrease in TDS levels in laundry effluent. According to (Rusyani, 2014), the decrease in TDS is influenced by plant roots, which function as absorption media within effluent. The root ends serve as a site for the absorption of pollutants. This is also due to the presence of microorganisms in the roots. Microbes in the roots of B. juncea and B. rapa plants aid the roots in the process of absorbing laundry refuse water. This is supported by (Fadhli, 2020), which states that the decrease in TDS is due to the activity of microorganisms present in plant roots. The opinion

(Kustiyantingsih and Irawanto, 2020) that plants also utilize stems and foliage in the phytoremediation process lends support to the occurrence of phytoextraction in both plant treatments. Figure 8 also reveals that B. juncea plants are more tolerant of laundry refuse than B. rapa plants.

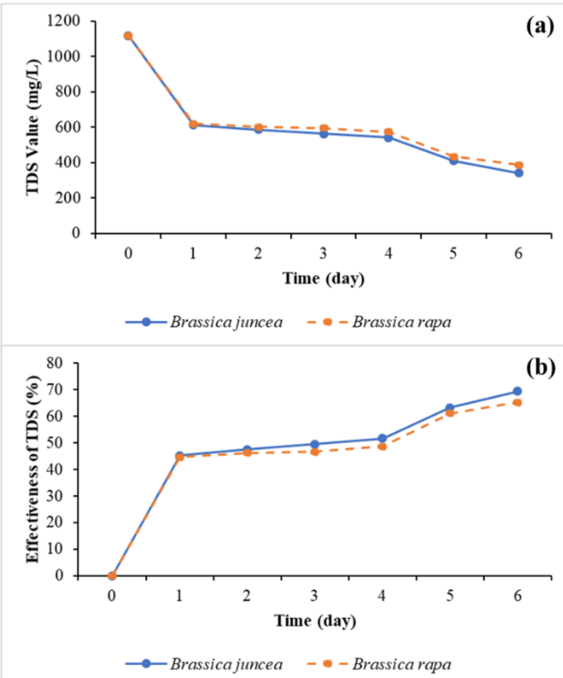

Figure 7. Graph of reduction and percentage of reduction of TDS (mg/L) against time (days) in phytoremediation treatment using B. juncea and B. rapa plants.

The decrease in TDS concentrations in the two plant treatments affected Electrical Conductivity (EC) concentrations as well. Figure 9 demonstrates that after six days of processing the two plant treatments, the EC levels decreased in both plant treatments. It was believed that the decline in EC levels in the laundry wastewater was a result of the decrease in TDS levels in the laundry wastewater.

(a) *B. juncea plants*

(b) *B. rapa plants*

Figure 8. Physical condition of *B. juncea* and *B. rapa plants.*

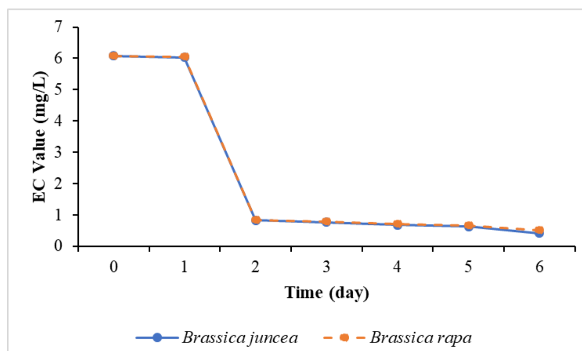

Figure 9. Graph of decrease in EC (mg/L) against time (days) in phytoremediation treatment using B. juncea and B. rapa plants.

According to Retnaningdyah and Arisaesilaningsih (2018), the quantity of dissolved salt (salinity) in wastewater causes the EC value to decrease. In accordance with the statement (Widowati et al., 2015) that there is a process of absorption of inorganic materials such as ions dissolved in wastewater, both plants can absorb dissolved solids (salt) during the process of TDS degradation in laundry wastewater. Therefore, when the TDS value decreases, the EC value will also diminish. According to the findings of the study (Pambudi, 2020), there is a correlation between the TDS value and the EC value of effluent.

Turbidity Parameters

Using both B. juncea and B. rapa plants, the turbidity level continued to decrease with increasing residence time, as shown in Table 1. Figure 11 the results of the straightforward linear regression test indicated that both *B. juncea* and *B. rapa* plants reduced turbidity over time (respectively sig value 0.018 < probability 0.05). This indicates that plant residence time (days) has an effect on the turbidity parameters of the two plant treatments.

(a) Processed samples of *B. juncea*

(b) Processing samples of *B. rapa*

Figure 10. Change in color of laundry waste samples from time (days) to time (days)

The ability of the two plant treatments (B. juncea and B. rapa) to assimilate contaminants in sediments and water bodies may also have contributed to the decline in turbidity levels in laundry waste. The assertion (Taufiq, 2020) that plants can absorb pollutants and transform them into dissolved materials, thereby reducing the amount of suspended substances in laundry waste, supports this. In both treatments, aeration was introduced to expedite the removal of turbidity. This is consistent with the view (Safrizal, 2016) that the decrease in turbidity is the result of aeration, which results in a continuous supply of air from the aerator. In order to aid plants in the degradation of organic matter in laundry waste.

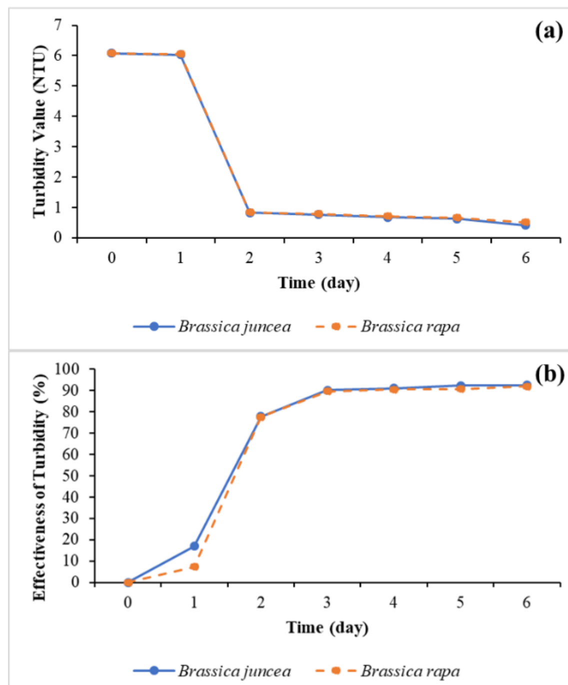

Figure 11. Graph of turbidity reduction (NTU) against time (days) in phytoremediation treatment using B. *juncea* and B. *rapa* plants.

The initial condition of the laundry waste was brownish blue; on day 1, the color changed to yellowish, and the water became clearer until day 6 of the treatment. Figure 10 depicts the variation in color of the laundry effluent for the two plant treatments. This may be affected by the hydroponic circuit system, as water continues to circulate and flow, and plant roots can filter out detritus when waste water flows. This is consistent with the assertion (Darma, 2020) that plant roots are capable of filtering suspended sediment from flowing effluent. The best color change occurred in the B. juncea treatment, where the color of the laundry wastewater became more transparent than in the B. rapa treatment.

Conclusions

The effectiveness of laundry wastewater treatment using B. juncea plants with the DFT hydroponic system in reducing COD was 94.1%, TSS was 84.8%, phosphate was 95.0%, TDS was 69.4%, turbidity was 92.5% , EC is 0.42 mS/cm. This system also increases the DO value in the range of 6.2 – 7.8 mg/L, and the pH is in the range of 7.1-8.

While the treatment of laundry wastewater using B. rapa plants with the DFT hydroponic system in reducing COD values was 88.2%, TSS was 80.3%, phosphate was 88.9%, TDS was 65.3%, turbidity was 91.9 %, EC is 0.52 mS/cm. The B. rapa treatment also increased DO values in the range of 6.0 – 7.6 mg/L, and the pH was in the range of 8.2 – 7.2. Based on the content of TSS and phosphate in the results of processing with B. rapa treatment, the value of TSS and phosphate has not reached the regulated quality standard.

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