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Phytoremediation of Domestic Wastewater and Leachate Using Free Floating Aquatic Plants: Comparative Study

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Abstract

Phytoremediation is a form of environmental remediation that uses plants to remove, degrade, or immobilize pollutants and contaminants from soil, water, and air. In this current study the potential of Eichhornia crassipes (water hyacinth) and Lemna minor (duckweed) to remove pollutants (TSS, TDS, BOD, COD) from wastewater and leachate was investigated over a period of 30 days. The efficiency of both plants in removing contaminants were calculated and compared. The experiment was conducted on raw domestic wastewater, raw leachate, and diluted leachate (75, 30, and 15%). TSS, TDS, BOD, and COD were reduced in wastewater by Lemna minor (66, 78, 78, 76%) and Eichhornia crassipes (71, 90, 85, 78%), respectively. Better removal efficiency in leachate was recorded at 75% concentrated leachate after 1 day by 25% BOD and 39% COD reduces with duckweed and 31% and 52% with water hyacinth. 30% concentrated leachate was attained a significant amount of removal efficiency after 30 days by 49% BOD and 53% COD with duckweed and 51%, 57% with water hyacinth. According to the findings of this investigation, Lemna minor and Eichhornia crassipes both considerably reduced pollutants in wastewater by more than 71% and normal clearance from leachate by more than 30%. This study's findings demonstrate the potential of Eichhornia crassipes(water hyacinth) over lemna minor (duckweed), both plants can be used for the phytoremediation of domestic wastewater and by using enhanced methods and plants in leachate. This phytoremediation technique can be used as a pretreatment method.

Keywords: Eichhornia crassipes; Duckweed; Pollutants; Domestic Wastewater; Leachate.

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Introduction

Water is the most important component of all life. It is an easy solvent, thus most toxins may be dissolved effortlessly in it and polluting it. Due to increased population, advancement, and industrialization, water quality has decreased. Water pollution quickly harms aquatic life, including amphibians, and also land and water vegetation. Household and commercial waste is the main cause of water pollution.[1] High levels of organic, suspended particles, oil, and fats found in untreated wastewater are hazardous to the natural world and people's health. Groundwater can be impacted by pollutants as well. Since organic matter offers nutrients to caterpillars and mosquitoes improvement, when water is polluted with decaying matter, larval mosquitoes will be created and may multiply. Drinking freshwater contamination can result in major health issues including cholera, diarrheal infections, along with other ailments such digestive disorders, Typhoid fever and intestinal worm infection. Due to its colourlessness as well as flavourlessness, high nitrogen-containing water is hard to distinguish. Although this kind of water could not have immediate negative consequences, it gradually interacts with haemoglobin and lowers the body's oxygen content. Numerous investigations have identified a number of significant illnesses brought on by nitrate, including persistent inflammatory disease, blue-baby disease, cancerous growths, difficulty breathing and brain congestion, pharyngitis, and muscular, digestive system, neurological, reproductive, as well as abnormalities in genes. Controlling waste water is crucial for the welfare of the community and the generations to come. Three different processes, including chemical, physical, and biological ones that change and consume organic materials, are utilized to treat wastewater.[2]

Urban solid waste undergoes a mix of biological, physical, and chemical alterations which has extreme

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strength and harmful effects, arises in garbage dumps, composting amenities, incinerators, and transfer terminals. Leachate removal continues to be a significant obstacle to the global reduction and eradication of pollution sources. Comprehensive leachate purification methods should be used to adequately treat leachate beforehand it is released into reservoirs or recycled.[3]

The quantity of leachate produced differs with the quantity of rainfall and rainwater input. The primary source of leachate arises from the excessive moisture materials of some eliminated garbage. Another source of leachate appears from the percolation of rain water within a solidwaste collection place, gathering pollutants and discharging into underground regions.[4]

Phytoremediation is a plant-based technologies and microbiological techniques to remove pollutants from the natural environment. It represents one of the biologically sound sewage treatment approaches. This approach refers to the use of green plants (such as grasses, marine microorganisms, trees, shrubs, and phorbs) to remove or neutralize environmental toxins such as metallic minor components, organic matter, and radioactive maters in soil or water. An inexpensive, simple tech option for cleaning up polluted underground water, soils, and effluent is phytoremediation. The specialized floating-plant, replanting combinations, built wetlands (Construction Wetland) mechanisms, and other restoration procedures, numerous different patterns are applied.[5]

Free Floating Aquatic Plants are the types of plants that are commonly found in bodies of water. Such as ponds, lakes, and rivers, where their roots are buried and their shoots float above the top of the water. Free-floating aquatic species like Eichhornia crassipes (water hyacinth), Pistia stratiotes L (water lettuce) and L minor (duckweed) etc., are particularly efficient and cost-effective to utilize in the phytoremediation method of sewage treatment. These plants rise quickly and are widely available. These plants absorb any dangerous metals and toxins from polluted water through their roots, which subsequently transport them via roots to the plant's foliage, stems, and other network system. Among a variety of aquatic plant species, Eichhornia crassipes (water hyacinth) and L. minor (duckweed) have been selected for this study because they possess exceptional absorption capabilities.[6]

Materials and Methodology

Domestic Wastewater Sample Collection

Under normal weather circumstances, raw samples of domestic wastewater were collected from Sewage drainage at B Kalapanahalli near the sewage treatment plant site (14°29′46.0″N 75°55′19.2″E) Davangere. Samples were collected in 20 Litres polypropylene cans and wastewater samples were then directly transported to the lab. Standard methods were used to examine physiochemical parameters.

Leachate Collection

Under normal weather circumstances, raw samples of leachate were collected at Avaragolla solid waste disposal site (14°30′41.4″N 75°52′39.1″E) which is 15 km away from Davanagere city. Polypropylene cans were used to collect and leachate samples were then directly transported to the lab. Standard methods were used to examine physiochemical parameters.

Plant Sample Collection

Specimens of plants Lemna minor (duckweed) and Eichhornia crassipes (water hyacinth) were collected from a freshwater lake at the Bathi, Davanagere (14°28′27.4″N 75°52′12.5″E). To eliminate larval insects and epiphytes, plants were thoroughly cleansed with water. For a few days, plant specimens were put in a plastic jar with water to acclimatize to their new environment. Following that, plants of similar size were harvested and grown.

Experimental Set up

The experiments were carried out in six jars. This is done to determine how effective the plants are in reducing pollutants from wastewater and leachate (Figure 1). The raw samples of leachate are diluted with water. Experiment was conducted for raw leachate and diluted leachate (30% leachate with 70% water and 75% leachate with 25% water). For the first two sets of experiments, the physiochemical parameters were examined for every three days (3rd day and 6th day), after that the analyses were carried out for every five days for the remaining trials (10, 15, 20, 25, and 30 days).The dilutions are as follows:

- 100% Raw leachate
- 75% (22.5 L leachate with 7.5L Water)
- 30%(9L leachate with 21L water)

Results and Discussions

Phytoremediation is a promising and eco-friendly approach for wastewater treatment and Leachate, and it seems that the established procedures followed during the experiment were successful in achieving the desired outcomes. By utilizing plants natural ability to absorb and break down pollutants, phytoremediation offers a sustainable solution for treating wastewater and making it safe for release into the environment without causing harm to ecosystems or public health. Diffrent factor influence the quality of domestic

Figure 1: Experimental Setup

wastewater and leachate such as pH, temperature, organic matters, composition of municipal solid waste, available oxygen and moisture content, and quality of leachate might different from a similar type of waste in landfills located at different diverse climatic regions.[7]

Domestic Wastewater

The physicochemical parameter were analysed before and after phytoremediation, initial characteristics were analysed before starting of the experiment. The Table 1 shows the results after 30 days of phytoremediation. This successful treatment implies that the phytoremediation process effectively removed or reduced the pollutants that are present in domestic wastewater.

The pH of the wastewater remained relatively stable throughout the phytoremediation process, typically ranging between 7 and 8. Furthermore, the pH levels in the duckweed samples were found to be higher in comparison to those observed in the water hyacinth samples. Both water hyacinth and duckweed demonstrated their effectiveness in

Table 1: Domestic wastewater parameters before phytoremediation and after phytoremediation

Parameters	*Days*	*Duckweed*			*Water hyacinth*		
		Initial	*Final*	*Removal efficiency*	*Initial*	*Final*	*Removal efficiency*
TSS mg/l	0	452.00	452.00	0	452.00	452.00	0
	3		227.45	49.68		199.51	55.86
	6		214.56	52.53		187.90	58.43
	10		201.68	55.38		176.28	61.00
	15		188.80	58.23		164.66	63.57
	20		175.92	61.08		153.05	66.14
	25		163.04	63.93		141.43	68.71
	30		150.15	66.78		129.81	71.28
TDS mg/l	0	380.00	380.00	0	380.00	380.00	0
	3		153.98	59.48		110.05	71.04
	6		142.04	62.62		97.70	74.29
	10		130.11	65.76		85.35	77.54
	15		118.18	68.90		73.00	80.79
	20		106.25	72.04		60.65	84.04
	25		94.32	75.18		48.30	87.29
	30		82.38	78.32		35.95	90.54
BOD mg/l	0	750.00	750.00	0	750.00	750.00	0
	3		387.30	48.36		366.30	51.16
	6		334.88	55.35		320.55	57.26
	10		296.63	60.45		272.70	63.64
	15		250.80	66.56		235.50	68.60
	20		291.90	70.68		174.68	76.71
	25		182.03	75.73		138.00	81.60
	30		160.05	78.66		112.05	85.06
COD mg/l	0	1530.00	1530.0	0	1530.00	1530.00	0
	3		837.22	45.28		806.92	47.26
	6		757.96	50.46		727.67	52.44
	10		67.75	56.16		640.46	58.14
	15		569.16	62.80		538.87	64.78
	20		500.77	67.27		470.48	69.25
	25		423.20	72.34		392.90	74.32
	30		362.30	76.32		325.13	78.75

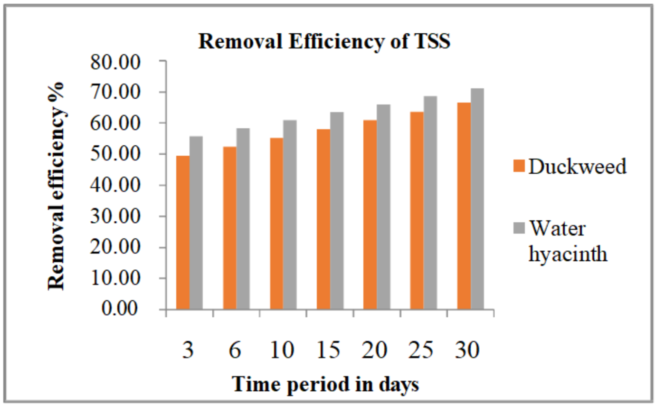

Figure 2: Removal efficiency of TSS

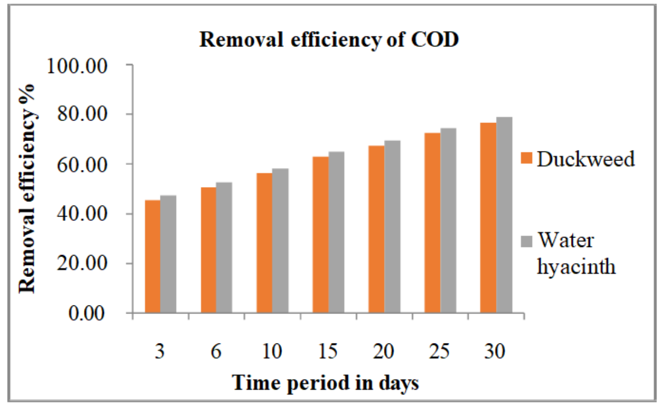

Figure 4: Removal efficiency of COD

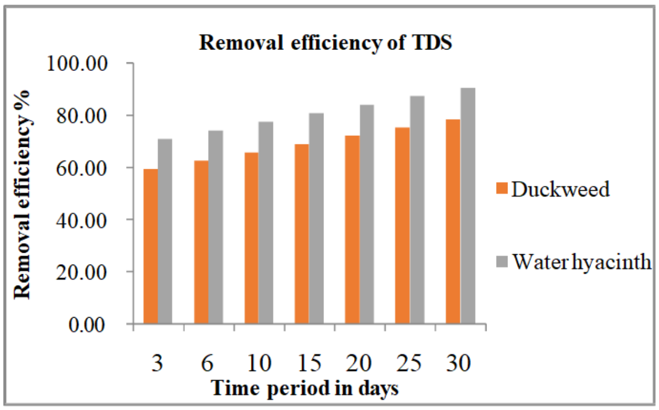

Figure 3: Removal efficiency of TDS

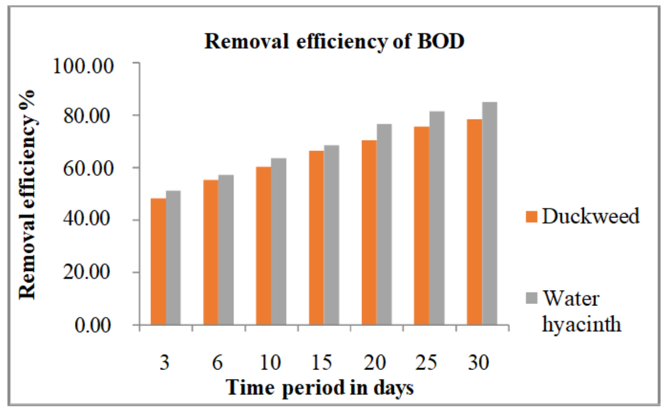

Figure 5: Removal efficiency of BOD

significantly lowering the TSS concentration in wastewater is an important measure for water quality. By reducing the suspended solids, these plants contributed to the purification of the wastewater and improved its overall clarity.

The TSS and TDS levels showed a progressive decrease from starting point to the ending of the trial, suggesting that the phytoremediation process was actively removing suspended particles and dissolved solids from the wastewater (Figures 1 and 2). The percentage reductions achieved by each plant species are as follows:

- Duckweed: 68% reduction in Total Suspended Solids (TSS) and Water Hyacinth: 71% reduction in Total Suspended Solids (TSS).
- Duckweed: 78% reduction in Total Dissolved Solids (TDS) and Water Hyacinth: 90% reduction in Total Dissolved Solids (TDS).
- Duckweed: 78% reduction in Biochemical Oxygen Demand (BOD) and Water Hyacinth: 85% reduction in Biochemical Oxygen Demand (BOD) and Duckweed: 76% reduction in Chemical Oxygen Demand (COD) and Water Hyacinth: 78% reduction in Chemical Oxygen Demand (COD).

During the phytoremediation procedure, both duckweed and water hyacinth were very effective in lowering the concentration of biochemical oxygen demand (BOD) in effluent. BOD is an important metric for calculating the amount of dissolved oxygen absorbed by microbes while breaking down organic materials in water (Figure 3). These findings reveal that water hyacinth and duckweed are both capable of greatly lowering the organic content and, hence, the dissolved oxygen of wastewater improved by efficiently removing organic pollutants, these plants play a crucial role in improving water quality and preventing oxygen depletion in aquatic environments. BOD and COD represent the amount of oxygen required for the biological and chemical decomposition of either organic or inorganic matter respectively under aerobic condition at a standardized temperature in surface water (e.g. lakes and rivers) or leachate.[8] The substantial reduction in BOD levels indicates that the phytoremediation process successfully enhanced the wastewater's biodegradability. Water hyacinth with its longer roots and larger biomass, demonstrated a higher efficiency in eliminating BOD compare to duckweed.

These results highlight the efficiency of both duckweed and water hyacinth in removing organic pollutants from the wastewater, thereby lowering the chemical oxygen demand. By effectively reducing COD, these plants contribute to the purification of the wastewater. The successful decrease in

Table 2: Results of leachate before phytoremediation and after phytoremediation (after 30 hrs of sowing)

Dilution	*Parameters (mg/l)*	*Initial Value (mg/l)*	*Duckweed*		*Water Hyacinth*	
			Final mg/l	*Removal Efficiency %*	*Final mg/l*	*Removal Efficiency%*
Raw Leachate	TSS	1212	950	21.62	920	24.09
	TDS	1050	870	17.14	850	19.05
	BOD	4150	3650	12.05	3200	22.89
	COD	13800	9200	33.33	8600	37.68
	EC(ms/cm)	7.63	5.95	22.02	5.75	24.64
75%	TSS	910	684	24.84	671	26.26
	TDS	830	665	19.88	650	21.69
	BOD	3100	2324	25.03	2115	31.77
	COD	11400	6850	39.91	5400	52.63
	EC(ms/cm)	1.31	0.96	26.72	0.928	29.16

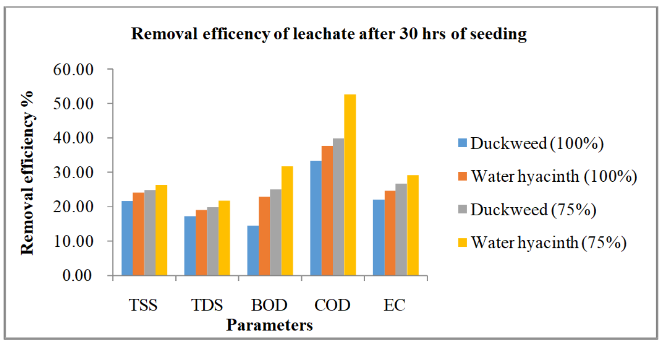

Figure 6: Removal efficiency of Raw leachate and 75% Concentrated leachate

COD content indicates that the phytoremediation process was successful in removing a significant portion of the organic pollutants present in the wastewater, enhancing its overall quality and lowering the environmental contamination risk related to high COD levels (Figure 4).

Leachate

The experiment was conducted for raw leachate and diluted leachate over a course of 30 days. The dilutions are as follows:

- 100% Raw leachate
- 75% (22.5 L leachate with 7.5L Water)
- 30%(9L leachate with 21L water)

Table 2 demonstrates leachate results before phytoremediation and after phytoremediation. Both duckweed and water hyacinth effectively reduce all major parameters in the leachate during the 30-day experiment. The pH of the leachate remains within the acceptable range of 7 to 8.5 throughout the study. However, when cultivated in 100% and 75% diluted concentrated leachate, both plants perish after 30 hours of seeding. Further investigation is required to understand the factors leading to plant mortality in diluted leachate, although the overall phytoremediation process successfully improves the leachate's quality and reduces its major pollutants. Compared to raw leachate, 75% diluted leachate showed more decrease in organic content in the form of biochemical oxygen demand (BOD) (Figure 5) and chemical oxygen demand (COD). Since raw leachate is more harmful than diluted leachate and both plants die within 30 hours after sowing when cultured in these concentrations of leachate, practically all the contaminants were lowered at a diluted leachate of 75% concentrated leachate compared to raw leachate within 30 hours (Figure 6).

30% Concentrated Leachate (30% leachate 70% water)

Table 3 display the outcomes of diluted (30 %) leacahet before phytoremediation and after phytoremediation. The accumulation capacity was more than absorption of raw leachate and 75% leachate may be due to high toxicity that may affect to plant growth. However the plants absorption capacity to leachate pollutants is lesser than wastewater pollutants.

The plants' ability to absorb pollutants in 30% concentrated leachate was only slightly greater than that of 75% concentration leachate, however the study found that pollutants reduced gradually in 30% concentrated leachate after 30 days. During the 30-day phytoremediation processes, water hyacinth and duckweed were around 30 to 50% effective in eliminating Total Suspended Solids (TSS), Total Dissolved Solids (TDS), and Bio chemical oxygen demand (BOD) and Chemical oxygen demand (COD).

Water hyacinth and duckweed contribute to the removal of solids from the wastewater, but water hyacinth exhibits slightly higher efficiency in reducing TSS and TDS levels. Their comparable absorption capacities (Figures 7 and 8) and the observed reductions in both pollutants signify the effectiveness of phytoremediation in enhancing the leachate quality by removing suspended and dissolved solids.

The percentage reductions achieved by each plant species are as follows:

Table 3: Leachate remediation before Phytoremediation and after Phytoremediation (30% leachate 70% water)

Parameters	*Days*	*Duckweed*			*Water hyacinth*		
		Initial mg/l	*Final mg/l*	*Removal efficiency %*	*Initial mg/l*	*Final mg/l*	*Removal efficiency %*
TSS mg/l	0	273	273.00	0.00	273	273.00	0.00
	3		258.09	5.46		256.63	6.00
	6		248.90	8.83		244.97	10.27
	10		237.71	12.93		234.05	14.27
	15		227.19	16.78		224.13	17.90
	20		215.50	21.06		212.67	22.10
	25		199.92	26.77		195.29	28.47
	30		188.78	30.85		184.64	32.37
TDS mg/l	0	540	540	0.00	540	540	0.00
	3		496.69	8.02		491.81	8.92
	6		483.08	10.54		474.49	12.13
	10		462.80	14.30		447.64	17.10
	15		439.78	18.56		425.89	21.13
	20		416.42	22.88		398.34	26.23
	25		384.42	28.81		372.68	30.99
	30		364.61	32.48		351.43	34.92
BOD mg/l	0	920	920	0.00	920	920	0.00
	3		845.62	8.08		819.48	10.93
	6		809.65	11.99		777.77	15.46
	10		736.13	19.99		695.98	24.35
	15		654.40	28.87		621.59	32.44
	20		606.80	34.04		586.05	36.30
	25		533.63	42.00		516.40	43.87
	30		466.90	49.25		441.95	51.96
COD mg/l	0	2800	2800	0.00	2800	2800	0.00
	3		2554.72	8.76		2548.23	8.99
	6		2338.28	16.49		2324.45	16.98
	10		2184.89	21.97		2135.28	23.74
	15		2016.31	27.99		1919.68	31.44
	20		1764.12	37.00		1691.76	39.58
	25		1540.87	44.97		1498.84	46.47
	30		1304.00	53.43		1196.65	57.26

For TSS (Total Suspended Solids):

- Duckweed: 30% reduction and Water Hyacinth: 32% reduction. For TDS (Total Dissolved Solids):
- Duckweed: 32% reduction and Water Hyacinth: 34% reduction.

The results demonstrate the potential of both plants in treating leachate and improving its environmental impact. It is significant to remember that in this particular study, regarding lowering of TSS and TDS, water hyacinth proved to have an advantage over duckweed.

For determining the effluent's organic strength, BOD and COD are commonly used. BOD and COD concentrations were reduced to 45 to 50% after phytoremediation Figures 9 and 10. Both plants exhibit higher accretion of organic material and overall reductions are as follows:

- BOD: 49% and 51% by duckweed and water hyacinth respectively.
- COD: 53% and 57% by duckweed and water hyacinth respectively.

In terms of BOD and COD, both plants exhibited superior

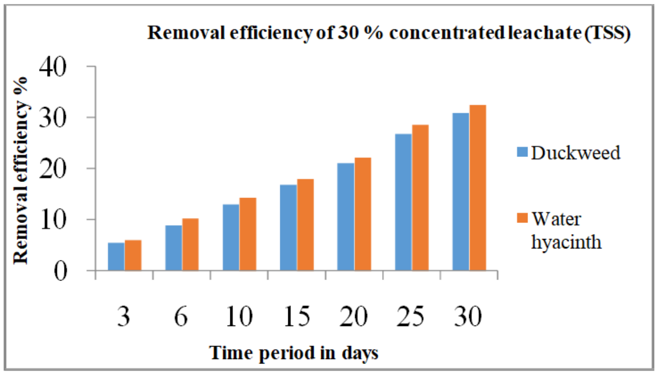

Figure 7: Comparison of Removal efficiency of TSS

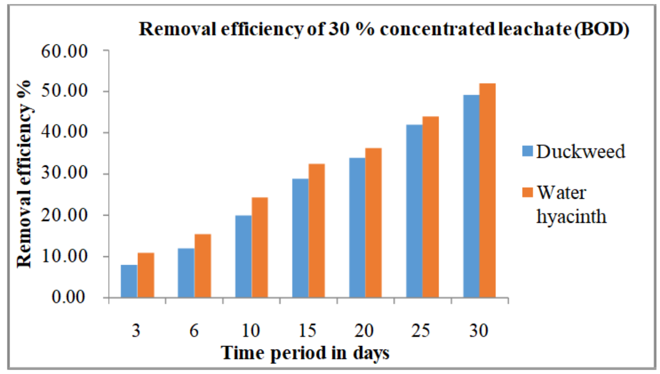

Figure 9: Comparison of Removal efficiency of BOD

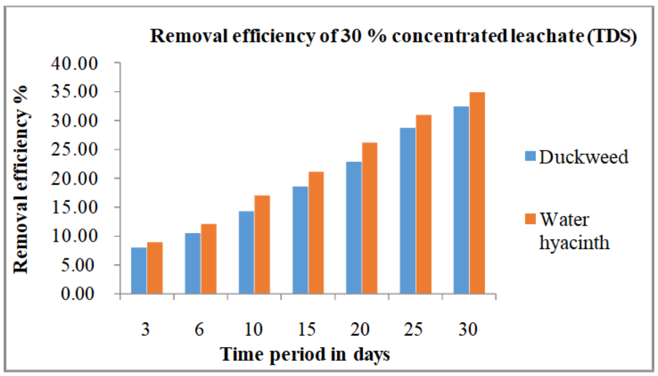

Figure 8: Comparison of Removal efficiency of TDS

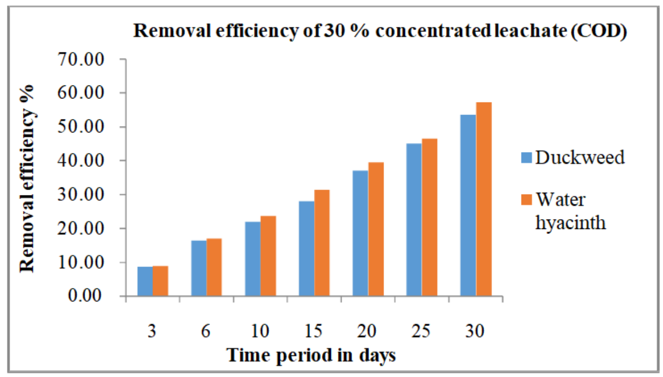

Figure 10: Comparison of Removal efficiency of COD

removal efficiencies for organic content. With more biomass and a longer root system than duckweed, water hyacinth exhibits better BOD and COD accumulation. Both duckweed and water hyacinth can be utilized as pre treatment methods to minimize organic load since they eliminate organic load more effectively than other pollutants.

Discussion

Domestic wastewater and leachate containing contaminants like heavy metals, TDS, BOD and COD are a matter of severe concern world.[7] Overall, the findings highlight the efficacy of both duckweed and water hyacinth in phytoremediation, especially in reducing organic contaminants like BOD and COD. High BOD and COD value as recorded in untreated leachate is an indication of high level of pollution which could result in high biodegradation activity by microbes.[8] According to Ibezute high biological and chemical oxygen demand in the leachate was reduced by 69.05% and 68.81 respectively after treatment.[8] The presence of plants in wastewater depletes dissolved CO_2 during the period of photosynthetic activity and an increase in DO of water, thus creates aerobic conditions in wastewater which favors the aerobic bacterial activity to reduce the BOD and COD.[9] According to abbas.z,[7] maximum reduction was oobtained at 50% and 75% when compared to this study maximum reduction was obtained at 30% and 75 % it may depend on the pollutants concentration. Because of the effective reduction of pollutants in 30% diluted leachate, these facilities are attractive options for leachate and other wastewater treatment to enhance water quality and protecting the environment. According to Justin L.d, all of the investigated wastewater parameters were reduced by 75 to 90% in 31 days, with 79% BOD, COD, and 91% TDS removed, which was consistent with my findings of 85% BOD, 75% COD, and 90% TDS.

According to Figure 11, which compares the results of wastewater and leachate produced by the two plants, water

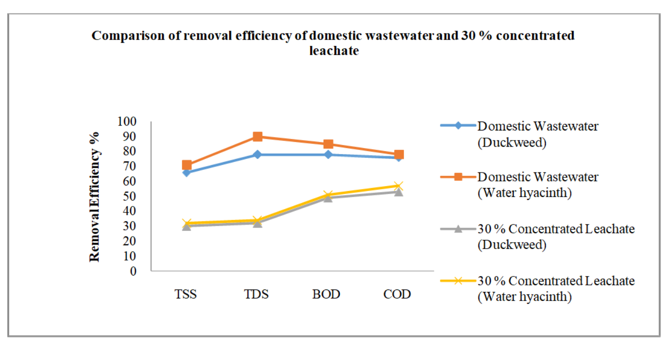

Figure 11: Comparison of removal efficiency of domestic wastewater and 30 % concentrated leachate

hyacinth and duckweed effectively eliminated the specified parameters from the wastewater compared to the leachate during a 30-day period. According to this present study, water hyacinth and duckweed were used in the phytoremediation process, which turned out to be a successful pretreatment method for domestic wastewater. Leachate cleanup with the application of improved methods and plant kinds may be possible.[10-15]

Conclusion

The Eichhornia crassipes (water hyacinth) and Lemna minor (Duckweed) plants reduce the parameters in domestic wastewater and leachate such as TSS, TDS, BOD and COD.

The experiment was conducted on raw domestic wastewater, raw leachate, and diluted leachate (75, 30, and 15%). TSS, TDS, BOD, and COD were reduced in wastewater by L.minor (66, 78, 78, 76%) and water hyacinth (71, 90, 85, 78%), respectively. Better removal efficiency in leachate was recorded at 75% concentrated leachate after 1 day by 25% BOD and 39% COD removal with duckweed and 31% and 52% with water hyacinth. Overall good removal efficiency was achived by 30% concentrated leachate after 30 days by 49% BOD and 53% COD with duckweed and 51%, 57% with water hyacinth.

Comparison of percentage of removal efficiency of domestic wastewater and leachate by Eichhornia crassipes (water hyacinth) and Lemna minor (Duckweed), both exhibits good removal of pollutants in wastewater and leachate. The overall reduction of contaminants in wastewater was over 70% and 30 % in leachate.

For domestic wastewater experimentation (1 to 30 days) it was observed that in the first 6 days of the trial show a rapid absorption of pollutants, which were then gradually reduced until day 30. For leachate pollutant reductions were found to be slower and more gradual from day 1 to day 30; there be no indication of a sudden increase during this time period. In view of this, it may be said that the contaminants in wastewater effectively removes compared to leachate.

Both plants have higher removal rates, however the present study found that Eichhornia crassipes (water hyacinth) is more effective at removing contaminants than Lemna minor (Duckweed).

Due to the slower plant growth rate (may due to lack of nutrients) and decreased in water level, the experiment was ended on day 30.

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