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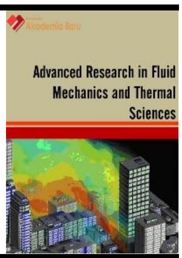

The Effect of Leachate Concentration on Typha Latifolia Plants

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ABSTRACT

Research on the ability of plants to reduce and transport pollutants, especially heavy metals, remain advancing to date in line with current technological developments. The purpose of this study was to investigate the effect of leachate concentration on the number of tillers of *Typha latifolia* plants. It also investigated the leaf length and number of leaf petals of these plants. The materials used in this study included liquid/leachate media sourced from a landfill in Banda Aceh, the aquatic plants of *Typha latifolia* (torch), and heavy metals such as chromium (Cr), mercury (Hg), and lead (Pb). The results showed that the increase in *Typha latifolia* plant roots occurred at leachate concentration of 20%, 40%, and 60% for sources of 4 cm, 2 cm, and 1 cm. Meanwhile, the leaf length was observed in the leachate concentrations of 20%, 40%, and 60%, resulting in enhancers of 6 cm, 1 cm and 1 cm. Besides, increments of leaf number occurred at leachate concentrations of 20% and 40%, yielding as much as 1 and one leaves on the 2nd and 4th week. The overall results of the study showed an increase in low concentrations.

Keywords:
Typha latifolia; wetlands; wetland wetting; heavy metals; wastewater

1. Introduction

Research on the ability of plants to reduce and transport pollutants, especially heavy metals, remain advancing to date in line with current technological developments. Hyper accumulator plant species are still very limited, rendering works that search for these types of plants as much-needed still. Previous researchers have highlighted that the phytoremediation technique offers high effectiveness [1]. Besides being readily available, such plant usage is inexpensive and environmentally friendly. Previous research on the ability of plants to absorb heavy metals have been

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carried out by [2], which used aquatic plants Lemna, tranHydrilla, kale and ginger to reduce ammonia, nitrate, nitrite, and phosphate in fish farming waste. Plants that are effective in reducing these chemicals are gender plants, which have values of 25.59%, 27.29%, and 26.73%, respectively, while Phosphate is a plant 24.39%. Furthermore, an investigation on the toxic effects of drugs at non-standard endpoints in the context of the two macrophyte species of *Lemna minor* and *Lemna gibba* has been done by [3–5]. The assessment has been performed acutely (96 hours) by using *L. minor* and *L. gibba* exposed to chlorpromazine (CPZ), paracetamol (APAP), and diclofenac (DCF) in the following concentration ranges: 0 to 20μg/L, 0 to 125μg/L, and 0 to 100μg/L, respectively. The study has highlighted that the higher concentrations of the drugs tested have caused significant effects on both Lemna species in terms of the different endpoints analysed.

Moreover, the use of water plants absorbing heavy metals has been evaluated by [6], which utilised *Eichhornia crassipes, Pistia stratiotes* and *Hydrilla verticillata*. Used to absorb Cr in the local *batik* industrial wastewater, the highest Cr-absorbing ability has been found in *E. crassipes* 49.56% and followed by *P. stratiotes* (33.61%), and *H. verticillata* (10.84%). More research on the application of phytoremediation in the removal of Cr metal ions using aquatic plants (e.g. *Typha latifolia*) has also been carried out by [7–10]. The Cr accumulation in the plants has yielded maximum amounts in their roots at the concentrations of 35, 43, and 65 mg-Cr/L to remove 0.3080, 1.0097, and 0.0690 mg-Cr/kg, respectively. Meanwhile, the ability to reduce Hg (%) in artificial wetland reactors has been evaluated over three days using various plants, yielding impressive percentages. The *Typha* sp plant has resulted in 84.18%, followed by *Eichhornia crassipes* (81.19%), *Nelumbium nelumbo* (80.78%), *Ipomea aquatic* (83.84%), and *Hydrilla verticillate* (83.96%). The results have indicated that *Typha* sp, Ipomea aquatic, and *Hydrilla verticillata* plants have a higher ability to reduce Hg compared to *Nelumbium nelumbo* and *Eichhornia crassipes* plants [11]. Furthermore, an evaluation of the changes in nutrient elements (i.e. S, Cl, K, Ca, Mn, Fe, Zn) in the roots, stems, and leaves over time has been examined when the Eichhornia crawled under Cr (VI) [12,13]. Plant cultivation has been conducted according to five Cr (VI) concentrations at 0, 10, 25, 50 and 100mg/L, showing that the increase in Cr enrichment correlates with a gradually decreased content of S, Cl, K, Ca, Fe and Zn. In contrast, the content of S, K, Ca Mn and Zn has shown a significant increase in the stems and leaves.

An investigation regarding the effect of various N sources in the surface water for the production of *Typha latifolia* biomass, typical paludiculture plants, and CH_4 and N_2O emissions has been carried out by [14–16]. It has been subsequently reported that N stimulates the production of aboveground and belowground biomass and the absorption of nutrients by T. Similarly, an analysis of the concentration of Al, As, Cd, Cr, Cu, Hg, Mn, Ni, Pb and Zn in three cattail species that grew spontaneously in natural wetlands has been previously undertaken [15]. It has corroborated the three *Typha* species that grow in metal-contaminated environments with attributes of high tolerance to toxic conditions, mass elemental concentrations in roots, and limited element translocation from roots to leaves. The results have further shown that all *Typha* species have the same concentrations of elements in their roots, rhizomes and leaves, while the mobility of similar elements flows from the sediments to roots and roots to leaves. Yet another study on *Typha latifolia* plants in wetlands has also been performed by [17], which discussed fly ash mixed with soil in four different proportions of 0% (FA0), 25% (FA25), 50% (FA50), and 75% (FA75). Meanwhile, an investigation on the pyrolysis of *Typha latifolia* has been investigated in [18], which utilised various mixtures of *T. latifolia, T. Angustifolia,* and *T. glauca.* These species have transacted across 1700 km from Michigan of the United States of America (USA) to Nova Scotia, Canada and investigated concerning the residential patterns with an average depth of trench at 3.4 cm [19]. The results have shown that the water depth cannot automatically explain the cattail occupancy pattern, rendering niche partitions by water depth to be incapable of promoting the isolation of mating in *Typha latifolia*. The research has used the FWO and CASH methods (134-204 kJ mol^{-1}). Additionally, research on tofu industrial wastewater treatment using *Typha latifolia* and water hyacinth plants by using the phytoremediation method has been carried out by [14,20,21]. The processing has been done by combining 1 gr/cm^2 *Typha latifolia* plant with 1.5 kg plant weight of water hyacinth at HLR 500 l/m^2 day. The highly efficient removal of pollutant parameters obtained in the study has proven that the phytoremediation method using *Typha latifolia* and water hyacinth is feasible as an alternative in the tofu industry wastewater treatment.

Furthermore, investigations regarding the effects of the physicochemical properties of ethane and homologous chlorinated ethanol on the competitive adsorption of trichloroethylene (TCE) into the roots of *Typha latifolia* have been performed [16,17]. The results show that chlorinated ethane provides a significantly stronger competition for TCE absorption compared to chlorinated ethane. Liquid products are changed from *Typha latifolia* stems using organic solvents (i.e. methanol, ethanol, acetone and 2-butanol) and catalysts (i.e. 10% NaOH or Na_2CO_3), and without catalysts in autoclaves at the temperatures of 518, 538 and 558 K [22]. The conversion results of methanol, ethanol, 2-butanol, and supercritical acetone yield 55.0, 58.5, 62.7 and 70.5, respectively at 538 K. The research had aimed to obtain alternative fuels from chemical or petroleum raw materials. Similarly, investigations regarding the potential of bioturbation as a tool for integrated bioremediation of metal-contaminated deposits in the aquatic ecosystems can be considered in the future [21,23]. This is the result of the aforementioned research that have underlined transport to change the distribution of cadmium across the sediment column and increase metal pumping. Such an increase has been observed from the surface of *Typha latifolia* to the anoxic sediment layer, thereby increasing the bioaccumulation of cadmium in the root system. Different studies have sought to investigate metal absorption and distribution in *Phragmites australis* and *Typha latifolia* plants on the brownfield site [24–26]. The main objective of such research is to understand the concentration of metals (i.e. Fe, Mn, Cu, Pb and Zn) and their spatial distribution in the root system of *P. Australis and T. latifolia*. The results have reported that the expression of transport and accumulation of metals in the root system may be element-specific.

In addition to the above plants, ornamental plants can also be used as phytoremediators. The use of ornamental tongue-in-law (*Sansiviera tripasciata*) and croton leaves (*Codiaeum variegatum*) has been implemented by [27,28]. The results have shown that leaf croton plants are more effective in absorbing Pb in ambient air. The problems that generally occur due to excessive anxiousness regarding the presence of heavy metals in the environment and poisoning are highly observed in all aspects of living things. Even under such conditions, the effects of heavy metal ions can directly impact due to their accumulation in the food chain. Some types of metal that may be involved in the bioaccumulation process include As, Cd, Cr, Cu, Pb, Hg, and Zn [29]. Poor waste management around landfills can result in contaminated air, soil and water (i.e. groundwater and surface water) as a result of the leachate [30]. Pollution of water sources by rubbish generally occurs when the waste is disposed of by open dumping and buried in the landfill decomposes; together with rainwater, they produce gases and leachate [31]. If left untreated, leachate generated from landfill sites will pollute rivers, the sea, and groundwater. The content of leachate produced from landfills includes hazardous materials, such as heavy metals, inorganic components, BTEX components (i.e. benzene, toluene, ethylbenzene, and xylene), and halogenated hydrocarbon components [30].

An alternative to processing water contaminated with heavy metals, especially for reducing heavy metal content in heavy metal-contaminated water is phytoremediation using aquatic plants. Water plants such as torch plants, water hyacinth, and *kiambang* are plants that may potentially become heavy metal phytoremediators in the processing of waste and wastewater, which can be used to absorb heavy metals. The selection of aquatic plants as phytoremediator plants in the current study was based on the consideration that such plants can grow in the water having low nutrient levels. Furthermore, this particular type of aquatic plants was selected due to their capacity to live in wetlands and polluted areas (i.e. capable of absorbing heavy metals and nutrients), are readily available, can be easily bred, and is economical. The purpose of this study is to investigate the effect of leachate concentration on the number of tillers of the *Typha latifolia* plants. It will also investigate the leaf length and number of leaf petals of the plants.

2. Material and Methodology

2.1 Material

This research was conducted at the final landfill in Banda Aceh as the study site is shown in Figure 1. The materials used in this study are such as 100 ml bottles and 50 ml plastic samples, 2 L volume measuring cups, plastic tank (barrels) volume of 150 L, buckets and paper labels. Map of sampling locations in this study as shown in Figure 2. Observations made in this study for 4 (four) weeks. Each observation is carried out every week, starting from the first week to the fourth week.

Fig. 1. Map of the location of Banda Aceh City

Fig. 2. Containers of the Typha latifolia plant during treatment

2.2 Methodology

This study used a Randomised Block Design (RBD) followed by further testing using the Duncan Multiple Range (DMRT) Test. For a confidence level of 95% and three factors examined, the aquatic plants of *Typha latifolia* plants were subjected to three treatment levels. Meanwhile, the heavy metals subjected to three levels, and leachate waste subjected to two levels and three replications. The type of plant used in this study was a torch (*Typha latifolia*), which was inserted into a prepared container (see Figure 2). The second treatment in this study consisted of the levels of heavy metals, which consisted of three treatment levels, namely: Cr (B1), Hg (B2), and Pb (B3). For each repetition, the treatment was assessed thrice, requiring experimental containers as many as 27 containers. They were placed randomly in all observation containers. Meanwhile, the independent variables in the study consisted of plant species and metal concentration (i.e. 20%, 40%, 60%, 80% and 100%).

The testing procedure performed in this study contained 3 (three) repetitions. Typha latifolia plants are the first factor. As for the second factor, heavy metals of the type are represented as Cr (B1), Hg (B2) and Pb (B3), metal concentrations such as 100, 200, 300, 400, and 500 ppm. All treatments were arranged in a factorial randomized block design with three replications.

3. Results and Discussion

3.1 Effect of Leachate on Plant Tests

The concentration of leachate was very influential towards the growth of the tested plants. The initial stage of this research consisted of growing the test plants as a result of their culture into a reactor containing leachate sourced from the final disposal site in Banda Aceh, without any dilution. The results showed that all of the test plants died in the first week. The death of the test plants was thought to be due to the high levels of Biological Oxygen Demand (BOD), Chemical Oxygen Demand (COD), pH and Total Suspended Solid (TSS) found in leachate. Therefore, in this study, the dilution of leachate was carried out to reduce the levels of BOD, COD, pH, and TSS in leachate and ensure that the test plants could grow. Furthermore, these results were also used to see the optimum leachate concentration for the growth of test plants, whereby the observations were carried out for four weeks. The effect of leachate concentration on the test plants can be seen in Table 1.

The results showed that a reduction in leachate concentration affected the growth of the test plants. The optimum growth occurred at a concentration of 50% leachate; at this particular concentration, the plants were still alive and better compared to those evaluated using other concentrations up to Week 4. This is thought to reduce the value of BOD, COD, pH and TSS in leachate, as shown in Table 1.

Table 1
Effect of BOD, COD, pH and TSS growth on test plants at maximum leachate concentration

Test parameters	Threshold	Unit	Test results
Color	-	-	-
Temperature	38*	^{0}C	27.9
pH	6-9*	-	7.92
BOD-5	150*	mg/L	2.683,31
COD	300*	mg/L	5.548,96
TSS	200**	mg/L	108,33

Source: Barista and Laboratory Banda Aceh
Not.*: Threshold LH P.59/2016 leachate water
**: Threshold LH No.5/2015 Unspecified waste quality standards

Therefore, this study incorporated leachate dilution of the leachate was carried out, this was intended to reduce the levels of BOD, COD, pH and TSS in leachate so that the test plants could grow. Furthermore, these results can be used to see the optimum leachate concentration for the growth of test plants; observations carried out for four weeks. Observations were made for tillers, root length, leaf length, and leaf petals of varying values. A representation of the test plants was measured weekly using a cm scale.

3.2 Typha Latifolia Plant

The effect of leachate concentration on *Typha* plants was observed for four weeks at the different leachate concentrations of 20%, 40%, 60%, 80% and 100%. The results were observed for tillers, root length, leaf length, and leaf petals of varying values (all measured in c).

3.2.1 Effect of leachate concentration on the root length of Typha latifolia plants

The impact of leachate concentration on the length of *Typha latifolia* plant roots was observed for four weeks and shown in Figure 3. This observation was undertaken using different concentrations of 20%, 40%, 60%, 80% and 100%, whereby increased growth of leachate concentration occurred at 20%, 40% and 60%. In contrast, the concentrations of 100% and 80% did not increase compared to the concentrations of 60%, 40% and 20%, which indicated the addition of root length in the plants. Root length at a concentration of 20% showed an increase of 4 cm in the fourth week compared to the first week from 30 cm to 34 cm. While at the concentration of 40% the root length increased by 2 cm during the fourth week. However, with increasing concentration given the root length decreases as shown in Figure 3. Where at a concentration of 20% the root length reaches 34 cm, but when the concentration reaches 100% the resulting root length remains 5 cm. So that higher concentrations can significantly reduce plant roots. The observations made during the treatment time (4 weeks) can be seen in Table 2. Similar research has also been conducted by [13,33]. In such studies, the concentrations of As, Cd, Cr, Cu, Fe, Mn, Ni and Zn were estimated differently and the displacement efficiency was assessed. It reached more than 90% for Fe, Mn and Ni in spring and autumn in the water compartment, while cattail biomass above and below ground varied significantly from 0.21 to 0.85 and 0.34 to 1.24 kg dry weight/m^2, respectively. The highest metal concentration was observed at the root of cattail, which grew on the first flow of the system pool. Meanwhile, the research conducted by [24] assessing the metal concentrations (i.e. Fe, Mn, Cu, Pb and Zn) and spatial distribution in the root system of *P. Australis* and *T. latifolia* showed a specific transport and accumulation of metals in the root system.

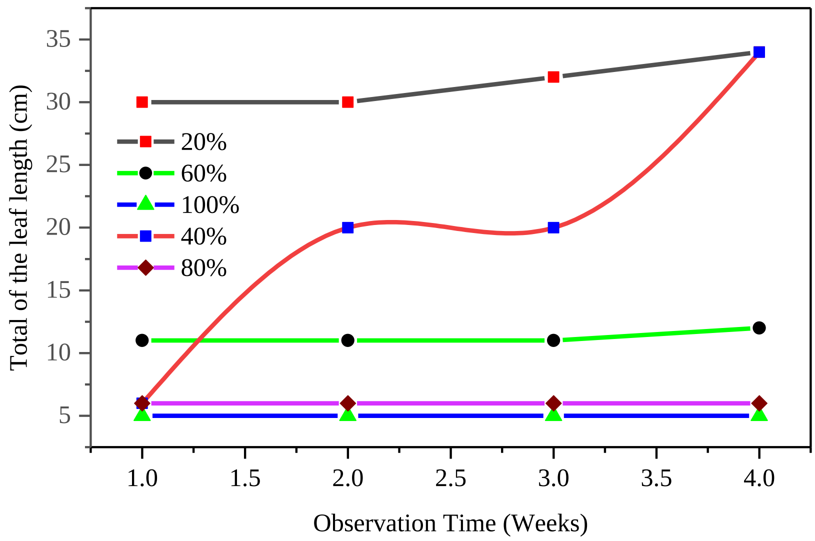

Fig. 3. Effect of leachate concentration on the length of Typha latifolia plant roots for four weeks at different concentrations

To prove this relationship, a variance analysis test was conducted on the relationship between leachate concentration and the length of *Typha latifolia* plant roots as shown in Table 3. The results of the analysis of variance shown in Table 3 showed the regression coefficient, R of 0.945 with a negative relationship. This indicated that the higher the concentration of leachate, the lower the growth of root length in *Typha latifolia* plants. Significant test based on t-test obtained a p-value of 0.015; this was less than 0.05 and indicated that it did not produce a relationship that was significant at that level of error. However, the magnitude of the R coefficient obtained has illustrated the important effect of leachate concentration on the length of *Typha latifolia* roots.

3.2.2 Effect of leachate concentration on Typha latifolia plant leaves

The effect of leachate concentration on increasing the leaf length of *Typha latifolia* plants was seen to be constant at the high concentrations of 60% and 80%, suggesting the lack of leaf extension. At a concentration of 20%, the length of Typha latifolia leaves increased by 6 cm from 60 cm in the first week increased to 66 cm in the fourth week. While the 40% concentration only increased by 1 cm from the first week to the fourth week. However, 100% concentration did not show improvement. A detailed effect of leachate concentration on the length of *Typha latifolia* plant leaves is shown in Table 2 and observed across four weeks (see Figure 4). The research obtained almost similar outcomes as those of [12,26]. The detected concentration of Cd was found in plant organs and showed the following distribution pattern: root> rhizome> stem. As *T. latifolia* has the highest proportion of all metals studied, this study proceeded to distinguish the three groups of metals, each with a different accumulation pattern in the plant.

The best increase in leaf length of *Typha latifolia* plants occurred at a concentration of 20%, which was observed during treatment from Week 2 to Week 4. At the concentrations of 40% and 60%, the increase in leaf length only occurred in Week 3, while concentrations of 80% and 100% did not show any increase in leaf length during the entire observation period. For more clarity of the effect of leachate concentration on the length of *Typha latifolia* plant leaves, variance analysis was carried out. The results are shown in Table 3.

The regression results from the analysis of variance obtained by the coefficient R was 0.819 in the direction of the negative relationship. This indicates that the higher the concentration of leachate, the smaller the plant's ability to increase the length of the leaves. Significant test based on t-test obtained a p-value of 0.090, which was above 0.05 and indicative of the lack of a relationship that was significant at the level of error. However, the magnitude of the R coefficient obtained has illustrated the magnitude of the effect of leachate concentration on the leaf length of *Typha latifolia* plants.

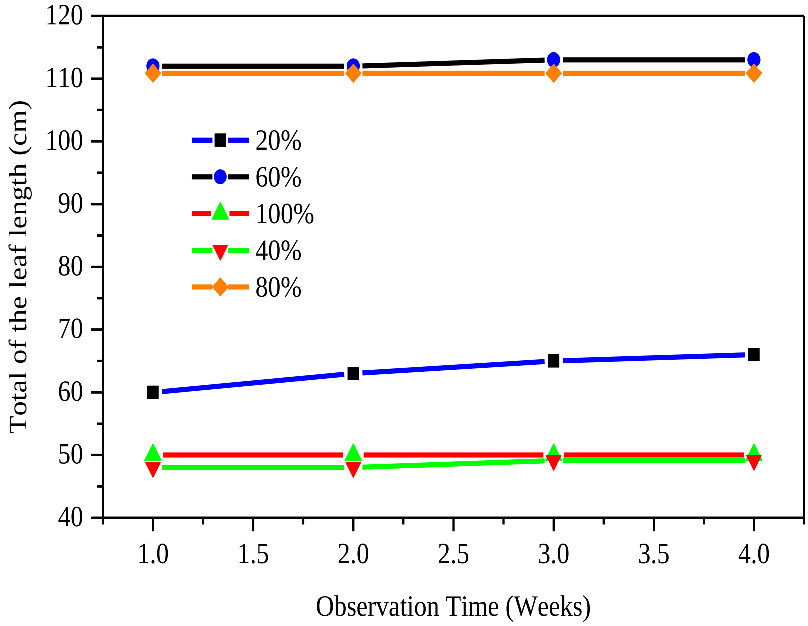

Fig. 4. Effect of leachate concentration on the leaf length of Typha latifolia plants for four weeks at different leachate concentrations

3.2.3 The Effect of leachate concentration on the number of Typha latifolia petals

The effect of leachate concentration on the number of *Typha latifolia* leaf petals across four weeks of observation is shown in Figure 5. The results obtained over three weeks showed that the concentration of lace at 20% and 40% revealed an increase in the number of leaves of the *Typha latifolia* plants. In contrast, the leachate concentrations of 60%, 80% and 100% did not yield any changing amount of *Typha latifolia* leaf petals. Table 2 shows the results of the observations made during the treatment. The research conducted by [33] showed the results in case of both parent species being protogynous, whereby *T. Angustifolia* flowered earlier than *Typha latifolia*. However, experimental studies have demonstrated that hybridization involving female *T. Angustifolia* and *T. latifolia* pollen flowers is very asymmetrical, resulting in minimal overlap when they are produced.

The increasing number of *Typha latifolia* leaf petals during the treatment was not significant. However, any increase occurred at the low leachate concentrations of 20% and 40%; each concentration showed an increase of one leaf petal only in Week 4. At high leachate concentration (i.e. 60%, 80% and 100%), there was no increase in leaf petal amount from the beginning until the end of the treatment. To ascertain the relationship between leachate concentration and the number of leaf petals, a statistical analysis of variance was carried out. The results of the statistical tests carried out are shown in Table 3.

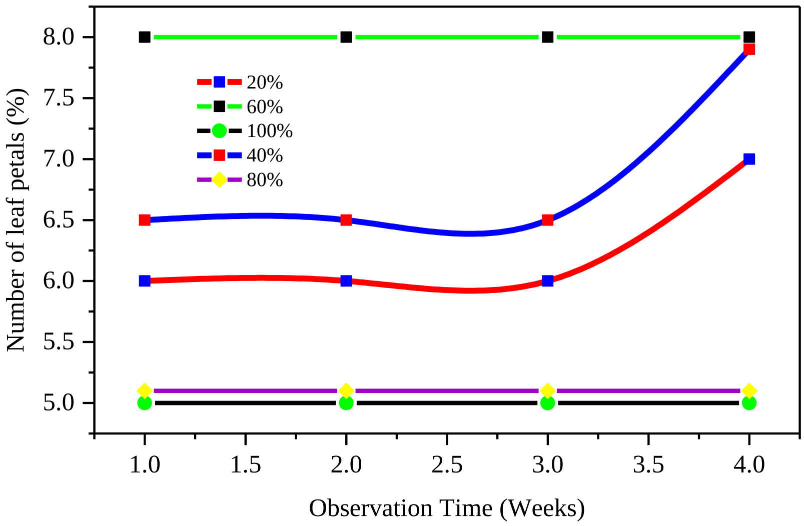

Fig. 5. Effect of leachate concentration on the number of leaf petals of *Typha latifolia* plants for four weeks at different concentrations

Table 2
Effect of leachate concentration on the number of leaf petals, number of tillers and leaves of *Typha latifolia* plants

Leachate Concentration (%)	Observation Time (Weeks) Number of root length of *Typha latifolia* plants			
	1	2	3	4
20	30	30	32	34
40	13	14	14	15
60	11	11	11	12
80	13	13	13	13
100	5	5	5	5
Leachate Concentration (%)	Observation Time (week) Number of leaves of *Typha latifolia* plants			
	1	2	3	4
20	60	63	65	66
40	67	67	68	68
60	112	112	113	113
80	122	122	122	122
100	50	50	50	50
Leachate Concentration (%)	Observation Time (week) Number of *Typha latifolia* Petals			
	1	2	3	4
20	6	6	6	7
40	7	7	7	8
60	8	8	8	8
80	6	6	6	6
100	5	5	5	5

Based on the results of the linear regression between the effects of leachate concentration on the number of *Typha Latifolia* leaf petals, the R-value of 0.866 was obtained in the direction of the negative relationship. This indicates that the higher the leachate content, the lower the number of leaf petals of the plant. However, a significant test based on the t-test obtained a p-value of 0.058, which exceeded 0.05 and indicated the lack of a relationship that was significant at that level of error. Nevertheless, the magnitude of the R coefficient obtained has illustrated the magnitude of the effect of leachate levels towards growth in the context of the number of petals.

Table 3
Variant analysis results of the effect of leachate concentration on the root length, leaves and number of leaf petals of *Typha latifolia* plants

Model	Unstandardized Coefficients		Standardised Coefficients	t	Sig.
	B	Std. Error	Beta		
Constant Leachate	4.400	663	-945	6.633	007
Levels	-.050	010		-5.000	015
Second test					
Model	Unstandardized Coefficients		Standardised Coefficients	t	Sig.
	B	Std. Error	Beta		
Constant Leachate	1.300	332	-866	3.920	030
Levels	-.015	005		-3.000	058
Third test					
Model	Unstandardized Coefficients		Standardised Coefficients	t	Sig.
	B	Std. Error	Beta		
Constant Leachate	5.500	1.745	-819	3.153	051
Levels	-.065	026		-2.472	090

4. Conclusions

The results of the analysis carried out in this study clearly show that the concentration of leachate is very influential for the roots, leaves and petals of *Typha Latifolia* plants. Such findings were observed at leachate concentrations of 20%, 40% and 60%, which yielded an increment of 1.5cm, 1.80cm and 2cm for roots, and 2.5cm, 2.90cm and 3.20cm for leaf lengths, respectively. Furthermore, the leachate concentrations of 20% and 40% was found to increase the number of *Typha Latifolia* petals, whereby each concentration resulted in two and four leaves at the second and fourth week, respectively. Besides, positive and significant correlations were found between 20%, 40% and 60% of total leachate concentrations during the observation period. Therefore, *Typha latifolia* plants can be used as an alternative to phytoremediation of plants.

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