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Comparative Assessment of the Phytodesalination rates of Duckweed and Water Hyacinth in Brackish Water

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ABSTRACT

Brackish surface water is a challenge for most estuarine communities to meet the water requirement for agricultural purposes. Desalination plants on the other hand, are costly and energy consuming method to run. This research compares the possible use of duckweed and water hyacinth for their Phytodesalination rates of brackish water. Three replicates containing about 100 g of each aquatic macrophytes in a trough with 10 litres of brackish water (salinity 7.69 ppt) were studied daily for 6 days. Electrical conductivity (EC), pH, total dissolved solids (TDS) and salinity were the measured water parameters thereafter, the treatment means were calculated. Results showed that maximum reductions of most of the water parameter were observed after 3 days of the research for both aquatic macrophytes. A reduction of EC by 16.4 %, TDS by 16.3 % and salinity by 20.7 % for duckweed while for water hyacinth, a reduction of EC by 20 %, TDS by 19 % and salinity by 29.1 % were observed. Thereafter, both aquatic macrophytes started showing signs of nutrient starvation and a reduced rate of desalination. This can be addressed by removing the spent and wilting aquatic plants and re-introducing fresh ones in 3 days intervals until desalination is achieved. Anova shows that there was significant difference between pre-and post-treatment values at 95 % confidence level in EC for both duckweed and water hyacinth treatment and also in TDS and salinity for water hyacinth treatment. This suggests potency of water hyacinth in the desalination of brackish water for crop irrigation and other agricultural purposes.

Keywords: Brackish water, Duckweed, Phytodesalination, Salinity, Water hyacinth.

1.0 INTRODUCTION

Accessing freshwater in most estuarine communities like in the Niger Delta region of Nigeria, is challenging as both surface and groundwater around have higher salinity than acceptable standards, therefore the need to desalinate brackish water so it can be used for agricultural practices is of importance. Salinity is one of the most serious factors limiting the productivity of agricultural crops, with adverse effects on germination, plant vigour and crop yield [1]. Improper salinity control can result in soil sodicity, damaging soil structure. In particular, as they enter the cation exchange complex of clay particles, the action of Na+ ions cause soil aggregates to breakdown, increases bulk density, make the soil more compact and decreases overall porosity, hampering the aeration of soil. As a result, plants in saline soils are not only affected by high levels of Na^+ but also by some degree of hypoxia [2]. Calcium (Ca^{2+}), magnesium (Mg^{2+}) and sodium (Na^+) are found in irrigation water. Calcium and magnesium ions frequently precipitate into carbonates when water evaporates, leaving sodium (Na^+) ions dominant in the soil [3]. As a result, the Na^+ concentrations often surpass other macronutrient concentrations by one or two orders of magnitude, and even more in the case of micronutrients. High soil solution concentrations of Na^+ can depress nutrient ion activity and produce extreme Na^+/Ca^{2+} or Na^+/K^+ ratios [4]. Increases in cations and their salts, especially NaCl generate external osmotic potential in the soil, which can prevent or reduce the flow of water into the root. The resulting water shortage is close to drought and further exacerbated by the presence of sodium (Na^+) ions [5].

In some temperate regions, where chemicals are used on roads in the winter months, salinization is increasing [6]. NaCl is the primary defrosting agent used in the north-eastern United States and North America and half of the road salt applied is believed to enter surface waters at the site of application through roadside drainage network, while the other half is either removed during snow removal or enters the soil and groundwater [7]. Salinity would therefore be a major problem affecting agriculture in the nearest future if nothing is done to address this.

In coastal Bangladesh, [8] assessed the phytodesalination of salty soils utilizing certain hyperaccumulating halophytes. From 35 species cultivated in various saline regions of Bangladesh, the hyperaccumulating halophytes species Thankuni (Centella asiatica), Holud nakful (Eclipta alba), Helencha (Enhydra fluctuans) and Lona pata (Sesuvium edmonstonei) were selected. For four months, each of the four halophytes that were chosen was cultivated in saline soil with deciSiemens/meter (dS m−1) values of 4.36, 4.85, 5.77, and 6.57. All four halophytes were good Na+ accumulators, and translocation factor and bio-concentration factor values showed that sodium ions (Na+) were easily transferred from soil to root to shoot. Halophytes have been used to reduce salinity in saline soils [9],[10]

Several researchers have successfully used aquatic macrophytes for wastewater treatment and nutrients removal [11], [12], [13]. Water hyacinth is reported to be clogging up Lagos waterways. These waterways which open to the lagoon are brackish and this invasion by water hyacinth is causing navigational and fishing problems [14]. This suggests halophytic potentials of water hyacinth.

For agricultural operations, desalination of brackish water requires the removal of large quantities of sodium and chlorine. Effective Brackish water desalination is energy-consuming, expensive to install and operate using conventional methods. Therefore, certain non-conventional methods need to be explored that are not only economically viable and easy to operate, but also environmentally friendly. Salt water intrusion to groundwater and brackish surface water are challenges for most estuarine communities to meet the water need for crop irrigation and other agricultural purposes.

1.1 Research Objective

The objectives of this research were to measure both the salinity level of brackish water and compare it with the effects of duckweed and water hyacinth on the brackish water for 6 days for possible phytodesalination use.

2.0 MATERIALS AND METHODS

2.1 Experimental site

The experimental site was an open space in front of the laboratory of the Department of Agricultural and Environmental Engineering, Niger Delta University, Wilberforce Island, Bayelsa State, Nigeria. Located in the vegetative mangrove swamp area, the University has a tropical climate with two seasons: the wet season from March to October and the dry season from November to April.

2.2 Experimental apparatus and procedure

The experimental apparatus consists of a plastic water storage tank, a weighing scale, 1000 ml measuring cylinder, salt meter (KADY Salt meter MT-8071), electric conductivity meter/TDS meter/thermometer (LTLutron YK-22CT) and p.H meter (Testo 206-PH3). Brackish water on was obtained from Ozuboko River (4.7715913^0 N, 7.0427778^0 E) in Abuloma community in Rivers State, Nigeria and transported down to the experimental site. Some of the physico-chemical characteristics of the brackish are presented in Table 1

The experiment was conducted as described by [11]. Appropriate quantities of the selected aquatic macrophytes which were duckweed (*Lemna minor*) and water hyacinth (*Eichornia crassipes*) in their natural habitats were carefully harvested from within and around Amassoma in Southern Ijaw Local Government Area in Bayelsa State. Approximately 100 g of each aquatic macrophytes were then placed in three replicates of plastic trough containing 10 litres of brackish water and a control. Each trough was analysed on a 24 hrs interval for 6 days on the desalination abilities of the aquatic macrophytes on the selected water parameters which were salinity, electrical conductivity (EC), pH, total dissolved solids (TDS)

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Table 1. Some physico-chemical characteristics of the brackish water

Parameters	Value
pH	6.1
Conductivity (S/m)	13.19
Temperature (^{0}C)	27
T.D.S (ppt)	8801
Salinity (ppt)	7.690

3.0 RESULTS AND DISCUSSION

The macrophytes started showing signs of nutrients starvation after day 5 of the research. This is understandable since essential nutrients for plant survival in brackish water are limited but contain so much salts. Tables 2 and 3 show that both duckweed and water hyacinth were able to gradually reduce the concentrations of EC and TDS within the first three days of their introduction, thereafter, an increase in concentration levels were observed which suggests re-introduction of the EC and TDS. Also, there was a steady reduction of the concentration levels of salinity for both macrophytes. Figures 1 to 4 show the comparisons of the control and the effects the macrophytes with respect to the selected water parameters. The trend shows that with the exception of their effects on salinity, there was an increase in concentration levels after 3 days for pH, EC and TDS.

Results indicated that maximum reductions of most of the water parameter were observed after 3 days of the research for both aquatic macrophytes. Tables 4 and 5 show the physicochemical reduction by both aquatic macrophytes of the brackish water after 3 days of the research.

Table 2. Mean effects of the duckweed treatment on some physicochemical characteristics of the brackish water for the 6 days intervals

Brackish water parameters	Phytodesalination Period (Days)						
	0	1	2	3	4	5	6
pH	6.10	6.74	6.79	6.30	6.40	6.43	6.27
EC (S/m)	13.19	12.30	11.23	11.05	11.18	11.09	11.87
Temp (^{0} C)	27	29.2	30	26	27	31	30
TDS (ppt)	8801	8187	7480	7367	8653	8587	7907
Salinity (ppt)	7.69	7.2	6.31	6.10	5.35	5.24	5.34

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Table 3. Mean effects of the water hyacinth treatment on some physicochemical characteristics of the brackish water for the 6 days intervals

Brackish water parameters	Phytodesalination Period (Days)						
	0	1	2	3	4	5	6
pH	6.10	6.76	6.37	5.84	6.60	6.47	6.38
EC (S/m)	13.19	12.50	10.85	10.69	11.55	11.41	11.69
Temp (^{0} C)	27	29	30	26	27	31	30
TDS (ppt)	8801	8377	7200	7127	7700	7600	7800
Salinity (ppt)	7.69	7.2	6.34	5.45	5.08	4.94	4.60

There was a reduction of EC by 16.4 %, TDS by 16.3 % and salinity by 20.7 % for duckweed while for water hyacinth, a reduction of EC by 20 %, TDS by 19 % and salinity by 29.1 %.

Table 6 shows a summary of the analysis of variance (Anova) between the control and duckweed treatment on the brackish water. The result show F (cal) is less than F (crit) and the P value is > 0.05, therefore it can be concluded statistically that there was no significant difference between duckweed treatment and the control for pH, TDS and salinity. Electrical conductivity (EC) showed a significant difference between the duckweed and control. Anova between the control and water hyacinth treatment on the brackish water show that with the exception of pH, F (cal) is greater than F (crit) and the P value is < 0.05, therefore it can be concluded statistically that there was a significant difference between water hyacinth treatment and the control for EC, TDS and salinity (Table 7).

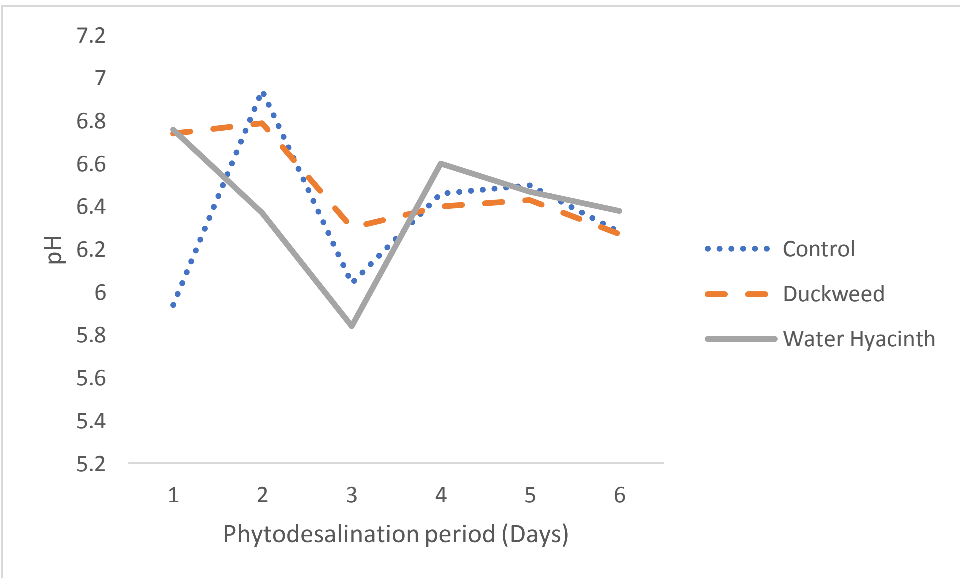

Figure 1. Comparison between control, duckweed and water hyacinth treatment means with respect to pH

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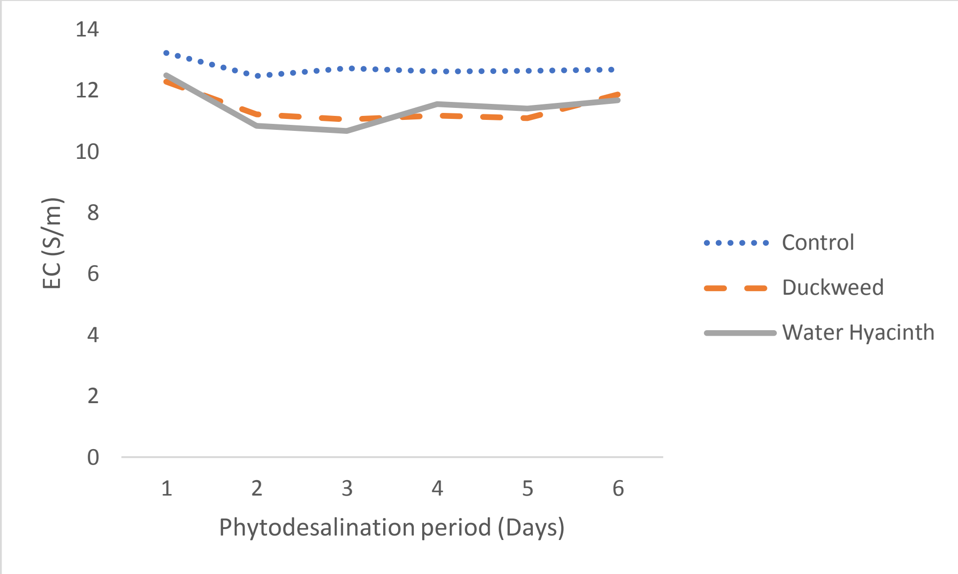

Figure 2. Comparison between control, duckweed and water hyacinth treatment means with respect to EC

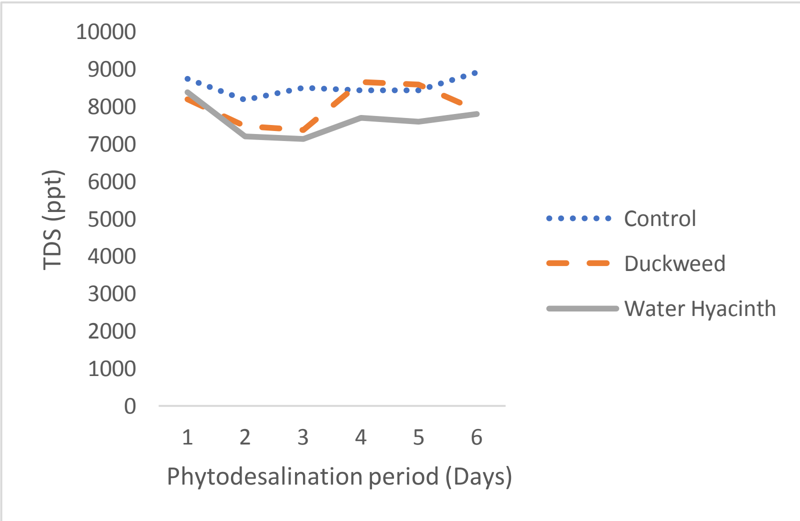

Figure 3. Comparison between control, duckweed and water hyacinth treatment means with respect to TDS

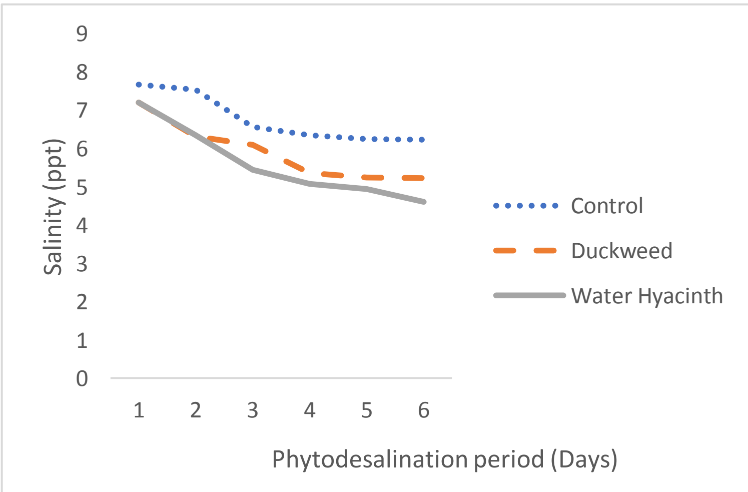

Figure 4. Comparison between control, duckweed and water hyacinth treatment means with respect to salinity

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Table 4 Physico-chemical reduction by duckweed treatment of the brackish water after 3 days

Parameter	Phytodesalination Intervals (days)	Treatment	Influent	Effluent	Reduction	
						(%)
pH	3	Duckweed	6.10	6.30	-0.2	-3.3
EC (S/m)	3	Duckweed	13.19	11.03	2.16	16.4
TDS (ppt)	3	Duckweed	8801	7367	1434	16.3
Salinity (ppt)	3	Duckweed	7.69	6.1	1.59	20.7

Table 5 Physico-chemical reduction by water hyacinth treatment of the brackish water after 3 days

Parameter	Phytodesalination Intervals (days)	Treatment	Influent	Effluent	Reduction	
						(%)
pH	3	Water hyacinth	6.10	5.84	0.26	4.3
EC (S/m)	3	Water hyacinth	13.19	10.69	2.5	20.0
TDS (ppt)	3	Water hyacinth	8801	7127	1674	19.0
Salinity (ppt)	3	Water hyacinth	7.69	5.45	2.24	29.1

Table 6: ANOVA summary between the control and duckweed treatment on the brackish water

Parameter	Control mean	Treatment mean	Control variance	Treatment variance	F (Cal)	F (Crit)	P (value)	*Treatment Remarks
pH	6.36	6.49	0.13024	0.049737	0.55	4.96	0.475745	NS
EC(S/m)	12.73	11.45	0.069747	0.261947	29.64	4.96	0.000283	S
TDS (ppt)	8531.167	8030.167	66619.37	296045	4.15	4.96	0.068901	NS
Salinity (ppt)	6.765	5.905	0.43347	0.61699	4.22	4.96	0.066907	NS

*Treatment Remarks: S = Significant; NS = Not significant

Table 7: ANOVA summary between the control and water hyacinth treatment on the brackish water

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Parameter	Control mean	Treatment mean	Control variance	Treatment variance	F (Cal)	F (Crit)	P (value)	*Treatment Remarks
pH	6.36	6.40	0.13024	0.097867	0.049	4.96	0.828598	NS
EC(S/m)	12.73	11.45	0.069747	0.421857	20.15	4.96	0.001162	S
TDS (ppt)	8531.17	7634	66619.37	206104.4	17.71	4.96	0.001805	S
Salinity (ppt)	6.77	5.60	0.43347	0.967217	5.80	4.96	0.036825	S

*Treatment Remarks: S = Significant; NS = Not significant

4.0 CONCLUSIONS AND RECOMMENDATIONS

The conclusions of this research are:

1. Duckweed and water hyacinth were able to reduce the concentration levels of the selected brackish water parameter
2. The maximum reduction of concentrations of water parameters was at day 3 of the research except for salinity
3. The concentration levels of the water parameter began to increase after day 3 except for salinity

It is therefore recommended that the aquatic macrophytes should be removed after 3 days to prevent re-introduction of the absorbed salts and fresh aquatic macrophytes introduced to continue the phytodesalination process in 3days intervals until desalination is complete.

This research has shown that a cheaper alternative to conventional desalination processes is phytodesalination. It should also be embraced in the design and operation of desalination of brackish water and surface water polluted by the salt used as deicer in the winter months.

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