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Preface

Kalpitiya and Anuradhapura are major agricultural regions in Sri Lanka. The high Electrical Conductivity (Salinity) ground water of these areas has been negatively affected to the growth rates and crop yield. The Electrical Conductivity (EC) values of these areas vary from 4 dS m^{-1} to 50 dS m^{-}. As an Agricultural country it is necessary to find a method to secure agricultural water by reducing salinity for sustainable food production. Hence the main goal of the current study is apply environmental friendly agricultural wastes for reducing salinity from agricultural water using column bed sorption method and measure the efficiency of adsorbents .Main aim is to explore the improving productivity of cultivars in Sri Lanka.

In truth I could not achieve my current level of success without a strong support group. First of all my parents who supported me with love and understanding Secondly for all the Research officers, Research Assistants ,Technical Assistants and laborers who works in Horticulture Crop Research and Development Institute whom has provided patient advice and guidance throughout the research Process. Finally, for the University of Sri Jayawardanapura, Thank you all for your unwavering support.

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1) INTRODUCTION

For a sustainable life it is essential to have stable supply of food. So it is important to secure agricultural water in order to have stable food production. Quality of the water is most important natural resource. Hence a reliable supply of water is essential to development of communities.

Abiotic stresses is one of major thing that diminishing the productivity and limit the expansion of cultivated extent of agricultural fields in Sri Lanka. Salinity mainly contribute to the abiotic stresses especially in paddy soils. [1].There are two types of salinity areas in Sri Lanka; Inland salinity and coastal salinity. Inland salinity mainly exists in areas like Anuradhapura, Polonnaruwa and Ampara. Mannar, Puttalam, Kalpitiya are areas with costal salinity.

Salts has been accumulated in paddy fields of Sri Lanka mainly due to the salt containing minerals, low rainfall, high evaporation, high salt content in ground water, salt containing minerals, intrusion of sea water to inland areas [1] [2].

Anuradhapura and Kalpitiya districts are major agricultural regions in Sri Lanka where owning limited availability of water bodies. In those areas for an average salinity level (5 dS m^{-1}) the calculated marginal damage was about 757kg/ha paddy . In areas where salinity is high (>5 dS m^{-1}) the grain yield has been reduces more than 20% than unaffected areas. Hence soil salinity was the major determinant factor of paddy production [3].

Salts in the soil water may inhibit plant growth for two reasons. First, the presence of salt in the soil solution reduces the ability of the plant to take up water, and this leads to reduction in the growth rate [4] .With increase of salinity decline in water resource for crops is a recent environmental problem.

Desalination technologies such as multi-stage flash (MSF) method or reverse osmosis membrane method (RO) are well known worldwide [5]. But the problem of these methods are; those cannot use in large scale desalination and it remove all the ions leaving high quality water. In this research mainly focus on removing Salinity of water in large scale which help to agriculture. The most common use of water worldwide is for irrigation; 70% of the total use of freshwater is for irrigation [6].Water use for agriculture should contain some nutrients at some extent. Such as Potassium ions, Magnesium ions, phosphate ions and nitrate ions [4] . And also those methods associated with problems such as insufficient performance, complexity, and low efficiency, co-production of wastes and high cost of installation [7].

Recently, removal of solutes by adsorption onto selective adsorbents has shown promising perspectives in removing salinity in large scale. Use of various natural adsorbents for the removal of salinity from water has been subjected to many studies mainly due to their abundance and low cost. Different types of adsorbents such as zeolites, carbon nanotubes (CNTs), activated carbons, graphene, magnetic adsorbents, and low-cost adsorbents (natural materials, industrial by-products and wastes, bio-sorbents, and biopolymer) have been synthesized and examined for salt removal from aqueous solutions. It is obvious from literature that the existing adsorbents have good potentials for desalination and water softening [8].However, most of them have been found out to be having very low adsorption capacity.

Recently researchers are focused on environment friendly adsorbents for the removal metal ions from aqueous solutions. Agricultural waste has received much attention as adsorbents because they are available in a large quantity at a low cost such as Sugar Cane bagasse, Tea refuse, Rice husk and other low cost adsorbents [9]. They are mainly composed of hemicellulose, lignin, cellulose, simple sugar, protein each having different functional groups. Sugar Cane Bagasse mainly obtain as a waste from large scale industrial operations. It composed of cellulose, lignin, polyoses in its chemical structure. And have a high capacity for binding with metal cations such as Ca^{2+},Mg^{2+},Na^{+} due to occurrence of hydroxyl, phenolic and carboxylic groups [8].

In Sri Lanka Rice is one of the main agricultural crop and rice husk is the major by product waste obtain from rice milling [10].Rice husk contains about 96% silica as well as some organic compounds and impurities. By appropriate washing with double distill water can obtain about 99% silica [10].When it partially burn at a controlled temperature silica converting to H_2Sio_3 acid which showing high affinity to metal cations. It contains much pores which can lock anions and cations; average pore radii of a burnt rice husk is about 6.14nm [11].

Tea also a main export product of Sri Lanka and the waste tea powder using as an adsorbent. It binds with metal ions due to occurrence of phenolic groups.

Objectives: As an Agricultural country it is necessary to find a method to secure agricultural water by reducing salinity for sustainable food production. Hence the main goal of the current study is apply environmental friendly agricultural wastes for reducing salinity from agricultural water using column bed sorption method and measure the efficiency of adsorbents. Main aim is to explore the improving productivity of cultivars in Sri Lanka.

1.1 Description of Study Area

Water samples were collected from Anuradhapura and puttalam districts which shows the inlet salinity and costal salinity.

Anuradhapura and Kalpitiya are main agricultural regions of Sri Lanka. Anuradhapura is where intensive rice cultivation practice and in kalpitiya intensive vegetable cultivation is practicing. The growth of plants and crop yield has been reduces due to high salinity of water in those areas.

In Dry zone of Sri Lanka agro wells are the main water resources for irrigation.

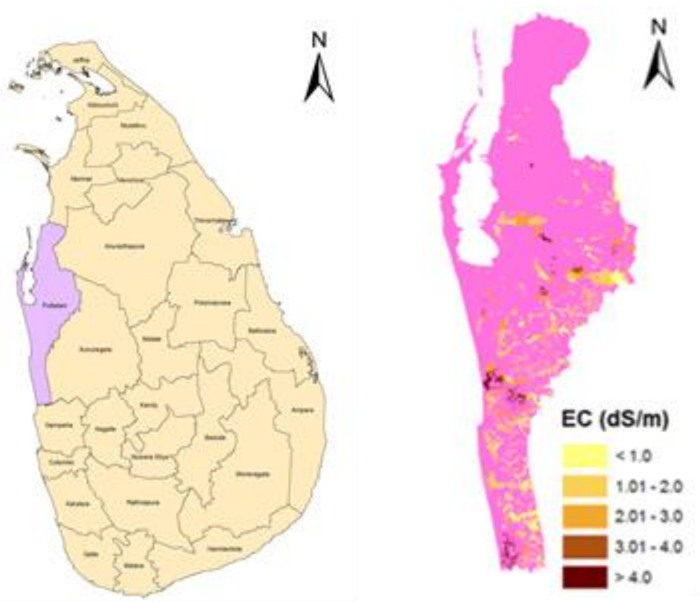

Figure 0.1: Map 1. Soil salinity affected areas in the Puttlam district

In Dry zone ground water shows 2-12 fold increase in salinity than surface water. But especially in dry season (yala season) the surface water source is not sufficient for cultivation hence farmers use the water in agro wells for irrigation purposes [3] .Farmers in

Madawachchiya in Anuradhapura district usually using water from agro wells which have high EC value (>5).Hence diseases like tip burn disease are very common in these areas.

Kalpitiya has different water sources than dry zone. Surface water of kalpitiya is highly contaminated due to intrusion of sea water hence people using ground water for their irrigation purposes. Their ground water also have high EC values which are not recommended for irrigation due to that diseases like tip burn are not uncommon in these areas.

2) LITRATURE REVIEW

2.1 Adsorption

Adhesion of ion, atoms or molecules from gas, liquid or dissolved solid to a surface known as adsorption and it is different from absorption. In Adsorption ion exchange and chromatography are sorption process. Adsorption occurs on the surface and the whole volume of the material involves with the adsorption process. In 1881 German physicist HeninrichKayser was coined the word “Adsorption”. But the term ‘adsorption’ proposed by the Bois Raymond. There are four main steps in adsorption

1) Ions transport to the adsorbent surface from bulk solution
2) Adsorption at the surface
3) Transport within the adsorbent site
4) Desorption of adsorbed ions from adsorbent surface (for regeneration and reuse purposes)

Physisorption and chemisorption are two categorize of adsorption this is due to the nature of surface forces. Chemisorption is stronger than physisorption because physisorption is due to Van der waals forces between adsorbent and adsorbate; whereas chemisorption is because of chemical bonds. Adsorbents can be categorize according to the chemical composition, surface area, particle size distribution etc.

There are varies kinds of adsorbent materials such as activated carbon, agricultural and biological wastes, industrial by products ,natural materials, magnetic adsorbents, bio adsorbents etc. Those are apply in water softening and removal of salt ions [12].

2.2 Salinity

Salinity is due to all the salts dissolved in water. Salinity levels of water changing due to many reasons such as temperature, location, pH etc. TDS or Electrical conductivity (EC) is using for measure salinity. Usually EC is using for measurement of salinity in irrigation water [13] .In Sri Lanka there are two types of salinity areas;

1) Inland salinity

2) Costal salinity

Main reasons for develop inland salinity are Salt laden irrigation water, low rain fall, high evaporation, high salt containing minerals in soil profile (Plate 1) and high salt contents in ground water.

Plate 2-1: Plate 1-high salt containing minerals in soil profile

Inland Salinity can be seen mainly in Anuradhapura, Polonnaruwa, Puttalama, Hambanthota and Ampara districts where intensive rice cultivation is practiced [14] .

Costal salinity is mainly due to intrusion of sea water in to inland areas. This can be occur through many ways. Occurrence of tides and dikes is the major reason for intrusion of sea water into inland areas and it exists in districts of Mannar, Puttalama, Jaffna, Trincomalee, Ampara, Hambanthota, Galle, Kalutara and Mataradistrics (Map 1).

Rice lands of coastal areas experience tidal waves ranging between 45 cm and 60 cm during spring tide and between 10 cm and 25 cm during neap. Due to this considerable amount of salt coming to agricultural fields in coastal areas. And also dry weather causes sea water entry in to rivers.

Through this research considered about the water quality in Puttalama and Anuradhapura Districts.

In dry zone areas in order to increase cultivated extent blocking the drainage canals increase this causes to prevent draining off salts hence salt accumulation in larger quantities taken place.

Plate 2-2: Blockage of drainage canals in irrigated paddy fields in the Dry Zone areas.

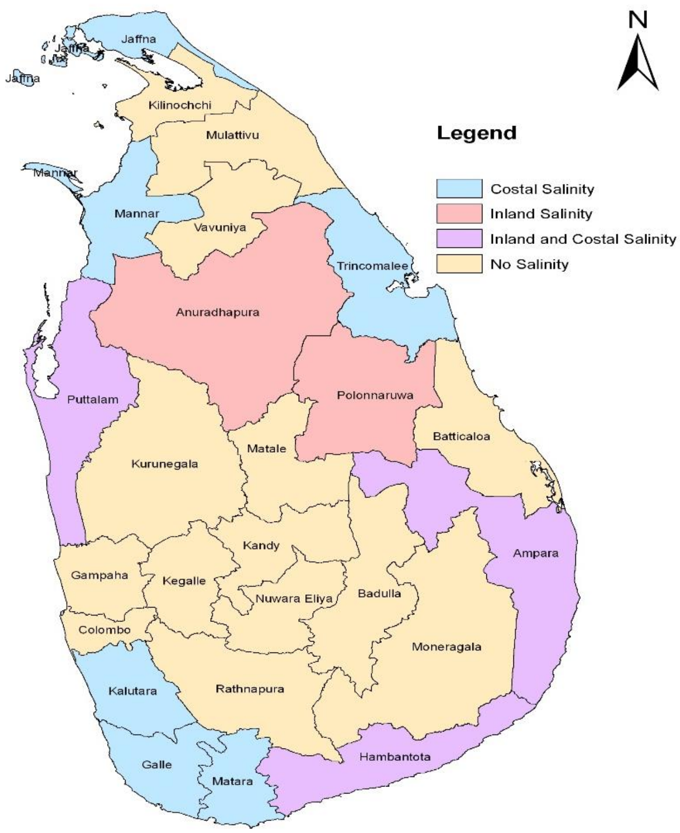

Figure 2.1: map 1: Distribution of Saline water

According to recent researches coastal saline water are rich in K, Ca, Mg and S but poor in phosphorus. And also the most prominent cations in dry zone water of Sri Lanka are Ca and Mg. Sodium also a major cation found in lower quantities in dry zone soils of Sri Lanka.

2.3 Effect of Salinity in irrigation

Rice is the primary form of agriculture in Sri Lanka. It cultivated during Yala and Maha seasons. Salinity of water and soil arises due to many reasons such as temperature, low rainfall, high salt content in ground water etc. Salinity condition in yala season is much higher than maha season because maha season is the wet season and has a poor drainage and the yala season is the dry season due to this high evaporation occurs.

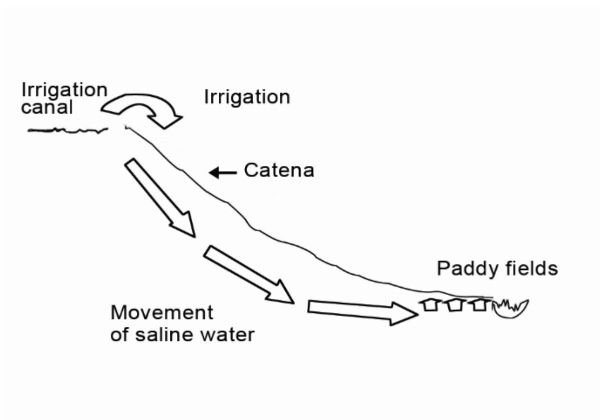

Figure 2.2: Movement of salt through irrigation water

In dry Zone areas of Sri Lanka where the salinity is high (>5dS/m), more than 20% of grain yield has been reduces than that of the unaffected areas. The calculated marginal damage was about 757kg/ha paddy at average salinity levels (5 dS m^{-1}) [3].In paddy production salinity has become the main determinant factor [15].

50% of 24000 ha cultivable paddy lands of puttalam district of Sri Lanka are out of cultivation due to salinity. Remaining 24% of area also having Electrical conductivity values above 2dS/m [9].

2.4 Current Methods for reducing salinity

It is important to reduce salinity of water in large scale using low cost methods. Due to high expanses of energy researches focus on low cost methods. There are biological, physical and chemical methods. Reverse osmosis, coagulation ,filtration ,multistage flash, electro dialysis, multi effect distillation are the most common techniques using for desalination process .Microbial reduction, Advance oxidation process ,Aerobic and anaerobic treatment also major techniques to reduce salinity. But the problem with these methods are energy intensive and high cost and also it's difficult to use in large scale processes [16] .

Among those treatments adsorbents are better due to its wider applicability, Simplicity and most of them are cost effective. There are two types of adsorbents commercial adsorbents and alterative low cost adsorbents.

Commercial adsorbents

Silica gel considered as a good adsorbent which is use in many industries. It shows high surface area 750m^2/g. It has explored to removal of various kinds of pollutants [17].

Zeolite has observed for removal of pollutants from waste water. It has potential to remove metal cations [18].

All these commercial adsorbents are high cost and difficult to regenerate. Hence low cost alternative adsorbents has received much attention. Among those adsorbents Agricultural wastes have highest potential on removal of salinity ions.

2.5 Agricultural waste as adsorbents

Among biological adsorbents agricultural wastes has a high potential to reduce salinity of water. Usually they contains cellulose, hemicellulose, starch, lipids, proteins, simple sugars and hydrocarbons. Cellulose shows potential sorption capacity towards pollutants. Agricultural wastes contains unique chemical composition due to that it has become eco-friendly [18] .Hence in this study mainly concern about agricultural wastes which are cost effective and abundance.

2.5.1 Rice Husk

Rice is a major crop in Sri Lanka and also throughout the world and it is the seed of *Oryza sativa*. Rice is the major food in Sri Lanka. Rice industry produces by products such as rice hull, rice husk and rice bran [18] .Rice husk is the major by product and it is 20% (w/w %) of a paddy produced. In Sri Lanka and China Rice Husk are burned and buried in cultivated lands due to low levels of protein and high ash content and also they are difficult to decompose by bacteria due to their high lignin ,high silica content and hard surface [10]

Plate 2-3:Rice Husk

Unwashed rice husk contains about 96% silica, by giving an appropriate washing it can contain >99% silica. When partially burn rice husk under controlled temperature silica converting to $H2SiO3$ acid which shows high affinity on metal ions. The researches has tested rice husk in removal of Pb(II), Sb(III), Hg(II) [18]. From this study tested the potential of rice husk in order to remove metal ions which are responsible for water salinity.

2.5.2 Sugar Cane bagasse

Sugar Cane Bagasse obtain as a byproduct from large scale Sugar industries. Sugar cane bagasse contains cellulose, hemicellulose lignin, hydroxyl groups and small sugars which have potential to remove metal ions. Lignin and hydroxyl groups have tested for selective adsorption of Ca^{2+} and Mg^{+2} ions. Sugar Cane Bagasse tested for removal of Zinc and Cadmium from the waste water [19].The adsorption capacity for Cd(II) and Zn(II) was 38.03mg/g and 31.11mg/g. Due to its porosity and unique chemical composition showing high potential on reduce salinity of water.

Plate 2-4: Raw Sugar Cane Bagasse

2.5.3 Coconut

Coconut is a common agricultural product .Coconut husk also contains cellulose, hemicellulose, and lignin which showed high potential in removing pollutants from water. Coconut shells also effectively use in purifying water [12]. Coconut husk and shells are available as wastes. Coconut husk is the mesocarp of coconut.35% of coconut contains coconut husk [20]. It has tested for used as an adsorbent in order to remove fluoride [20].

Plate 2-5: Coconut shell (a) and Husk (b)

2.5.4 Charcoal

Charcoal is amorphous form of Carbon. Usually produces by pyrolysis .Many Agricultural wastes are using for produce activated carbon. Charcoal commonly using for purify water. It is widely used as an adsorbent for the removal of various organic and inorganic pollutant due to its high porosity, large surface area, well developed internal pore structure and high degree of surface reactivity [12].Generally it has a very porous structure and with large surface area ranging from 600 m^2/g to 2000 m^2 /g. But its applications are restricted due to its higher cost [18].Activated carbon found to be adsorb metal cations, anions, dyes, phenols chlorinated hydrocarbons and many other chemicals and organisms [21].

Plate 2-6:charcoal

2.5.5 Clay

It can be used as a natural low cost adsorbent .Clay has been evaluated for treatment of salty water due to its metal binding capacity and High porosity. Mainly composed of SiO_3 and Al_2O_3 with a high water adsorption capacity (20%-30%) [12].

Plate 2-7:clay

2.5.6 Lemon leaves and peel

Lemon peel can collected as a waste. But it is no abundance. Difficult to find. But it has potential on remove metal ions due to its citric acid. Citric acid showing a high affinity towards metal cations such as Ca^{2+}, Na^{+} [12].

3) MATERIALS AND METHODS

3.1 Description of study areas

Water samples were collected from Anuradhapura and Kalpitiya areas which shows the inlet salinity and costal salinity.

Anuradhapura and Kalpitiya are main agricultural regions of Sri Lanka. The growth of plants and crop yield has been reduces due to high salinity of water in those areas.

The water samples were selected in 3 ranges.

Table 3.1.1 EC ranges of selected water samples

location	EC(dS/cm)	pH
Anuradhapura Madawachchiya(Agro well)	8.08	6.02
Kalpitiya Inlet-Mampoori	22.17	7.32
Kalpitiya Tank-Mampoori	10.95	6.35

3.2 Sampling and Sample Collections

The water Samples were collected to polyethylene containers and were tightly close and labeled. Then transported to the laboratory and kept under refrigerated condition until analysis.

3.3 Analytical Procedure

The pH and Electrical Conductivity (EC) at room temperature as soon as the water samples reached the laboratory. Samples were filtered through No.42 filter paper for other analysis. The Ammonium (NH_4^+) Chloride (Cl^-) Nitrate (No_3^-) Fluoride (F^-) and Calcium (Ca^{2+}) content were determined using ion selective electrode(Jenway Model) Magnesium was determined by using atomic absorption spectrometer(Varian–model No.AA140/240/280) Sodium(Na^+) was determined by a flame photometer(CORNINNG-Model No.410)

3.4 Collection and preparation of adsorbents

Firstly many (biological) waste materials were collected and checked with saline water to find its ability to reduce salinity of water. Usually using Electrical conductivity meter for measure salinity.

Biological material such as lemon peel, Coconut Husk, Crushed lemon leaves, Rice hull, Paddy Husk, Sugar Cane Bagasse, Partially burn rice husk, Tea refuse were checked with saline water samples.

Charcoal, Bricks and clay also checked for reduce salinity.

Finally selected Sugar Cane Bagasse, Rice husk and Tea refuse for further analysis by considering their performance on reducing salinity, abundance and its low cost.

Four replicates were done for each adsorbents for different EC levels at constant flow rate (8ml/min) and constant bed height of 19cm.

All the materials collected as wastes. Firstly materials were washed with double distill water and paddy husk, lemon leaves, Coconut husk were grounded using electrical blender and all the materials dried for 24 hours in oven at 60 ºC.

3.5 Adsorption measurements using batch equilibrium technique

The percentage extraction of salinity using adsorbents were determined using batch equilibrium technique under static conditions. Three replicates were done for each 4 g from each adsorbent were added to the 80 ml water samples in a measuring flask. Using a mechanical shaker the mixtures were mechanically shaken for 60 minutes at room temperature to attain equilibrium and adsorbents were separated by filtration [22] .And the EC of filtrates were measured.

Percentage of reducing EC= $\frac{(Eo-Ef)}{Eo}x100$

Where Eo refers to initial EC (Electrical Conductivity) of water samples in dS/m and Ef refers to EC of filtrate in dS/m.

Batch equilibrium technique used to check the performance of adsorbents in order to reduce salinity of water. Using that technique three adsorbents were selected which have highest potential in reducing salinity and they were used in fixed bed column to get maximum performance. Further analysis were did using those three adsorbents in a column bed. Because it should be practiced in a lab in industrially applicable way.

3.6 Preparation of adsorbents

Raw Sugar Cane Bagasse, Rice husk and Tea refuse collected as wastes. The samples were soaked in distilled water for 24 hours and washed with deionized water before use in order to remove impurities.

Step 1: Raw Sugar Cane Bagasse samples were boiled for 20 min to remove remain soluble sugars and soaked in double distilled water for 24 hours and filtered .Then dried in oven at 60 ºC for 48 hours.

Step 2: Dried materials were grounded using an electrical grinder and sieved. Average particle size was 7.5mm [23].

Plate 3-1:Raw Sugar Cane Bagasse

Step 2

Plate 3-2: Grounded sugar cane bagasse

Oryza sativa - rice which was obtained from the Horticulture Crop Development and Research Institute were used for this work. They were washed three times using distill water in order to remove impurities and soaked in double distill water for 24 hours and filtered. Then dried in oven at 60 ºC for 24 hours and then burnt at a controlled temperature in order to get partially burn rice husk then Cooled to room temperature [24].

Plate 3-3 Instrument to prepare partially Burn Rice Husk

Plate 3-4: Prepared Partially Burned Rice Husk

Raw Tea refuse was used in the column after washing with deionize water.

3.7 Adsorption measurements using fixed column bed sorption technique

Continuous flow adsorption studies were conducted in a column made of PVC having inner diameter of 4.5cm and 32cm height. Feed flow rate was 8ml/min. A layer of glass wool was placed to prevent loss of adsorbent [25].The adsorbents were washed with hot distilled water dried and packed in column in order to evaluate performance of selected adsorbents for the reducing salinity of water. Initial ion concentrations for Ca^{2+}, Na^{+}, Mg^{2+}, NO_3^{-}, NH_4^{+}, F^{-} and Cl^{-} were measured and ion concentrations of first filtrates were measured.(which was collected in first 20 minutes)

Effect on pH on reducing Electrical Conductivity also measured. NaOH and CH_3COOH used to adjust pH.

Reduction percentage was measured for ions by using following,

$$Reduction\% = \frac{ct}{co} x100$$

Where ct is the ion concentration for the filtrated samples in ppm and co is the initial ion concentrations of samples in ppm.

3.8 Bioassay

In order to measure bioassay, seeds of chilies were purchase from the Agriculture Department Peradeniya, Sri Lanka. Three Petri dishes which are covered with N0 5 filter papers were scattered with seeds (30 seeds for each)

Petri dish 01- treated with the saline water. (Mixture of water (EC 8/EC10.95/EC 22.17))

Petri dish 02 –Treated with tap water (0.25dS/m)

Petri dish 03 – Treated with filtrate

4) RESULTS AND DISCUSSION

4.1 Adsorption measurements using batch equilibrium technique (Synthetic samples);

At first Synthetic samples were tested with various materials in order to check its ability to reduce salinity.

Initial EC of the synthetic saline water Sample -13.54 dS/m

pH of synthetic saline water sample-6.67

Table 4.1.1 Coconut husk

Time(minutes)	Mean EC Reduction(dS/m)	Reduction%
30	12.80	21%

pH of the filtrate sample – 6.32

EC reduction percentage of Coconut Husk is 21% and it reducing it to 12.8 from 13.54 dS/m. According to the FAO Reports for safe surface irrigation EC should be in the range of 1-3 dS/m. Hence its potential to reduce EC is not in a satisfied level. In Sri Lanka Coconut Husk is an exporting material so it cannot be considered as a waste material hence it’s not selected for further analysis.

Table 4.1.2 Lemon peel

Time(minutes)	Mean EC Reduction(dS/m)	Reduction%
30	1.470	89.25%

According to the results lemon peel reducing the EC in 89.25% and at the same time it reducing the pH to 5.38.It converting salinity water for safer level which is safe for surface irrigation. But lemon peels are highly expensive and difficult to find. In this study mainly concerned about the materials which are abundant and cheap.

Initial pH of the water sample- 6.67

pH of the filtrate sample – 5.38

Table 4.1.3 Charcoal

Time(minutes)	Mean EC Reduction(dS/m)	Reduction%
30	13.27	2.28%

Initial pH of the water sample – 6.67

pH of the filtrate – 6.65

Charcoal is an adsorbent, most commonly used to purify water. But here its EC reduction percentage is 2.28. Hence according to the results its potential to reduce EC is low.

Table 4.1.4 Clay

Time(minutes)	Mean EC Reduction(dS/m)	Reduction%
30	13.22	2.25%

Initial pH of the water sample – 6.67

pH of the filtrate – 6.65

Clay is a most commonly used adsorbent. But here it is not reducing EC at a safe range. Hence according to results its potential to reduce EC is low.

Table 4.1.5 Paddy Husk

Time(minutes)	Mean EC Reduction(dS/m)	Reduction%
30	12.52	7.5%

Initial pH of the water sample – 6.67

pH of the filtrate – 6.58

Paddy Husk also showed a low potential in order to reduce EC of saline water sample.

Table 4.1.6 Guinea Grass

Time(minutes)	Mean EC Reduction(dS/m)	Reduction%
30	12.50	7.6%

Initial pH of the water sample – 6.67

pH of the filtrate – 6.55

Grounded Guinea grass were used for experiment. The reduction of EC was 7.6%. Not showed a successful reduction percentage.

Table 4.1.7 Partially Burned Rice Husk

Time(minutes)	Mean EC Reduction(dS/m)	Reduction%
30	3.92	70%

Initial pH of the water sample – 6.67

pH of the filtrate – 6.05

Partially Burned Rice Husk reducing the EC in 70%.Hence it showed high potential towards reducing EC. It has selected for further Analysis in a fixed bed in order to reduce salinity of ground water.

Table 4.1.8 Sugar Cane Bagasse

Time(minutes)	Mean EC Reduction(dS/m)	Reduction%
30	4.19	68%

Initial pH of the water sample – 6.67

pH of the filtrate – 6.15

Sugar Cane Bagasse reducing the EC in 68%.It also showed high affinity towards salinity ions. So selected for further analysis in fixed bed column.

Table 4.1.9 Tea refuse

Time(minutes)	Mean EC Reduction(dS/m)	Reduction%
30	2.84	78%

Initial pH of the water sample – 6.67

pH of the filtrate – 6.08

Reducing The EC in 78%.Tea refuse is a waste which can collect easily. Hence selected for further analysis in fixed bed column.

Here mainly concern about the cost effectiveness, simplicity and abundance when selecting biological materials as adsorbents in order to reduce salinity of water in large scale.

3 water samples selected in 3 ranges

Table 4.1.10 Selected Saline water Samples

Sample Number	location	EC(dS/cm)	pH
Sample 1	Kalpitiya Inlet-Mampoori	22.17	7.32
Sample 2	Anuradhapura Madawachchiya(Agro well)	8.08	6.56
Sample 3	Kalpitiya Tank-Mampoori	10.95	6.35

The pH of water samples are in between 6 to 7. It indicates that water were not sodic. The EC of collected water samples are very high. Not compatible for irrigation.

4.2 Breakthrough Curve Analysis

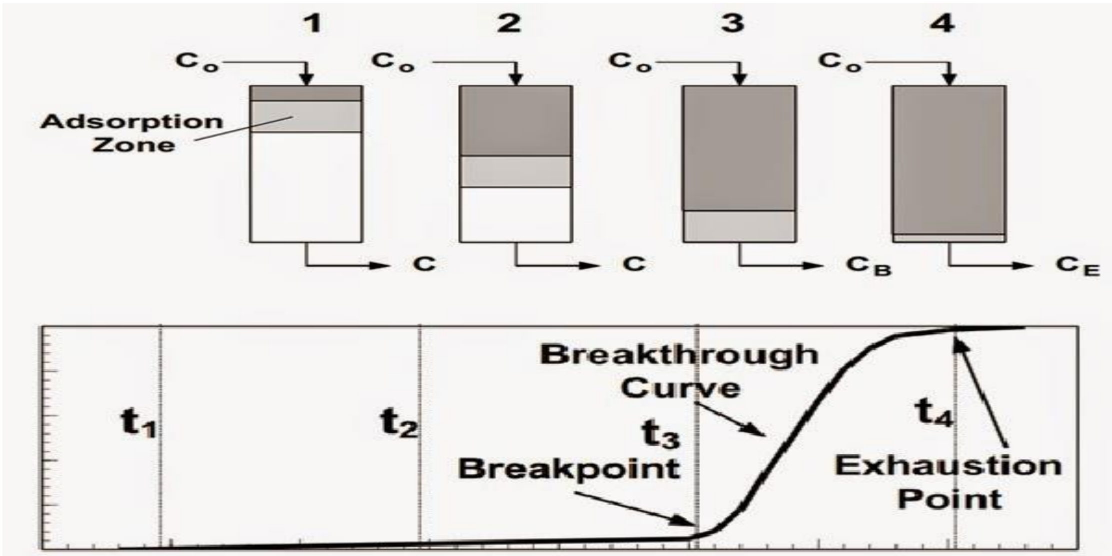

Figure 4.1: Typical breakthrough curve

Breakthrough curve is a graph between analyte and time. Breakthrough curves are used to analyze fixed bed column performances. There are two special points;

- Breakpoint
- Exhaustion point

Break point is a point which is filtrate EC (concentration) reached to its maximum reduction or adsorbent reached to its maximum performance.

Exhaustion point or saturated point – At that point the column is fully saturated. No available spaces in material for adsorption.

When adsorption column get saturated breakthrough happens. Usually it’s an S shape curve. When the slope stays constant indicates the column get saturation. Breakthrough Curves are important to study adsorption characteristics, for adsorptive separation technologies and for study the characteristics of porous materials.

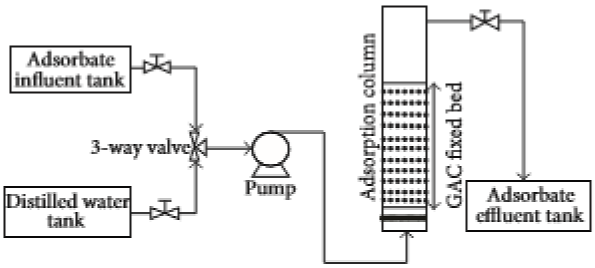

Figure 4.2: schematic flow diagram of fixed bed system [25]

Initial EC of samples were measured and the EC of filtrate was measured in first 20 minutes and within every 30 minutes until fixed bed column get saturated. The performance of adsorbents with different EC levels were analyzed using breakthrough curves. Breakthrough curve is a graph between analyte (EC) (dS/m) vs time for given conditions.

The total adsorbed salinity can be calculated by determining the area under the breakthrough curve [20].

The Bed capacity for unit cross section = Ls. Area above the curve

$$= Ls\int_0^T (Yin - Y)dt$$

$$= pZ(X_T - Xi_n)$$

P=Bulk density for unit cross section

X_{in} = Initial concentration of the adsorbate

X_T = Final concentration of the adsorbate

The volume of filtrate (effluent) which can be treated by this column can be calculated from the following equation [26].

$V_{eff} = Q.t_e$

Where;

Q is the volumetric flow rate (mL/min)

t_e is the exhaustion point(minutes)

4.3 Column Test Results;

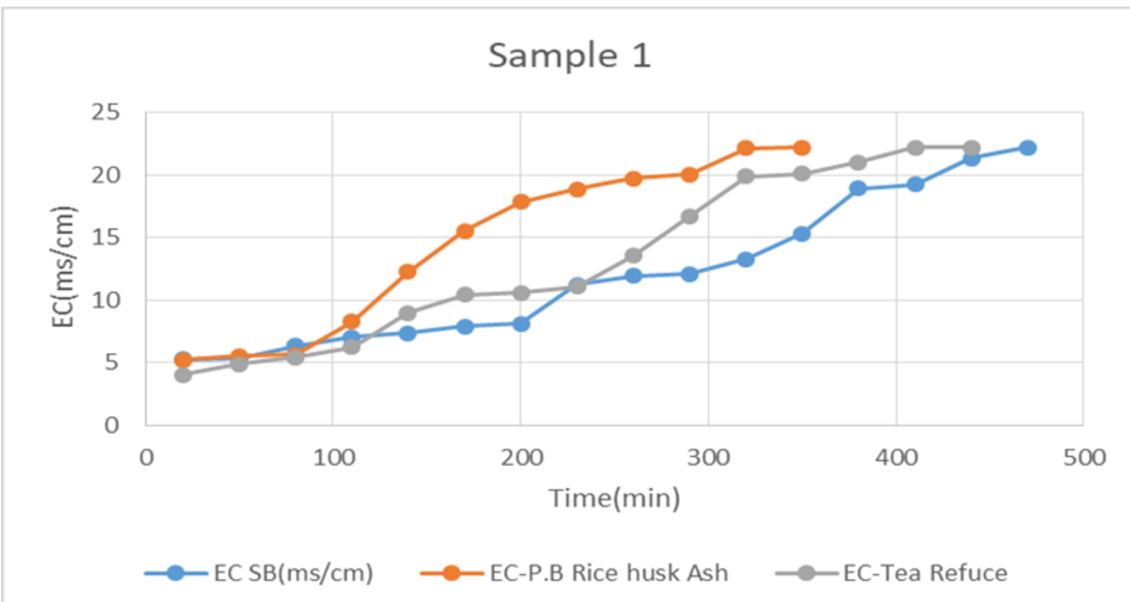

Figure 4.3: Breakthrough Curves for Sample 1

Breakthrough curves illustrated at a constant flow rate of 8 ml/min, Constant column diameter 8 cm, constant bed height of 19 cm and constant adsorbent weight.

When observing the results of these three adsorbents Tea refuse has the highest capability for reduce EC. It reducing the EC in $\frac{22.17-4.02}{22.17}$ x100 = 81.86 %.

Sugar Cane Bagasse reducing the EC = $\frac{22.17-5.25}{22.17}$ x100 = 76.31%

Partially Burn Rice Husk = $\frac{22.17-5.18}{22.17}$ x100 = 76.63%

Sample 1 has the highest EC level which is 22.17 dS/m. Sample 1 water is highly contaminated with ions.

Partially burn Rice Husk become saturated quickly. By considering about the break point can get an idea about the bed sorption capacity of adsorbents. According to above results Sugar Cane bagasse has the highest bed sorption capacity. It is getting 200 minutes to approach break point. Break point time of Partially Burn rice husk is 80 minutes and breakpoint time for Tea refuse is 120 minutes. Saturated points of adsorbents also different. Sugar Cane Bagasse has the highest saturated point time which is 420 minutes.

The volume of effluent can be calculated for each adsorbents.

V_{eff} = Q.te

For Sugar Cane Bagasse;

V_{eff} = 8ml/min x 440 min

=3.520 liter.

For partially Burnt Rice Husk;

V_{eff} = 8ml/min x 320 min

= 2.56 liter

For Tea refuse;

V_{eff} = 8ml/min x 410

=3.28 liter.

It showed that Sugar Cane Bagasse has the highest V_{eff} Value. Hence using this column with Sugar Cane Bagasse can treat highest volume of salinity water.

Bed Sorption Capacity – The bed sorption capacity under certain conditions can be calculated from the breakthrough curve. According to IUPAC Gold Book the amount of adsorbed substance reached in a saturated solution is called the adsorption capacity of the adsorbent for a specific solute [27].

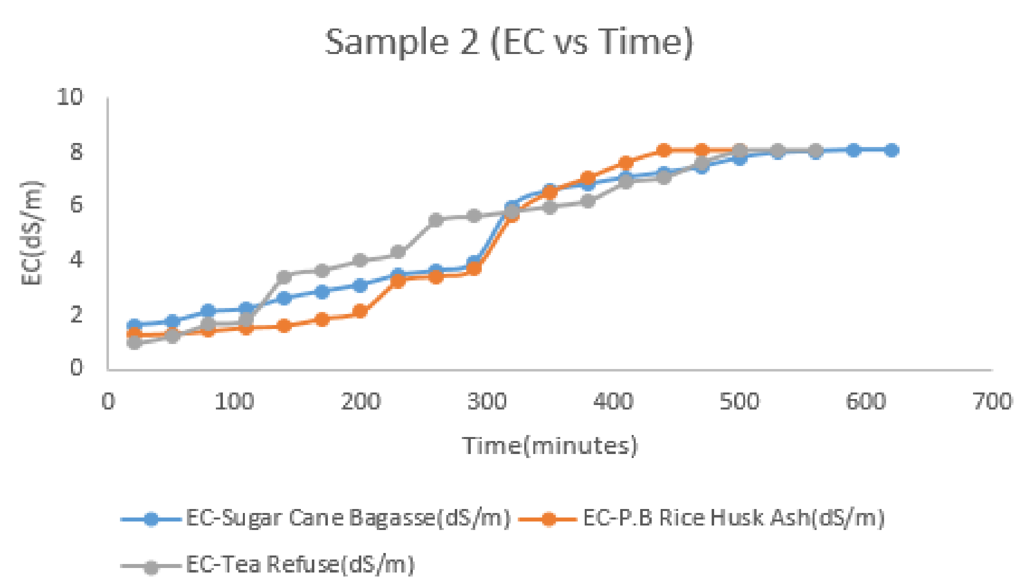

Figure 4.4: Breakthrough Curves for Sample 2

Breakthrough curves illustrated at a constant flow rate of 8 ml/min, Constant column diameter 8 cm, constant bed height of 19 cm and constant adsorbent weight.

When observing the results of these three adsorbents at EC of 8.08 dS/m Tea refuse has the highest capability for reduce EC. It reducing the EC in $\frac{8.08-0.98}{8.08}$ x100 = 87.87 %.

Sugar Cane Bagasse reducing the EC = $\frac{8.08-1.65}{8.08}$ x100 = 79.57%

Partially Burn Rice Husk = $\frac{8.08-1.28}{8.08}$ x100 = 84.15%

The EC of sample 2 is 8.08dS/m which is collected from Anuradhapura, Medawachchiya area. The EC level is higher than 3 dS/m .This indicates water sample highly contaminated with ions.

Partially burn rice husk become saturated quickly. Here also by considering about the break point can get an idea about the bed sorption capacity of adsorbents. According to above results Sugar Cane bagasse has the highest bed sorption capacity. It getting 300 minutes to approach break point. Break point time of partially burn rice husk is 200 minutes and breakpoint time for Tea refuse is 100 minutes. Saturated points of adsorbents also different. Sugar Cane Bagasse has the highest saturated point time which is 560 minutes. Saturated point time of Tea refuse is 500 minutes. And Partially Burn Rice Husk has the lowest saturated point time of 440 minutes.

The volume of effluent can be calculated for each adsorbents.

V_{eff} = Q.te

For Sugar Cane Bagasse;

V_{eff} = 8ml/min x 560 min

=4.480 liter.

For Tea refuse;

V_{eff} = 8ml/min x 500 min

= 4 liter

For partially Burn Rice Husk;

V_{eff} = 8ml/min x 440

=3.52 liter.

It showed that Sugar Cane Bagasse has the highest V_{eff} Value. Hence using this column with Sugar Cane Bagasse can treat highest volume of salinity water.

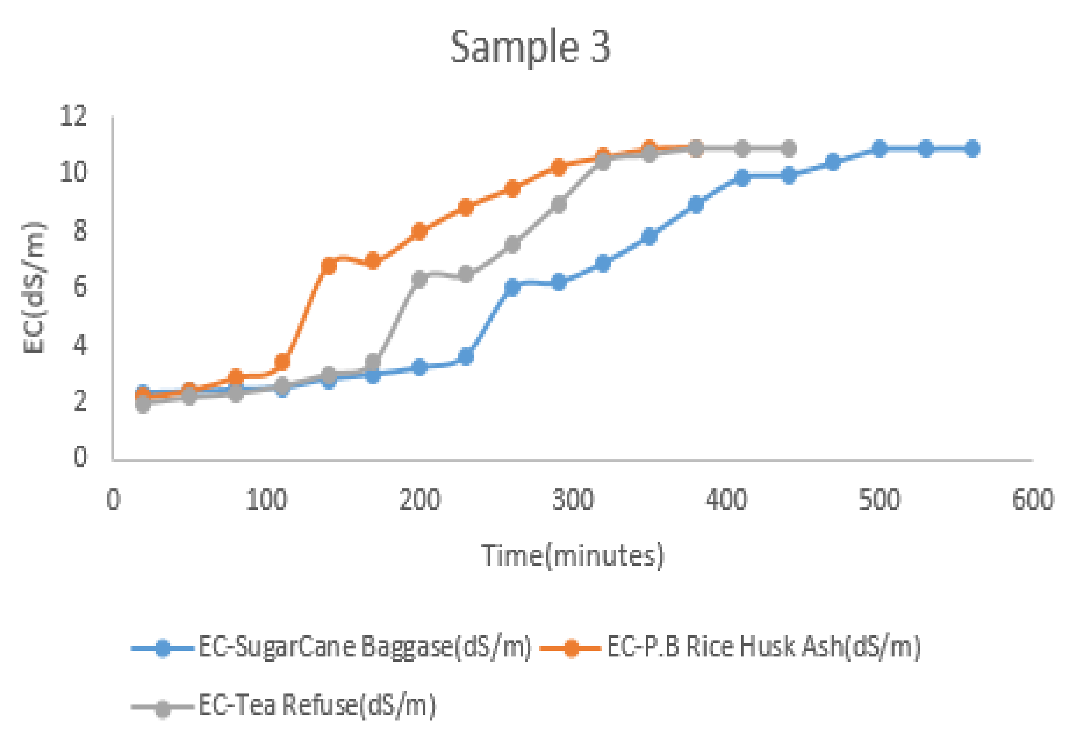

Figure 4.5: Breakthrough Curve Analysis for Sample 3

Breakthrough curves illustrated at a constant flow rate of 8 ml/min, Constant column diameter 8 cm, constant bed height of 19 cm and constant adsorbent weight.

When observing the results of these three adsorbents at EC of 10.95 dS/m Tea refuse has the highest capability for reduce EC. It reducing the EC in $\frac{10.95-1.98}{10.95}$ x100 = 81.91%.

Sugar Cane Bagasse reducing the EC = $\frac{10.95-2.35}{10.95}$ x100 = 79.72%

Partially Burn Rice Husk = $\frac{10.95-2.22}{10.95}$ x100 = 79.7 %

The EC of sample 3 is 10.95dS/m which is collected from Kalpitiya, Mampoori area. The EC level is higher than 3 dS/m .This indicates water sample highly contaminated with ions.

Partially burn Rice Husk become saturated quickly. Here also by considering about the break point can get an idea about the bed sorption capacity of adsorbents. According to above results Sugar Cane bagasse has the highest bed sorption capacity. It getting 260 minutes to approach break point. Break point time of Partially Burn rice husk is 140 minutes and breakpoint time for Tea refuse is 200 minutes. Saturated points of adsorbents also different. Sugar Cane Bagasse has the highest saturated point time which is 500 minutes. Saturated point time of Tea refuse is 380 minutes. And Partially Burn Rice Husk has the lowest saturated point time of 350 minutes.

The volume of effluent can be calculated for each adsorbents.

V_{eff} = Q.te

For Sugar Cane Bagasse;

V_{eff} = 8ml/min x 500 min

=4 liter.

For Tea refuse;

V_{eff} = 8ml/min x 380 min

= 3.04 liter

For partially Burn Rice Husk;

V_{eff} = 8ml/min x 350

=2.8 liter.

It showed that Sugar Cane Bagasse has the highest V_{eff} Value. Hence using this column with Sugar Cane Bagasse can treat highest volume of salinity water.

4.4 Effect of adsorbents

The three adsorbents showed different characteristics with different water samples. Sample 1 has the highest EC value and highest ion concentration. Sample 2 has the lowest ion concentration. It can observed that the adsorption depend on the initial EC value and the Initial ion concentration. Break point time and saturated point time also depends on the initial EC value of water samples.

The results indicates Sample 2 has the highest bed sorption capacity, saturated point time and the largest V_{eff} value. Thus lower EC levels utilized to treat the large volume of the influent

The results indicates adsorbents showing their best performance with low easy level water samples

In every EC levels Sugar Cane Bagasse has the highest adsorption capacity which means it can use in column bed to treat salinity water for longer period of time. It getting more time to approach to saturated point.

Percentage of EC reduction also depend on the EC value of water samples. For sample 2 the percentage of EC reduction in the range of 80%-88%. It is the highest reduction.

4.5 Effect of pH on reducing EC using Sugar Cane Bagasse, Partially Burnt Rice Husk and Tea refuse

pH of an aqueous solution is one of the main factor in adsorption. It is important for quantitative recoveries of analytes. Those adsorbents removing ions mainly through ion exchange mechanism. The effect of pH investigated in the pH ranges of 2-7 keeping the other parameters constant.

Adsorbents showed low efficiency towards adsorption of salinity from aqueous solutions at low pH values. At pH<2 metal species are positively charged. Uptake metal ions may proceed through M^{n+} exchange process with acidic sites H^+. The optimum pH range for effective adsorption chosen to be pH 6-7 range. Maximum adsorption observed in that range.

However the three adsorbents showed low efficiency towards adsorption at low pH values (<2). At lower pH values H^+ compete with metal ions for exchange sites, hence partially releasing the latter. At high pH values adsorbent surface become negatively charge and metal ions attract to adsorbent surface [22].

The results indicate that at low pH values it shows low extraction. The extraction at pH <5 is in the range of 2%-65%. It showed the best extraction by reducing the EC in the range of 75% to 83% at pH 6-7 range.

4.5.1 Percentage of Extraction as a function of pH using selected three adsorbents

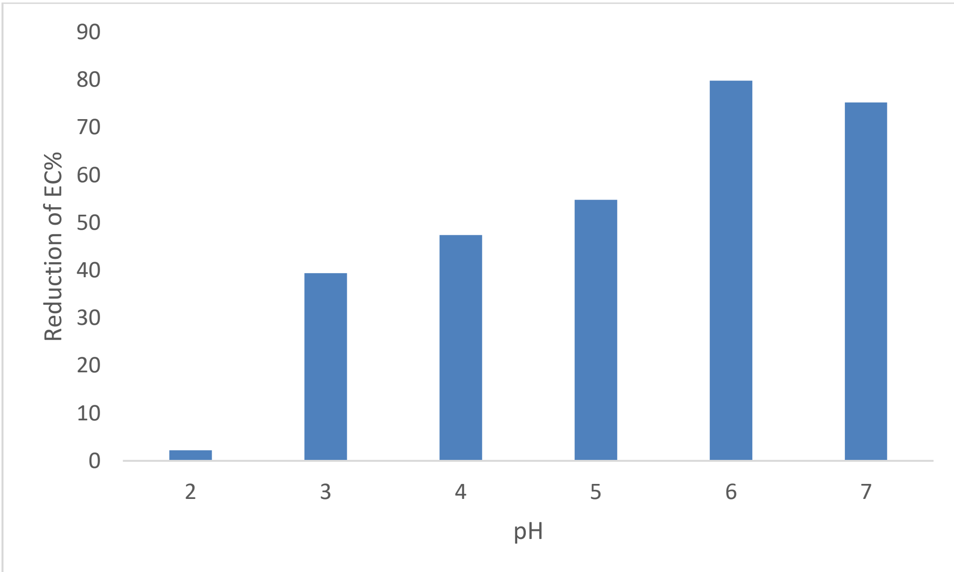

Figure 4.6: Reduction of EC of Saline water using Sugar Cane Bagasse at pH 2 - 7

<u>Percentage of extraction as a function of pH using Partially Burnt Rice Husk</u>

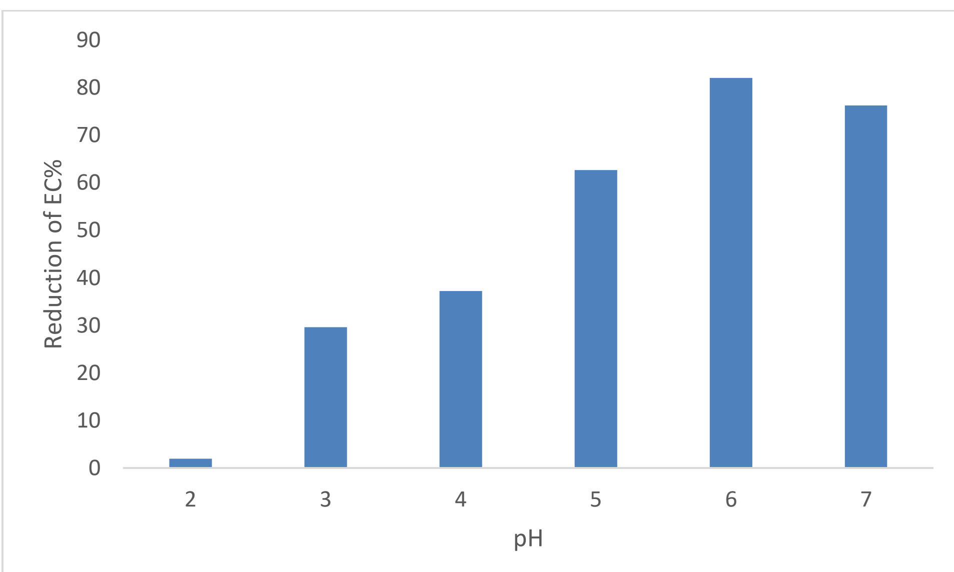

Plate 4-1: Reduction of EC of Saline water using Partially Burnt Rice Husk at pH 2 - 7

Percentage of extraction as a function of pH using Tea refuse

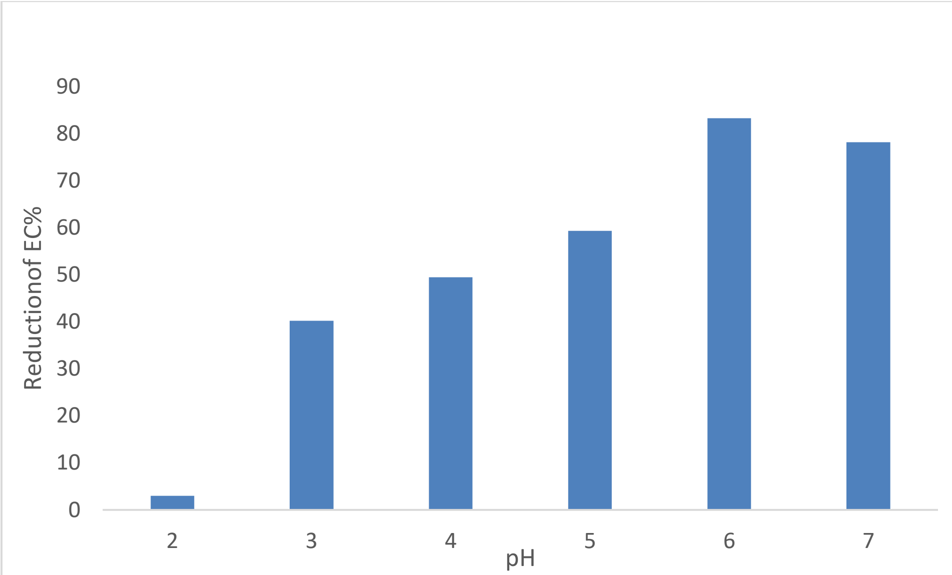

Figure 4.7: Reduction of EC of Saline water using Tea Refuse at pH 2 – 7

4.6 Ion Analysis

Table 4.6.1 Initial ion concentrations

Location	**EC(dS/m)**	**Ca^{2+} (ppm)**	**Cl^- (ppm)**	**F^- (ppm)**	**NO3- (ppm)**	**NH_4^+ (ppm)**	**Na^+ (ppm)**	**Mg^{2+} (ppm)**
Kalpitiya Inlet	22.17	424	788	10	262.4	4.8	1129	400
Kalpitiya Tank	10.95	408	640	6.8	188	4	878	380
Anuradhapura Madawachchiya	8.08	512	297.2	8.8	148.4	2	380	520

According to the analysis With EC the ion concentrations also increasing. Most prominent cations in dry zone are Calcium and Magnesium. According to the FAO records;

Water parameter	Symbol	Unit[1]	Usual range in irrigation water	
SALINITY				
Salt Content				
Electrical Conductivity	EC_w	dS/m	0 – 3	dS/m
(or)				
Total Dissolved Solids	TDS	mg/l	0 – 2000	mg/l
Cations and Anions				
Calcium	Ca^{++}	me/l	0 – 20	me/l
Magnesium	Mg^{++}	me/l	0 – 5	me/l
Sodium	Na^{+}	me/l	0 – 40	me/l
Carbonate	CO^{--}_3	me/l	0 – .1	me/l
Bicarbonate	HCO_3^{-}	me/l	0 – 10	me/l
Chloride	Cl^{-}	me/l	0 – 30	me/l
Sulphate	SO_4^{--}	me/l	0 – 20	me/l
NUTRIENTS[2]				
Nitrate-Nitrogen	NO_3-N	mg/l	0 – 10	mg/l
Ammonium-Nitrogen	NH_4-N	mg/l	0 – 5	mg/l
Phosphate-Phosphorus	PO_4-P	mg/l	0 – 2	mg/l
Potassium	K^{+}	mg/l	0 – 2	mg/l
MISCELLANEOUS				
Boron	B	mg/l	0 – 2	mg/l
Acid/Basicity	pH	1–14	6.0 – 8.5	
Sodium Adsorption Ratio[3]	SAR	(me/l)[1, 2]	0 – 15	

Figure 4.8: Recommended values for irrigation

Above are the recommended ranges for safe irrigation.

4.6.1 Calcium Analysis

Table 4.6.2 Calcium Analysis

Location	Ion concentration initial(ppm)	After treated with SCB(ppm)	After treated with rice husk ash(ppm)	After treated with Tea refuse (ppm)
Kalpitiya inlet	424	27.61	20.14	10.85
Kalpitiya Tank	408	42.25	1.02	0.98
Anuradhapura Madawachchiya	512	23.21	1.43	0.12
Reduction%		**91-94**	**95-99**	**98-100**

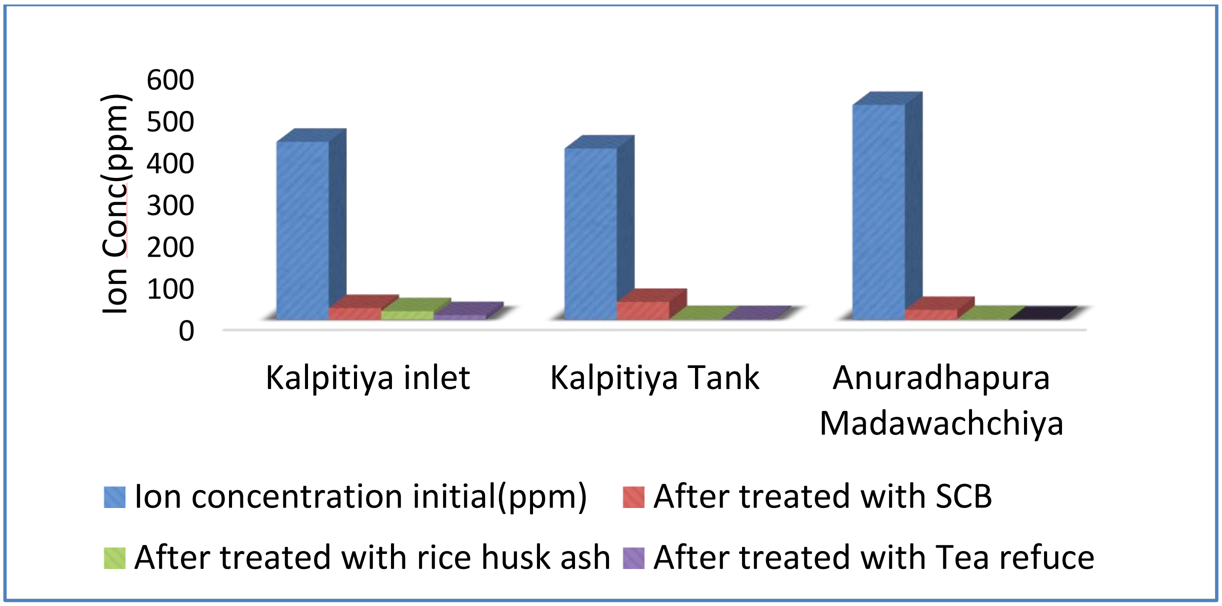

Figure 4.9: Calcium Ion Concentration reduction with Adsorbents

4.6.2 Chloride Analysis

Table 4.6.3 Chloride Analysis

Location	**Ion concentration initial(ppm)**	**After treated with SCB(ppm)**	**After treated with rice husk ash(ppm)**	**After treated with Tea refuse(ppm)**
Kalpitiya Inlet	788	600	510	620
Kalpitiya Tank	640	520	480	520
Anuradhapura Madawachchiya	297.2	190	92.1	200
Reduction%		**23-35**	**25-69**	**2-25**

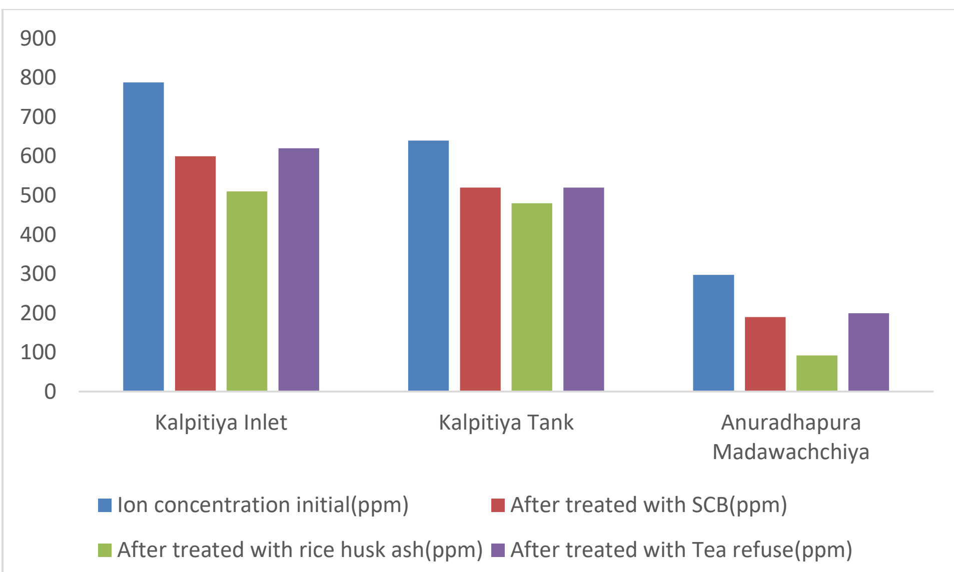

Figure 4.10: Chloride Ion Concentration reduction with Adsorbents

4.6.3 Fluoride analysis

Table 4.6.4 Fluoride Analysis

Location	**Initial Ion concentration initial(ppm)**	**After treated with SCB(ppm)**	**After treated with rice husk ash(ppm)**	**After treated with Tea refuse(ppm)**
Kalpitiya Inlet	10	0.56	1.50	6.02
Kalpitiya Tank	6.8	0.28	1.02	5.4
Anuradhapura Madawachchiya	8.8	0.42	1.53	6.5
Reduction%		***94-98***	***82-86***	***negligible***

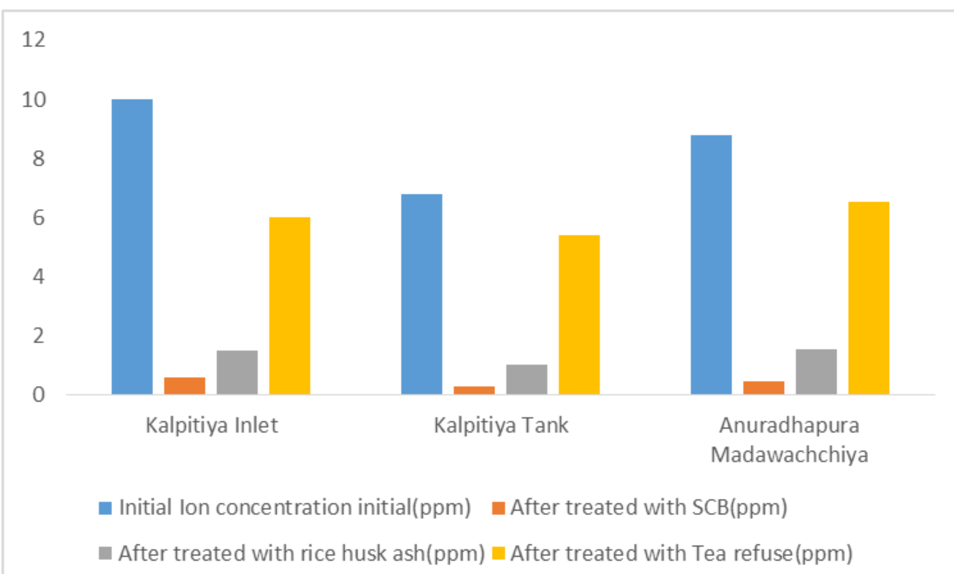

Figure 4.11: Fluoride Ion Concentration reduction with Adsorbent

4.6.4 Ammonium Ion Analysis

Table 4.6.5 Ammonium Analysis

Location	Ion concentration initial(ppm)	After treated with SCB	After treated with rice husk ash	After treated with Tea refuse
Kalpitiya Inlet	4.8	1.20	4.24	3.08
Kalpitiya Tank	4	0.99	3.02	3.08
Anuradhapura Madawachchiya	2	0.52	1.52	1.23
Reduction%		**74-76**	**1-2**	**1-2**

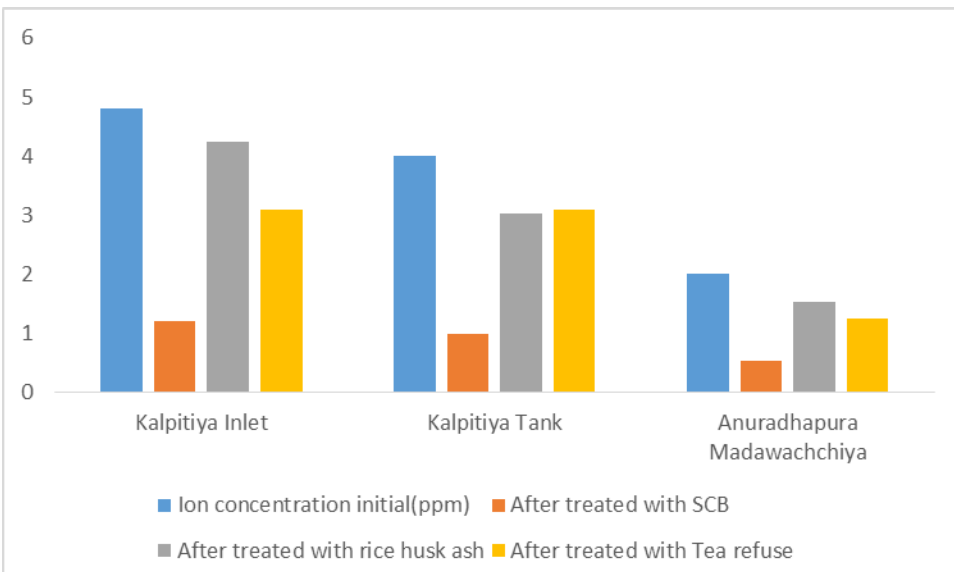

Figure 4.12: Ammonium Ion Concentration reduction with Adsorbents

4.6.5 Nitrate Analysis

Table 4.6.5 Nitrate Analysis

Location	**Ion concentration initial(ppm)**	**After treated with SCB**	**After treated with rice husk ash**	**After treated with Tea refuse**
Kalpitiya Inlet	262.4	25.8	12.44	99.20
Kalpitiya Tank	188	25.2	24.8	80.8
Anuradhapura Madawachchiya	148.4	14.02	13.12	92.80
Reduction%		**86-90**	**86-95**	**57-62**

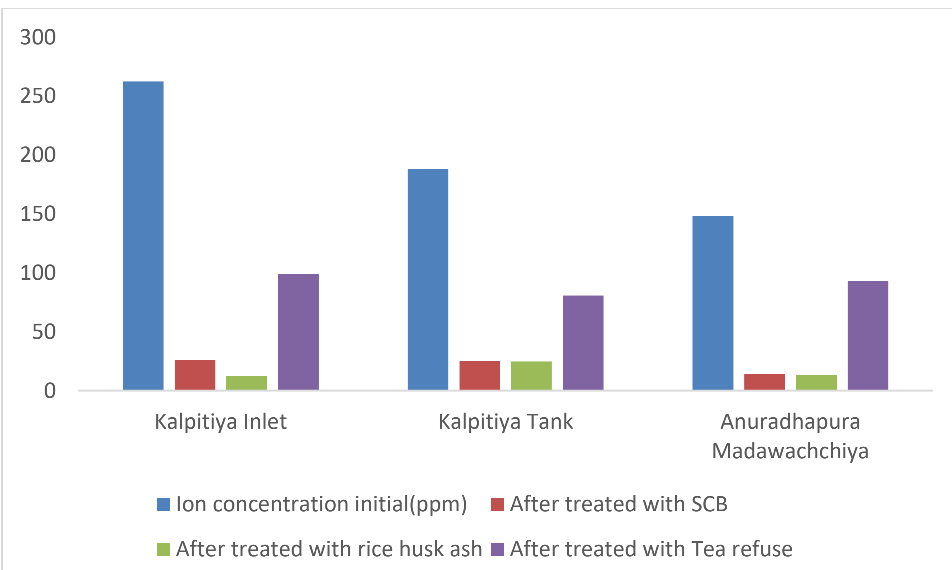

Figure 4.13: Nitrate Ion Concentration reduction with Adsorbents

4.6.6 Sodium Analysis

Table 4.6.6 Sodium Analysis

Location	Initial ion concentration (ppm)	After treated with SCB(ppm)	After treated with Partially Burn Rice Husk(ppm)	After treated with Tea Refuse (ppm)
Kalpitiya Inlet	1129	52.32	38.83	33.43
Kalpitiya Tank	878	43.12	22.32	21.28
Anuradhapura Madawachchiya	380	50.28	38.83	35.72
Reduction%		86%-97%	89%-99%	90%-99%

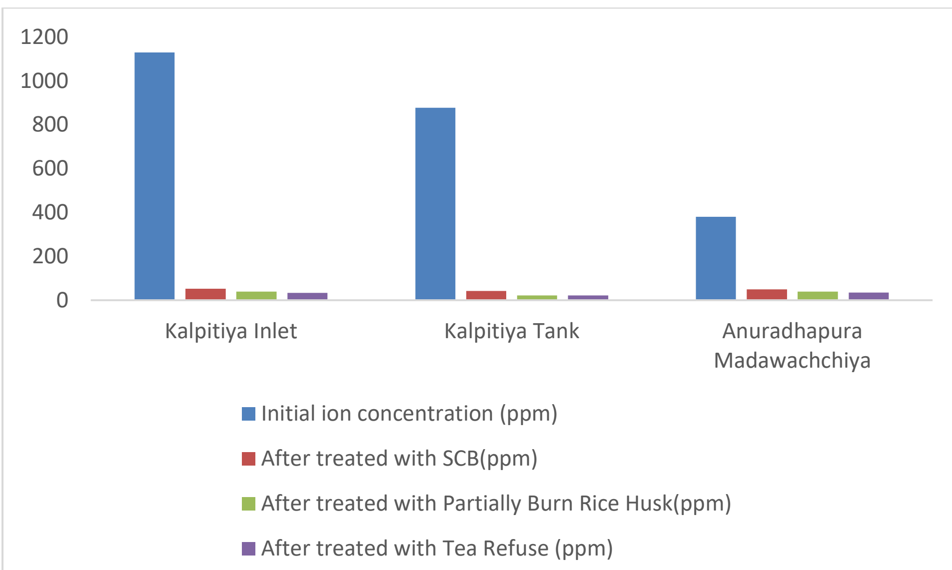

Figure 4.14: Sodium Ion Concentration reduction with Adsorbents

4.6.7 Magnesium Analysis

Table 4.6.7 Magnesium Analysis

Location	Initial ion concentration (ppm)	After treated with SCB(ppm)	After treated with Partially Burn Rice Husk(ppm)	After treated with Tea Refuse (ppm)
Kalpitiya Inlet	400	38.28	15.18	8.28
Kalpitiya Tank	380	30.98	3.23	2.21
Anuradhapura Madawachchiya	520	42.28	2.28	1.82
Reduction%		90%-91%	96%-99%	97%-99%

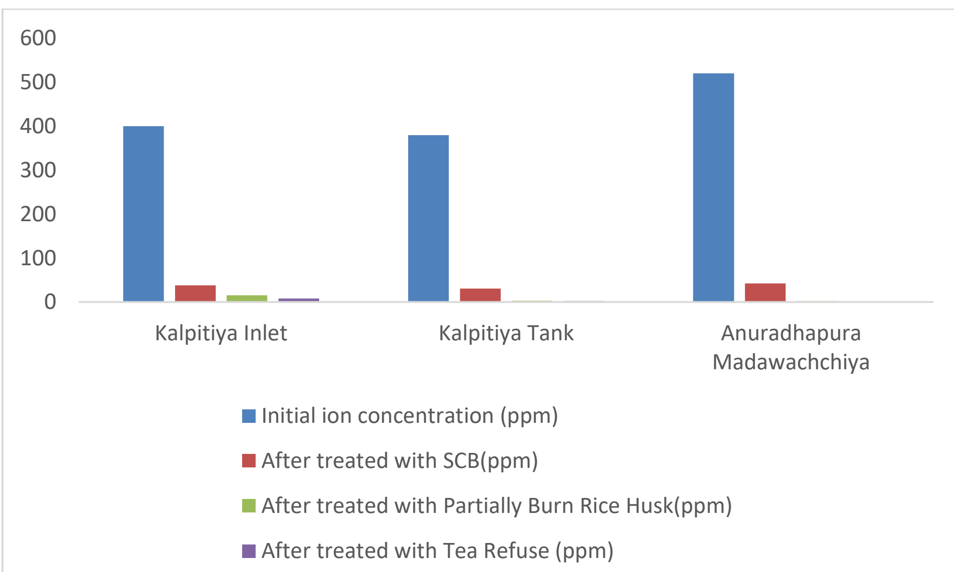

Figure 4.15: Magnesium Ion Concentration reduction with Adsorbents

Sugar Cane Bagasse mainly composed of lignin, cellulose, hemicellulose with a capacity to bind with metal cations [9].

Sugar Cane Bagasse and Tea refuse has the capability of binding with metal cations due to presence of oxygen donor atoms of methoxy, carboxyl and hydroxyl groups. However binding of metal ions on to the adsorbents basically due to ion exchange mechanism.

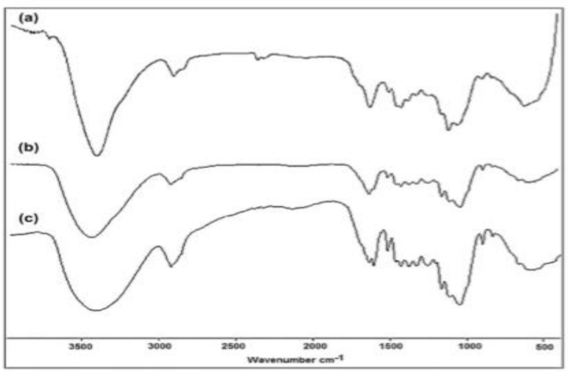

Figure 4.16:FT-IR spectra of (a) SCB, (b) SCB-Pb(II), and (c) SCB-Na(I) phases [22].

This proves that metal cations like Na^+ absorption basically occurs through ion exchange mechanism due to occurrence of hydroxyl and carboxylic groups.

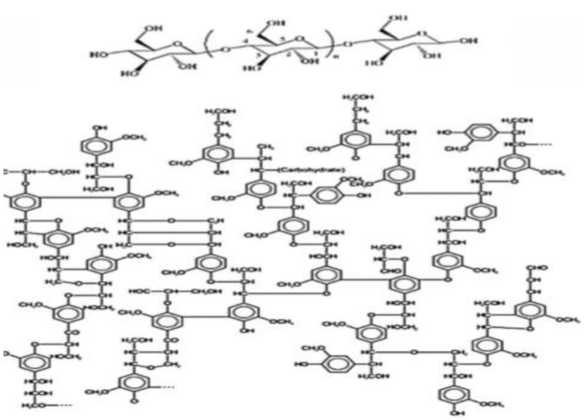

Figure 4.17: Chemical structure of (a) cellulose and (b) lignin in SCB [22].

Cellulose have hydroxyl groups and lignin have hydroxyl phenolic group which can selectively adsorb Ca^{2+} and Mg^{2+} ions [12]. Sugar Cane Bagasse has large surface area and large number of pores where anions can locked.

Rice Husk contains about 96% silica. When partially burned, it converting to H_2SiO_3 acid which shows high affinity to metal cations. Partially Burn Rice husk contains large number of pores and a large surface area with potential to adsorb ions. Average pore radii of a Partially Burn Rice husk ash is 6.14nm.pore volume is 0.1 cm^3g^{-1} [10].

Partially Burnt Rice Husk Ash contains 47.86% of carbon, 2.37% of hydrogen.32% of oxygen, 0.68% of nitrogen and 2.66m^2g^{-1} of specific surface area. Partially Burnt Rice Husk shows unique chemical properties due to incorporation of silica to its chemical structure [28].

4.6.8 Adsorption of Salinity ions

- Calcium

All adsorbents have higher affinity to adsorb calcium than Sodium. This can be related higher Ca valency or charge as compared to Na [29]. Adsorption of Calcium is mainly due to ion exchange mechanism.

Sugar Cane Bagasse removing Calcium in the range of 91% - 94%.Partiallyl Burnt Rice Husk reducing it in the range of 95% to 99% and Tea refuse reducing Ca in the range of 98% to 100%.

Tea refuse has the highest capability for bind with Ca. Tea refuse is compose of phenolic groups due to this calcium is adsorbed and releasing H in to the water.

Sugar Cane Bagasse also adsorb Ca due to presence of hydroxyl, phenolic groups and large number of pores.

Kalpitiya Samples have Ca in the range of 400 ppm to 425ppm.It's not safe to irrigation hence it reduces to safer range by these adsorbents.

- Chloride

As shown in tables all adsorbents didn't have high ability in Cl adsorption while high adsorption belongs to Partially Burn Rice Husk. But it showed different adsorption behaviors in Kalpitiya saline water samples and Anuradhapura saline water samples. It adsorb the Chloride 69% in Anuradhapura water sample which has the lowest EC value and it reducing Chloride in the range of 25%-35% in Kalpitiya water samples. This may due to initial ion concentration. Chloride generally less reactive than Fluoride. Initial Cl concentration of Kalpitiya samples 3 times higher than Anuradhapura Samples.

Adsorbents are adsorb Fluoride more than chloride because F^- have high water solubility than Cl. Hydrated ionic radii of Cl is higher than F^- and NO_3^- due to this pores cannot locked up more Cl ions. Hence the adsorption mainly due to large surface area and large number of pores in Partially Burn Rice Husk and Sugar cane Bagasse. Sugar Cane Bagasse removing cl in the range of 23%-25%. Tea Refuse has the lowest capability to adsorb Cl because it didn't have large surface area and pores. Cl showed low tendency to be adsorbed by those adsorbents.

- Fluoride

Sugar Cane Bagasse and Partially Burn Rice Husk Showed high affinity to adsorb Fluoride. Sugar Cane Bagasse adsorb F in 95% and Partially Burn Rice Husk removing Fin 82%-85%.

F have high water solubility than other anions. The adsorption process mainly due to pores and large surface area of Sugar Cane Bagasse and Partially Burn Rice Husk. Tea refuse showed a very low affinity to adsorb fluoride. It may be due to low surface area.

- Nitrate

Nitrogen is an important plant nutrition and it stimulate plant growth .But the excess will cause problems. Most readily available forms are nitrate and Ammonium. Usually Nitrogen content should be less than 5 mg/l in ground water. When water containing >50 mg/l of N almost no fruiting occurred in fruit plants such as grapes, Avocado[30] .In saline water samples collected from Anuradhapura and Kalpitiya, nitrogen content was forty times higher than 5mg/l.

Sugar Cane bagasse and Partially Burn Rice husk showed high affinity to adsorb nitrate ions. Partially Burn Rice Husk adsorb the Nitrate in the range of 90% to 95%.Sugar Cane Bagasse reducing it in the range of 86% to 90%. Tea refuse adsorbing No_3^- in the range of 57%-62%. All adsorbents had a higher tendency to adsorb NO_3^- adsorption compared to Cl.

- Ammonium

Only Sugar Cane Bagasse showed a high affinity to adsorb NH_4^+ .It adsorb it in 75%. The initial Ammonium ion concentration was 2ppm-4.8ppm.Sugar Cane Bagasse reducing it in the range of 0.99-1.20. All the adsorbents adsorb less amount of NH_4^+ than Ca, Mg and Na due to lower concentration of NH_4^+ in the saline water. Partially Burn Rice Husk adsorb it in the range of 1%-2%.That may be due to its pores and surface already saturated from other cations such as Ca ,Mg , Na. Tea refuse showing the lowest affinity to adsorb ammonium ions.

- Magnesium

All the Adsorbents showed great affinity towards Mg. Although all adsorbents adsorb less Mg than Na due to lower concentration of Mg in saline water. In Anuradhapura saline water samples Ca and Mg concentration is higher than Na concentration. But in Kalpitiya Na concentration is higher than Ca and Mg. Hence on Kalpitiya Samples adsorb low Mg than Na.

Sugar Cane bagasse adsorbed Mg in the range of 90%-91%. Tea refuse showed the highest affinity to adsorb Mg and it adsorb Mg in the range of 96%-99%.Partially Burn Rice Husk removing the Mg in the range of 96%-99%.

- Sodium

All the adsorbents showed high affinity to adsorb Sodium. In kalpitiya samples Na concentration is higher than other cations. Hence the adsorbents also adsorb Na at a great amount. All the adsorbents adsorb it in the range 95%-99% fro, Kalpitiya saline water samples. Tea refuse showed the highest affinity towards removing Na from saline water. Tea Refuse reduced Na from 1129 ppm to 33.43 in highest EC value sample.

In Anuradhapura samples Na concentration is lower than Ca and Mg. Hence potential of adsorbing Na is lower. Adsorbents Adsorb Na in the range of 86%-90% from Anuradhapura saline samples.

4.6.9 Bioassay using chili seeds

Bio Assay is an assessment of a biological substance and also an analytical method technique to measure potency of a substance.

- Plant Bioassay

A plant bioassay is a simple, accurate and direct method of determining if it is safe to grow plant crops with treated water.

The filtrate water used for irrigation of Chilies (*capsicum annum*). Growing Chili can be seen in dry Zone in Sri Lanka. Tap water (EC-0.25dS/m) used as a control and the improvement of growth of plants was measured by the height of plant and surface area of leaf.

Plate 4-2: After 7 days of incubation (Seeds treated with Saline water)

No growth observed after 7 days. It indicates almost no growth occurred when an EC Value of water >8 was continuously used. But in normal agriculture fields they got water not only from agro, but wells rain water also aid in agriculture. At the same time the EC value of ground water is not constant and it's varying due to various reasons such as temperature, rainfall. That may be the reason for slow growth or reduction of growth rate of crops in dry zone.

Plate 4-3: Control (Treated with Tap water)

The seeds were treated with tap water (EC-0.25dS/m). The pH of the tap water was 6.54. All the seeds were germinated. The pH of filtrate was 6.08 According to the results the slight pH reduction has not affected to the growth of seeds.

Plate 4-4: Growth of seeds after 7 days treated with filtrate

The seeds were treated with filtrate showed 99% growth within 7 days. The pH of filtrate was 6.08.The filtrate samples have a good potential to enhance the growth of crops in dry zone.

Plate 4-5: The appearance of plant 1 which treated with tap water and plant 2-treated with filtrate (After 3 weeks)

After 3 weeks the height of plants and the area of leaf were measured.

Plant 1 –From the seeds which treated with tap water. The height of the plant was 10.4cm.The leaf area is slightly higher than the plant 2

Plant 2 –From the seeds which treated with filtrate. The height of plant was 10cm.

The growth of plants has been improved after removal of salinity using adsorbents. Hence those adsorbents are applicable for removal of salinity using bed sorption system.

5) CONCLUSION

In this study, it was analyzed the feasibility of agricultural wastes to reduce the salinity in large scale. Three samples were collected from Kalpitiya and Anuradhapura areas. The EC value of water was in the range of 8dS/m – 22 dS/m. The pH range was 6 -7.5.

In order to reduce salinity agricultural wastes such as sugar cane bagasse, tea refuse, partially burnt rice husk were investigated in a fixed bed sorption system. The maximum reduction of EC of water was measured and breakthrough curves were illustrated. In order to measure the effect of inlet ion concentrations, feed flow rate 8ml/min adsorbent bed height 19cm on the breakthrough characteristics of fixed bed sorption system were determined.

The column performs better at lower EC values with higher bed height and in the pH range of 6-7.It showed low efficiency towards extraction of salts at lower pH values (<5)

Those three adsorbents reduce the EC value of water in the range of 75%-85%.Among them tea refuse has the highest ability to reduce EC of water. It reduces it in the range of 80%-84%. Sugar cane bagasse reducing the EC in the range of 76%-80% and partially burnt rice husk reducing it in the range of 79%-82%.

The EC reduction of water basically due to removal of ions by adsorbents. Adsorption characteristics of adsorbents are different they showing different affinities for different ions. All the adsorbents showed high percentage of extraction towards metal cations such as Na^{+} ,Ca^{2+} and Mg^{2+}.All the adsorbents removing those metal ions in the range of 95% -99%.This occurs basically through ion exchange mechanism.

Sugar Cane Bagasse and Partially Burned Rice Husk showed high percentage extraction of No_3^- and F^- ions (85%-90%).Sugar Cane Bagasse adsorb the NH_4^+ in the range of 70%-75%. Partially Burned Rice Husk and Tea refuse adsorbing NH_4^+ and Cl^- at a negligible amount.

Anions adsorbing by Sugar Cane Bagasse and Partially Burned Rice Husk basically due to their large number of pores and high surface area.

According to the adsorption capacities measured through breakthrough curves Sugar Cane Bagasse has the highest adsorption capacity at every EC values. The volume of effluent (V_{eff}) can be calculated from the breakthrough curve data. It showed that Sugar Cane Bagasse has the highest V_{eff} Value. Hence using this column with Sugar Cane Bagasse can treat highest volume of salinity water.

According to the bioassay results the treated saline water has a potential to enhance the growth of plants.

The study was successful in removal of salinity in order to have sustainable food production.

Future Works

In this study mainly address the problem of high EC value of ground water in dry zone in order to enhance the growth of plants. Many different adaptations and experiments have been left for the future due to lack of time.

In this study only concern about the breakthrough curves for EC values. But it can apply for individual ions also to get adsorption capacity for each ions. It support to find out the exact effective time of adsorbents.

The ion analysis can be done for other saline ions such as SO_4^{2-}, CO_3^{2-}etc. It might help to find out the best solution to reduce salinity.

All the adsorbents which used for study were agricultural wastes hence all of them can regenerate. Hence in future studies can find out the regeneration time and effectiveness of regenerated adsorbents.

Each adsorbents showing different characteristics in adsorption process. They showing different affinities towards salinity ions. As an example Tea refuse showed highest affinity towards Ca^{2+} ions but the least affinity towards F^- ions. At the same time partially burned rice husk showed the highest affinity towards F^- ions.

Hence a mixture of adsorbents may have high potential to reduce salinity of water in order to enhance the growth of plants and crop yield. So in future it will be better to find out the best mixture of adsorbents to purify water in advance.

Rice cultivation is the most effected field due to salinity. Hence it will be better to use Rice for measure bioassay in future.

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Appendixes

Breakthrough Curve Analysis for Sample 1

Time(minutes)	Mean EC-Sugar Cane Bagasse(dS/m)	MeanEC-P.B Rice husk Ash(dS/m)	MeanEC-Tea Refuse (dS/m)
20	5.25	5.18	4.02
50	5.32	5.53	4.85
80	6.3	5.6	5.43
110	7.02	8.28	6.23
140	7.32	12.21	8.95
170	7.89	15.5	10.43
200	8.08	17.8	10.58
230	11.23	18.82	11.07
260	11.89	19.73	13.55
290	12.08	20.05	16.72
320	13.23	22.15	19.88
350	15.28	22.17	20.06
380	18.9		20.97
410	19.2		22.17
440	21.17		22.17
470	22.18		

Breakthrough Curve Analysis for Sample 2

Time(min)	EC-Sugar Cane Bagasse(dS/m)	EC-P.B Rice Husk Ash(dS/m)	EC-Tea Refuse(dS/m)
20	1.65	1.28	0.98
50	1.78	1.32	1.23
80	2.13	1.43	1.69
110	2.25	1.56	1.88
140	2.63	1. 62	3.42
170	2.89	1.89	3.68
200	3.12	2.13	4.02
230	3.48	3.26	4.32
260	3.65	3.45	5.48
290	3.96	3.73	5.65
320	6.02	5.68	5.83
350	6.58	6.56	6.02
380	6.82	7.08	6.23
410	7.06	7.65	6.89
440	7.24	8.05	7.08
470	7.45	8.08	7.65
500	7.79	8.08	8.05
530	7.98		8.08

560	8.02		8.09
590	8.08		
620	8.08		

Breakthrough Curve Analysis for Sample 3

Time(minutes)	EC-SugarCaneBaggase(dS/m)	EC-P.B Rice Husk Ash(dS/m)	EC-Tea Refuse(dS/m)
20	2.35	2.22	1.98
50	2.38	2.45	2.18
80	2.46	2.92	2.31
110	2.52	3.41	2.57
140	2.83	6.85	2.98
170	2.98	6.95	3.41
200	3.23	8.01	6.32
230	3.65	8.88	6.48
260	6.02	9.53	7.56
290	6.23	10.28	8.98
320	6.92	10.6	10.49
350	7.86	10.9	10.72
380	8.98	10.95	10.95
410	9.92		10.95

440	10.02		10.95
470	10.45		
500	10.92		
530	10.95		
560	10.95		