Feasibility of *Avicennia Marina* (Grey Mangroves) in Salt Removal from Water

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Abstract

Phytoremediation is becoming a more popular way to remove certain contaminants in a given soil. From removing chromium with mangrove trees or in extreme cases phytoremediation can be used to remove carcinogenic benzene from the groundwater table from a chemical spill. In this study *Avicennia Marina* "Grey Mangrove" was used to see if this plant removes salt in the water that it was planted in. With this design we hope to integrate it into a real-life situation in which it could be beneficial to the public.

Introduction

According to the Environmental Protection Agency (EPA), the threshold for tasting of salt in the tap water ranges from 30 mg/l to 460 mg/l [1]. Therefore, the EPA recommends that the average drinking water sodium level not to exceed 30 to 60 mg/L [1]. Nevertheless, the range of salinity in the drinking water ranges dramatically among towns across Texas.For instance, according to the water quality reports from the city of San Angelo in West Texas, the average drinking water salinity level was around 119 mg/l in 2018 [2].

Phytoremediation is a remediation technology which utilizes a variety of plants for removing pollutants from the environment. This relatively new and encouraging treatment technology could be adopted to benefit areas which cannot afford expensive mechanical excavation or introduction of invasive chemicals in the subsurface. [3]

There have been several studies which applied phytoremediation for the removal of contaminants in a given soil. For example, Shelef et al. (2012)utilized *Bassia indica* plant for the removal of salt. In this study, 2 tests were performed which included a hydroponic system with different salt solutions, one test that recirculated vertical flow constructed wetlands with domestic wastewater, and another test that was a vertical flow constructed wetland for treating goat farm effluents. In these studies, both tests concluded that *Bassia indica* plants reduced the salinity by 20% - 60% [3].

Another test performed by Freedman et al. (2014), utilized halophytes in a constructed wetland for phytoremediation salinity in municipal wastewater. In this research, halophyte were planted in a horizontal subsurface to polish treated municipal wastewater quality and reduce salinity using a pilot system containing eight flow cells. This project concluded that the plants reduced the biological oxygen demand and reduced fecal coliforms and turbidity. Also, salt uptake was significant. However, the overall salinity of the treated wastewater increased despite salt uptake by Halophytes due to evapotranspiration [4].

Avicenna Marina or commonly known as the grey mangrove, typically grows around the inland side of tropical islands and swamps, along the east coast of Africa from around East London to Sudan, along the coasts of Arabia, India, and northern Australia [5]. These plants usually grow in soils that range in sands to clays and loam, they also tend to grow in brackish, salt water and even freshwater [5]. The seeds from a mangrove tree are called "propagules" which are mature plants growing on the parent tree before falling onto the ground and embedding into the soil to begin the growing process. *Avicennia Marina* propagules typically grows to a height of around 20 centimeters with a diameter of 1 centimeter. The leaves are thick 5 centimeters long with a bright, glossy green on the upper surface, and silvery-white on the surface below. Mangrove's optimal growth in salt water is typically 25% seawater, this allows the plant to grow in more versatile areas, it has salt secreting glands in its leaves to make it more salt tolerant .

In the article by MacFarlane and Burchett, it discusses the impact of heavy metals on the growth parameters of Grey Mangroves. More specifically they looked at the number of days, the seedling, height, and leaf number and leaf surface area in a 6-month time period. This study concluded that *Avicenna Marina* is highly tolerant to the metal that was applied [6].

The goal for this research is to reduce the current average of salt concentration of San Angelo, Texas from 119 mg/l to the EPA recommended taste threshold of 30 mg/l [1]. The hypothesize of this experiment is that *Avicennia marina* (grey mangrove) can be used for removal of salinity from drinking water. As a result, the overall goal of this research is to investigate the capacity of capacity of *Avicennia marina* (grey mangrove) in salinity removal.

Materials & Methods

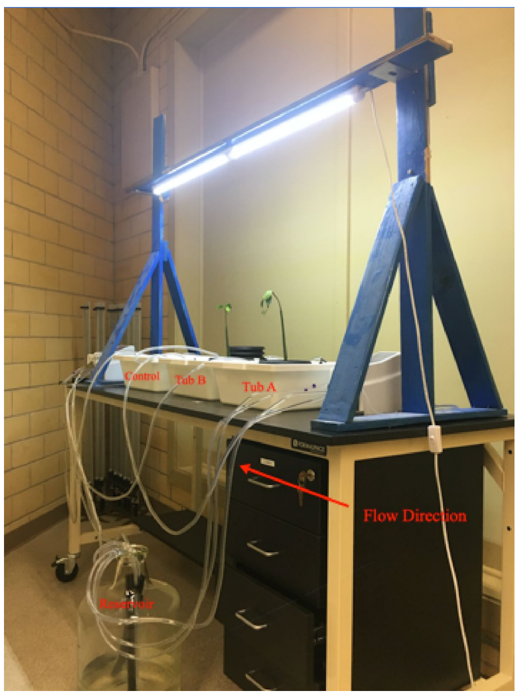
- Experimental Setup

This laboratory experiment was performed in a soil/water environment [4]. Young *Avicennia Marina* were planted in three individual pots, placed into an aquaria (white tubs in Figure 1). The aquaria were 37.3 cm in length, 34 cm in width and 12.5 cm in depth. The 0.5-gallon pots' had dimensions of 6.5 inches top diameter, 3.5 in bottom diameter, and a height of 5.25 inches, and each contained 256 g of organic Miracle grow potting mix soil, refer to Figure 1. Prior to planting the propagules, 50 mL of water was added to the mix.

To initiate the water flow from the inflow-reservoir to the tubs and from the tubs to the out-flow reservoir, two ISMATEC REGLO ICC pumps were utilized to create the inflow and outflow. Pumps delivered the water to the tubs through , flexible plastic, ¼'' tubings, The inflow and outflow reservoirs consist of two glass Pyrex carboys,This allowed us to test the salinity of the water coming from the tubs. Each pump is equipped with 2, ¼'' tubes that have a connection glass pipet that was trimmed and burned in order to have a smooth connection which diminishes risk of puncture of the plastic tubing. The design flow rate was measured and maintained to be at 0.4 l/d [3,6].

Next, the lighting system was installed in a way that best stimulates the growth of *Avicennia Marina* plants. This included the addition of the 2, 2-ft LED tube lights from Kalina that shine at 6000 k at 75 cm height from the surface of the tubs, 52 cm from top leaf of the plants [7]. The average temperature of the room was 20.06 celsius. This temperature is within the optimal range for the growth of these plants [7]. Finally, Deionized Water (DIW) was introduced to the system through the inflow-reservoir for 19 days, to eliminate background noise. Depth of DIW in the tubs were maintained at 8.5 cm and 8.6 cm respectively, which is 4 cm lower than the soil level in the pots. After xx days, a saline solution of 120 mg/l was prepared by adding table salt (Morton Iodized Table Salt) to DIW. The saline solution was pumped to the system for a duration of 19 days. The chosen salinity level is based on the 2018 average San Angelo water quality report [2]. Salinity of the aquaria was measured using a HACH LANGE DR 900 portable colorimeter prior to the introduction of salt.

Figure 1: Experimental Setup



- Water Quality Analysis

In this experiment several water quality parameters were described and determined in the following paragraphs, using the HACH LANGE DR 900 and taken from each of the three white tubs, these measurements were determined on six different days as depicted in Figure 1 .

Cations and Anions

The Ion Chromatography machine (IC), separates ions based upon their interactions with a resin (stationary phase) and an eluent (mobile phase) and is used to identify ions in water samples. The IC consists of three sections: 1) an autosampler, 2) a "Cation-Exchange column" for the ions that are charged positively, and 3) an "Anion-Exchange column" for the negatively charged ions. The IC generates a chromatogram of conductivity versus time where a peak on this graph is produced from an ion and the height of which depends on the relative ion concentration in the injected solution [8]. These measurements can then be utilized to determine concentrations of analytes in a sample. The Ion Chromatography is also used to measure the quantity of each ion present is water samples. The IC utilized in this analysis was Dionex Aquion for Cations and Dionex Integrion HPIC for Anions, equipped with Dionex AS-AP Autosampler.

pH and temperature

pH was determined by using the HACH DR 900 program "461 pH", this procedure, directly from each tub. Along with pH, two thermometers were used in the lab to record the air temperature at the time of testing and an average of the two was used to determine the room temperature.

Total Chlorine and Free Chlorine

Using the HACH DR 900 program "80 Chlorine F&T PP" and following the procedures free chlorine was determined by sampling from the white tubs. Along with free chlorine, total chlorine was determined by using the program "88 Chlorine F&T HR".

Sulfate and Total Hardness

Using the HACH DR 900 program "680 Sulfate", and samples were taken from the white tubs and determined following the procedure. Similarly total hardness was determined using the HACH total hardness Test Kit was used (20-4000 mg/l, model 5-EP MG-L) method and procedure was followed.

Results & Discussion

- Growth Analysis

Roots

Figure 1 and Figure 2 in Appendix B depict the root system before and after the experiment. These photos were taken on the first day of the experiment and the last day of the experiment. From these pictures we cannot conclude that the salinity of the water had an impact on the length of the roots, we can infer that the roots had significantly shrunk over the duration of the experiment.

Length

Throughout the duration of the experiment, the length of the plants was not measured. Nevertheless, it was observed that the stem color changed from green to brown, and new stem segment grew. (Figure 3 and Figure 4). Besides, the stems of the plants began straight, then as the experiment went on the stems began to curve down.

Weight

In the beginning of the experiment the weight of the plants was not measured. Through the life of the experiment, the majority of plants lost several, if not all leaves.

- Analytical Parameters

Cations

Cations are positive ions in an aqueous sample. Samples from each tub were tested on the final day of the experiment and the results are shown in Table 3. From these test results sodium in Tub B was the highest at 50.20 (mg/l). Concentration of ammonium, in the control tub was recorded to be the highest, at145.69 (mg/l). The Control tub measured to have the highest concentration of potassium at 104.76 (mg/l). Lastly, at the highest, the control tub's magnesium and calcium concentrations were 35.49 (mg/l) and 39.92 (mg/l), respectively.

Anions

Anions are negative ions in an aqueous sample. Samples from each tub were tested using the IC machine, and the results are shown in Table 4. The anions tested included the following compound, fluoride, chloride, nitrite, nitrate, sulfate, and phosphate measured in parts per million (ppm). The Control tub had the highest concentration of fluoride at 0.98 (ppm), along with the highest concentration of nitrate at 479.66 (ppm), sulfate, phosphate at 167.81 (ppm) and 112.85 (ppm), respectively. Tub B has the highest concentration of chloride at 56.16 (ppm). Tub A recorded the highest concentration of nitrite at 0.68 (ppm).

pH and Temperature

pH is a measurement of H^+ ions in water and shows whether or not the sample is acidic, neutral or alkaline. Comparing the pH from the 3rd day with the 19th day, the pH only increased slightly from 6 to 7.2 with plus or minus value of 0.1. Therefore, it can be concluded that the water for all 3 tubs remained at neutral pH throughout the experiment. The maximum air temperature recorded was 24.15 degrees celsius, and the minimum temperature was recorded as 19.95 degrees celsius. These temperatures were within the typical temperature range of 17 to 26 degrees celsius that the mangrove plant can tolerate [5]. Therefore, the room temperature did not inhibit the growth of the plants, in this experimental setup.

Total Chlorine and Free chlorine

Total chlorine is the sum of free and combined chlorine, in this experiment combined chlorine was not tested. Total chlorine was measured for a total of 4 days throughout the experiment, with the highest concentration of 0.6 (mg/l Cl_2) and the smallest concentration of 0.03 (mg/l Cl_2). Table 1 depicts that the total chlorine increased from 0.03 (mg/l Cl_2) to 0.6 (mg/l Cl_2) in Tub A, and increased significantly in all the tubs. his increase could be a result of the introduction of potting soil in the water causing a larger concentration of total chlorine.

Free chlorine is the measurement of hypochlorous acid (HOCL) and hypochlorite (OCI^-) [9]. In this experiment, the smallest measurement was 0 (mg/l Cl_2) and the largest was 0.4 (mg/l Cl_2). Similar to the total chlorine concentration , the largest value was found in Tub A, and all tubs increased significantly consecutively after every measurement on average as shown in Table 1.

Total Hardness and Sulfate

Total hardness is the measurement of the cation concentration in water. This parameter was measured only one time in this experiment with the highest measurement of 260 (mg/l $CaCO_3$) in the Control tub and the lowest of 140 (mg/l $CaCO_3$) in Tub B (Table 1). Sulfate is the measurement of $(SO_4)^{-2}$ in a sample of water [10]. In this experiment, sulfate was measured for a total of 3 times, where the highest concentration was 152 (mg/l) in the Control tub and the lowest was 50 (mg/l) in Tub B (Table 2).

Conclusion

In 2018, according to the water quality reports in San Angelo, Texas the average salinity is 119 (mg/l) [2]. After extensive literature research *Avicennia Marina* can be used to remediate the salinity of water up to 60% [3]. With this information, *Avicennia Marina* could possibly reduce the San Angelo salinity to 72 (mg/l).

This study aimed to utilize Avicennia Marina for phytoremediation. In future studies, optimizing the growth of the plant and increasing the duration of the experiment could possibly yield results that would justify using *Avicennia Marina* for salt uptake.Another way to yield more results would be to increase the number of *Avicennia Marina,* to count for unforeseen circumstances which could lead to loss of plants. *Avicennia Marina* appears as a viable candidate for salt removal from water.

Appendix A:

Table 1: Effect of salt water on *Avicennia Marina* and their parameters.

Duration	pH			Sulfate (mg/l)			Total Hardness (mg/l $CaCO_3$)		
	Control	Tub A	Tub B	Control	Tub A	Tub B	Control	Tub A	Tub B
3rd Day	6 (±0.1)	6 (±0.1)	6 (±0.1)	120 (±0.4)	134 (±0.4)	106 (±0.4)	260 (±10)	160 (±10)	140 (±10)
10th Day	6 (±0.1)	6 (±0.1)	6 (±0.1)	152 (±0.4)	102 (±0.4)	50 (±0.4)	N/A	N/A	N/A
13th Day	7.2 (±0.1)	7.2 (±0.1)	7.2 (±0.1)	N/A	N/A	N/A	N/A	N/A	N/A
16th Day	7.2 (±0.1)	7.2 (±0.1)	7.2 (±0.1)	N/A	N/A	N/A	N/A	N/A	N/A
19th Day	7.2 (±0.1)	7.2 (±0.1)	7.2 (±0.1)	150 (±0.4)	102 (±0.4)	60 (±0.4)	N/A	N/A	N/A

Table 2: Effect of salt water on *Avicennia Marina* and their parameters.

Duration	Chlorine (mg/l Cl_2)			Total Chlorine (mg/l Cl_2)		
	Control	Tub A	Tub B	Control	Tub A	Tub B
0 Day	0.05 (±0.02)	0.12 (±0.02)	0.07 (±0.02)	0.2 (±0.1)	0.03 (±0.1)	0.1 (±0.1)
3rd Day	0.08 (±0.02)	0.22 (±0.02)	0.11 (±0.02)	0.5 (±0.1)	0.6 (±0.1)	0.6 (±0.1)
13th Day	0 (±0.02)	0.2 (±0.02)	0.01 (±0.02)	0 (±0.1)	0.2 (±0.1)	0.1 (±0.1)
19th Day	0.04 (±0.02)	0.4 (±0.02)	0.04 (±0.02)	0.2 (±0.1)	0.1 (±0.1)	0.1 (±0.1)

Table 3: IC DATA - CATION

Peak Name	Peak Time (min)	Control (ppm)	Tub A (ppm)	Tub B (ppm)
Sodium	5.13	24.58	13.64	50.21
Ammonium	5.94	125.69	29.89	58.66
Potassium	7.68	104.76	12.64	27.08
Magnesium	15.01	35.49	2.79	5.25
Calcium	19.44	38.93	2.56	5.35

Table 4: IC DATA - ANION

Peak Name	Peak Time (min)	Control (ppm)	Tub A (ppm)	Tub B (ppm)
Flouride	5.21	0.99	0.06	0.24
Chloride	9.50	55.17	25.59	56.17
Nitrite	12.26	0.00	0.69	0.06
Nitrate	16.74	479.67	27.78	21.83
Sulfate	20.44	167.82	20.06	26.38
Phosphate	25.60	112.86	12.62	23.37

Appendix B:

Figure 1: Root before planting (day 1).

Figure 2: Root after experiment (day 19).

Figure 3: Avicennia Marina before planting.

Figure 4: Avicennia Marina in the end of the experiment.

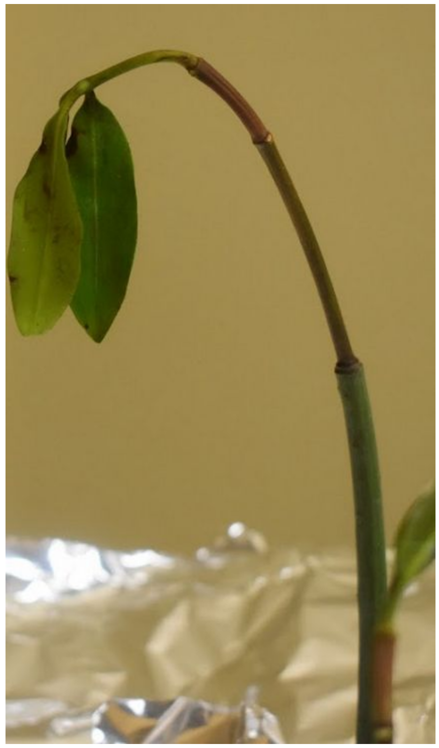
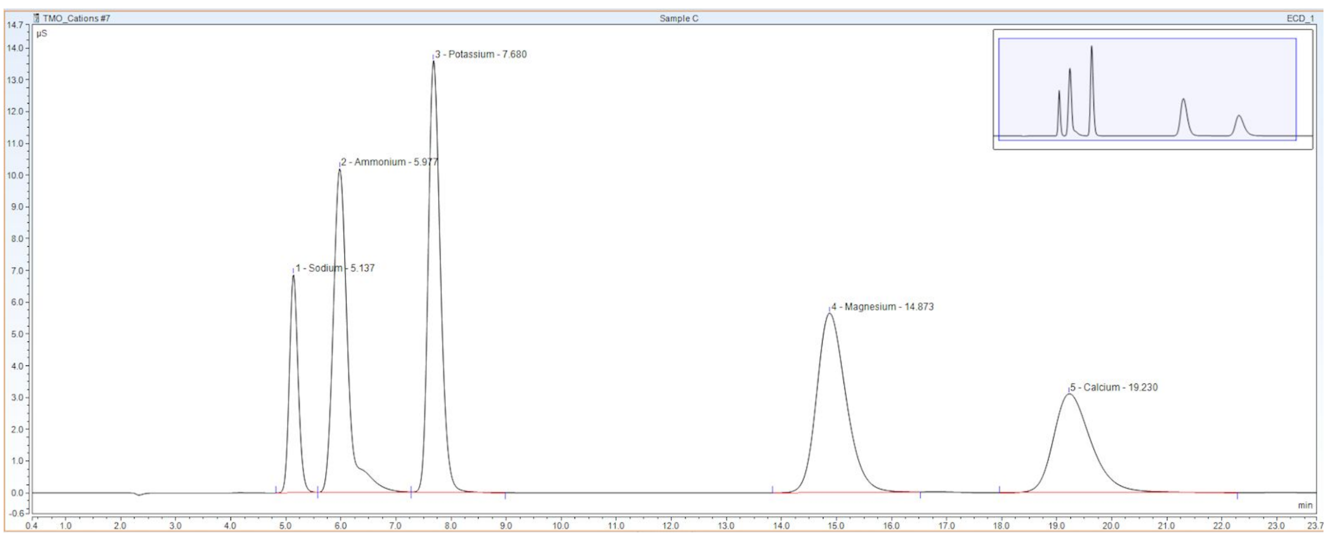


Figure 5: Typical IC Machine graph.



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