Proceeding SYMBION
(Symposium on Biology Education)
http://seminar.uad.ac.id/index.php/symbion
2540-752X (print) | 2528-5726 (online)

The ability and potential of *Echinodorus palaefolius*, *Pontederia lanceolata*, and *Zantedeschia aethiopica* as a phosphate and nitrogen phytoremediator

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ARTICLE INFO

Article history
Submission Dec 11th, 2022
Revision May 11th, 2023
Accepted May 17th, 2023
Keyword
Phytoremediation
Phosphate
Nitrogen
Domestic Liquid Waste

ABSTRACT

The purpose of the study was to identify the potential and effectiveness of Zantedeschia aethiopica, Pontederia lanceolata, and Echinodorus palaefolius plants as nitrogen and phosphate phytoremediators in domestic wastewater. The study was conducted using a randomized complete design with 3 treatments and 9 repetitions. Plants are planted using wetland construction. The parameters measured were total nitrogen content, total phosphate content, pH, biomass, tolerance index, bioconcentration factors and phytoremediation effectiveness. Measurement of total nitrogen and total phosphate using analytical methods using a 10S uv-vis genesis spectrophotometer. The results showed that the three plants have the potential as a phytoremediator of nitrogen and phosphate in domestic wastewater and can increase pH and reduce E. coli populations.

Introduction

Water is a very essential resource for life. The last few decades have seen a tremendous increase in water demand due to rapid population growth and the accelerating pace of industrialization [1]. Anthropogenic activities related to urbanization, agriculture, industrialization, and population expansion have led to a decline in water quality in many parts of the world [2,3]. In addition, diminishing water resources make it more difficult to control water pollution and improve water quality [4].

Sources of anthropogenic pollution, especially from agricultural and domestic activities, can contribute to the flow of nutrient concentrations in the form of nitrogen and phosphorus in water bodies. Activities in the agricultural sector that are a source of nitrogen and phosphate pollution include excessive use of fertilizers, while domestic activities are sources of pollution from daily activities such as the use of soap, detergents and disposal of organic waste containing protein. Strokal explained that nitrogen and phosphate enrichment had a significant relationship with the use of agricultural land and in urban areas [5]. Nitrogen flow and total nitrate concentrations in rivers are correlated with human population density.

Nitrogen and phosphate are macronutrients needed by plants and algae in order to provide food and habitat for other living things in aquatic ecosystems, but if they are excessive they will cause rapid algae growth which can have a negative impact on the environment and humans. Rapid algae growth results in a decrease in oxygen levels in the waters and has an impact on fish mortality and rapid siltation [6]. Algae during their growth can produce toxins and if the water is used as a source of drinking water it can cause stomach aches, rashes and more serious problems for humans [7].

Phytoremediation is a strategy that can be used to reduce nitrogen and phosphate concentrations in waters because it has several advantages. Kinidi and Salleh reported that phytoremediation is an environmentally friendly, economical and sustainable technique that can be used to reduce nitrogen content in sewage treatment systems [8]. Several phytoremediation studies have shown that nitrogen and phosphate concentrations in waters can be reduced. Ojoawo recommends nitrogen and phosphate remediation in domestic waste using the phytoremediation method [9].

Many plants that can be used as nitrogen and phosphate phytoremediator agents have been identified, including Ojoawo reported that Canna x generalis can effectively reduce nitrogen and phosphorus pollution by up to 51.2% [9]. Seo used Populus euramericana and Salix alba as phytoremediator agents and demonstrated effective performance in reducing nitrogen and phosphate pollution [10] and Malik used 3 plants namely *Zantedeschia aethiopica*, *Pontederia lanceolata*, *Echinodorus palaefolius* for heavy metal remediation in the textile industry wastewater [11].

Zantedeschia aethiopica, Pontederia lanceolata, and Echinodorus palaefolius are ornamental plants and have potential as remediators for metals and organic waste in textile industry wastewater [11]. Based on this study, this research will be carried out to identify the potential and effectiveness of the three plants for remediation of nitrogen and phosphate in domestic waste.

Method

The study was conducted using an experimental method with a completely randomized design consisting of control or no plants and 3 treatments using 3 different types of plants. The sample consisted of 27 pieces with 9 repetitions each. The domestic liquid waste used is liquid waste from the Bojong Soang PDAM Wastewater Treatment Plant, Bandung City. The planting medium used consists of gravel and sand which are stored in a planting tank with a Wetland Construction system. The research parameters measured were total nitrogen content, total phosphate content, pH, biomass, tolerance index, bioconcentration factors and phytoremediation effectiveness. Measurement of total nitrogen and total phosphate using the analytical method using a 10S uv-vis genesis spectophotometer.

Results and Discussion

Phytoremediation is a method for the process of restoring environmental quality due to pollution by utilizing plants to degrade, transform, inactivate or immobilize pollutants into harmless forms [12]. Plants that can be agents for phytoremediation must have certain criteria, including being able to grow in polluted media and being able to degrade, transform, inactivate or immobilize pollutants [13]. The ability to grow on polluted media can be identified based on the presence of plant growth, namely by the indicator of an increase in biomass and having a tolerance index of more than 1. Table 1 shows the increase in plant biomass for 28 days and its tolerance index.

Table 1. Plant Biomass and Tolerance Index (IT).

Plant	Biomass Gain (%)	IT
Echinodorus palaefolis	73.06	1.71
Potenderia lanceolata	22.92	1.23
Zantedeschia aethiopica	39.45	1.39

[a] sample of a tale footnote

Table 1 shows that the three plants are able to grow on the media. This indicates that the three plants can adapt to growing media that experience nitrogen and phosphate pollution. Growth ability Echinodorus palaefolius has better adaptability and growth in polluted media than Pontederia lanceolata and Zantedeschia aethiopica which is characterized by an increase in biomass of 73.06%. Another indicator of the adaptability of plants to nitrogen and phosphate stress in the media can be indicated by the tolerance index. The tolerance index is a value to show the growth comparison in the treatment and control media. if the tolerance index value is equal to or greater than 1 indicates no stress, whereas if the tolerance index value is less than 1 it indicates that the plant is experiencing stress due to stress [14]. Table 1 shows that the value of the tolerance index for the 3 plants is more than 1, this indicates that the plant is not experiencing stress due to stress from nitrogen and phosphate pollution.

The second criterion for identifying the potential of plants to act as phytoremediator agents is the ability of these plants to eliminate pollutants in the environment. Table 2 shows the ability of Zantedeschia aethiopica, Pontederia lanceolata, and Echinodorus palaefolius to elementify nitrogen and phosphate in domestic wastewater.

Table 2. Bioconcentration Factor Values

Plant	Bioconcentration Factor	
	Nitrogen	Phosphate
Control	0.20	0.39
Echinodorus palaefolis	0.43	27.5
Potenderia lanceolata	1.91	32
Zantedeschia aethiopica	0.21	30

The bioconcentration factor is the value of the ratio of the total concentration of the pollutant absorbed to the concentration of the pollutant in the ambient media [15]. Bioconcentration factor values of more than one indicate the concentration of pollutant absorbed is higher than its concentration in the media after the phytoremediation process. Table 2 shows that the value of the bioconcentration factor in the control or without plants was the lowest compared to the treatment with the addition of plants. This shows that the presence of plants causes an increase in the uptake of nitrogen and phosphate, the higher the value of the bioconcentration factor, the greater the amount of pollutant absorbed by the plant.

Bioconcentration is different from the effectiveness of phytoremediation. The effectiveness of phytoremediation is the comparison between the concentrations of the eliminated pollutants and the pollutant concentrations prior to the remediation process. Table 3 shows the phytoremediation effectiveness of the three plants.

Table 3. Effectiveness of phytoremediation

Plant	Effectiveness of phytoremediation (%)	
	Nitrogen	Phosphate
Control	16.7^{c}	27.7^{b}
Echinodorus palaefolis	31.5^{b}	96.5^{a}
Potenderia lanceolata	65.6^{a}	94.1^{a}
Zantedeschia aethiopica	17.5^{c}	96.8^{a}

Table 3 shows that plants can enhance the pollutant uptake process. Nitrogen in domestic wastewater decreased from 16.7% to 65.6% for 28 days. The reduction in nitrogen concentration in the control wastewater and the treatment using the Zantedeschia aethiopica plant was not significantly different. This indicated that Zantedeschia aethiopica had no effect on increasing nitrogen elimination in domestic wastewater, while for Echinodorus palaefolius and Pontederia lanceolata the effectiveness was significantly different from the control and identified that the two plants have the potential as phytoremediators of nitrogen pollutants in domestic wastewater. Pontederia lanceolata can eliminate nitrogen in domestic wastewater by 65.6% and Echinodorus palaefolius can reduce nitrogen concentration by 31.5%.

Factors affecting nitrogen assimilation by plants are influenced by several factors including age, plant genetic characteristics, and growing medium conditions [17]. The optimum concentration of nitrogen in the medium for plants is a factor that influences photosynthesis and nitrogen absorption [16] and affects the increase in plant biomass [11]. The process of nitrogen assimilation in domestic wastewater will affect other water quality indicators including pH. Figure 1 shows the change in pH of the liquid waste during treatment. Figure 1 shows that during the nitrogen uptake process in domestic wastewater the pH which is initially acidic increases tends to become neutral.

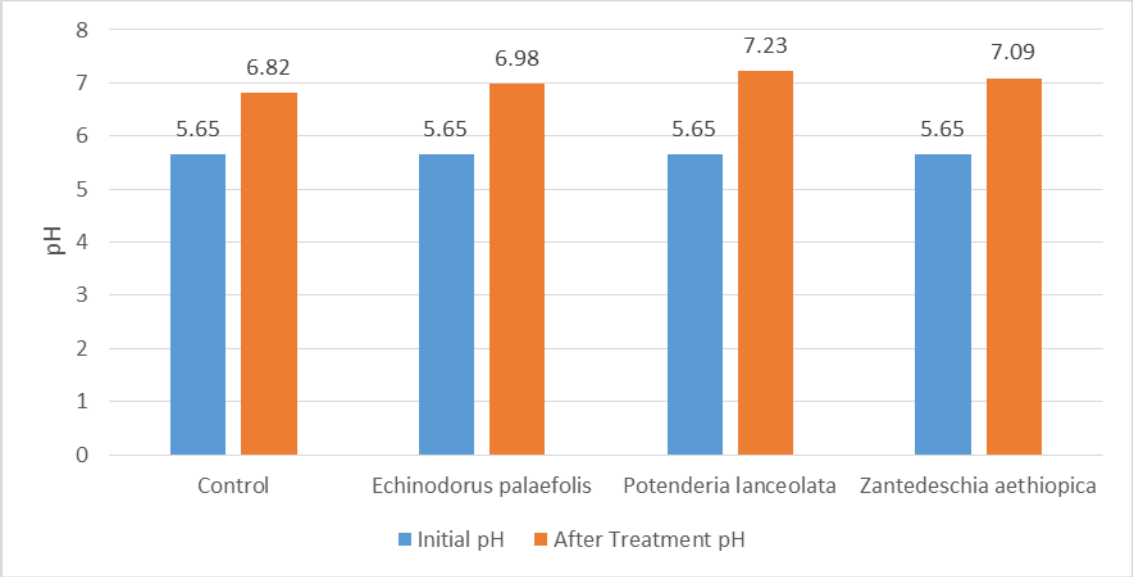

Figure 1. The pH of Domestic Liquid Waste

The increase in effluent pH occurs because plants have the ability to induce pH changes in the rhizosphere either by releasing protons (H^+) or hydroxyl ions (OH^-) to maintain ionic balance, depending on the nutritional status of the plants, therefore, the rhizosphere pH can increase or decrease depending on process and the type of ion in effect released. In the process of changing nitrogen compounds from nitrate to ammonium, H+ binding occurs so that it can increase the pH [18].

Plants Utilize nitrogen mainly in the form of NH4 and NO_3, molecular nitrogen (N_2) and amino acids. The uptake of each of the four forms of nitrogen accompanies the release of the appropriate ion to maintain electroneutrality in the rhizosphere. When nitrates predominate in the soil or when their uptake dominates, plants must release bicarbonate (HCO_3^-) or hydroxyl ions (OH^-) to maintain electrical neutrality across the soil-root interface and can result in an increase in rhizosphere pH [18].

Changes in pH in the rhizosphere are not only influenced by the process of changing nitrogen compounds and plant nitrogen uptake, but also by the process of uptake of phosphate compounds. Table 3 shows that phosphate in domestic wastewater has decreased in

concentration after the phytoremediation process from 27.7% to 96.8%. Statistical test results showed that there was a significant difference in the ability to eliminate phosphate in domestic wastewater between the control and the treatment. This shows that the three plants can act as phosphate phytoremediators and the ability of the three plants is not significantly different. Phosphate can be reduced in concentration between 94.1% to 96.8% within a period of 28 days. The decrease in the concentration of phosphate indicates a process of absorption of phosphate by plants.

The process of absorption of phosphate by plants occurs due to depolarization between the cytoplasm and the cell membrane so that a neutralization process occurs in the cytoplasm by absorbing phosphate in the form of H_2PO_4 or 2 HPO_4 molecules and H^+ ion exchange occurs. Research conducted by Brad showed the same phenomenon that there was an increase in pH around Rhizopere during the process of uptake of phosphate by wheat plants [19].

Phosphate and nitrogen are nutrients whose presence in the media is needed by plants, algae and bacteria [6]. Phytoremediation causes the availability of phosphate and nitrogen in the media to decrease so that it can also reduce the source of nutrients for bacteria. E coli is a bacterium that can be found in water contaminated with domestic waste and is used as an indicator of water pollution. Decreasing the concentration of nitrogen and phosphorus in the medium can reduce the source of nutrients and affect the E.coli population. Table 4 shows changes in the E.coli population during phytoremediation.

Table 4. Population of E. coli

Plant	E.Coli Population	
	T_0	T_{28}
Control	$1.46 X10^6$	$1 X10^4$
Echinodorus palaefolis	$6.24X10^5$	$5.2X10^4$
Potenderia lanceolata	$1.12X10^6$	$9.9X10^4$
Zantedeschia aethiopica	$1.46 X10^6$	$1 X10^4$

The decrease in nitrogen and phosphate concentrations caused a decrease in the E.coli population as shown in Table 4. The decrease in the E coli population occurred because E.coli could not compete with the plants Echinodorus palaefolius and Pontederia lanceolata and Zantedeschia aethiopica utilizing nitrogen and phosphate in the media so that the fulfillment of the nutrients it needed was disrupted and cause a decrease in the population of E.coli. Taabodi's research shows the same phenomenon, the growth of E.coli is affected by the concentration of nitrogen in the media, the decrease in the concentration of ammonium chloride affects the decrease in the population of E.coli [20].

Conclusion

Echinodorus palaefolius and *Pontederia lanceolata* and *Zantedeschia aethiopica* plants have potential as nitrogen and phosphate phytoremediator plants and can improve water quality by increasing pH towards neutral pH and decreasing E.coli populations.

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