Concentration of I_2, Na, K, Mg and Fe^{2+} in Soils, Plants, Ash and Salt Samples of Selected Areas of Western Kenya

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Abstract: *Table salt is one of the most used food additives with a unique place in food consumption. The chemical and physical composition of traditional salts is not well understood. Two types of reeds from Lugari and Busia regions of western Kenya were studied to establish the concentration of selected nutrients and determine some of the factors affecting the micronutrient content. Cyperus papyrus and Typha latifolia reeds of Lugari and Busia regions respectively, grow in weak acidic soils of pH range from 4.9-6.5. It was observed that an increase in the soil's percentage clay content increases CEC while an increase in soil bulk density decreases the soil's CEC. Soil iodine was found to depend largely on depth, SBD, percentage clay clay and moisture. An increase in depth led to a decrease in iodine level in soil with the top soils (0-15 cm,) recording higher iodine content than sub-soils (15-30 cm deep). As iodine increased with increase in SBD and % clay, Fe^{2+} concentration increased with increase in depth in the dry season. There was higher concentration of iodine in Cyperus papyrus reeds from Bidimbidi than in Ululo during both the wet and dry seasons. The K content of T. latifolia was higher than that of C. papyrus with K levels increasing with increase in iodine concentration in both plants. Busia reeds had more Na and K than Lugari reeds for both the wet (2871.8 mg/kg > 2519 mg/kg) and the dry (367 mg/kg > 223 mg/kg) seasons. In the present study, Iodine, K, Na, concentrations increased with ashing process while a decrease in Mg was noted. The concentrations of K and Na were higher in soils than in plants with a Tf ranking order of Na > K > Mg > I for both Busia and Lugari regions. The order of decreasing concentration of the micronutrients in the salt was of the form Na> K >Mg for Busia while for Lugari it was K >Na >Mg. On average, Busia Cyperus papyrus salt had higher Na, pH and moisture content but lower K, 11,930 mg/kg, 10.3, 10.1 % and 3,736.2 mg/kg compared to Lugari Typha latifolia salt whose Na, K, pH and moisture are 3,943.8 mg/kg, 4,635.8 mg/kg, 9.7 and 0.8 % respectively. . Lugari salt samples had a Na:K ratio of 0.9 while Busia's C. papyrus salt had a Na:K ratio of 3.2. Comparing the Na: K ratio of the types of reed salts, T. latifolia has 0.85:1 while C. papyrus has 3.2:1 compared to 4:1 recommended by WHO 2006. From the results, Cyperus papyrus salt may be a better and ideal food salt than Typha latifolia.*

Keywords: Typha latifolia, Cyperus papyrus, Micronutrients

1. Introduction

Table salt is one of the mostly used food additive with unique place in food consumption (Soylak *et al.,* 2008). Its production is one of the most ancient and widely distributed industries in the world. The physical and chemical composition of salt produced from the various sources varies widely depending upon the climatic conditions, source, techniques, and processes adopted. Edible salt is biologically necessary because it provides two important macro elements of sodium and chlorine for human body. Furthermore, it improves food taste, could serve as a preservative, and elongates shelf life. Today most people have become accustomed to the taste of salt such that its consumption has increased despite the numerous diseases it is associated with like hypertension, cardiovascular and kidney diseases (Jean *et al.,* 2015). Because of the damage salt does on the human health, many consumers and especially in Africa prefer vegetable salt from ash obtained by burning plant parts which are expected to be potassium rich.

In East Africa, indigenous plant salt is still traditionally produced and consumed either by alimentary habit or for therapeutic reasons. It is used as a substitute of modern salt for atrophic gastritis, for icterus, to lower the blood pressure and as sedative against cough (Allaramadji, 2011).

Communities around the Lake Victoria such as the Samia/Luhya communities in Western province of Kenya, the Kwaya/Kurya communities of Mara region, Tanzania and the Basoga communities in Uganda are known to harvest and use traditional salts from different plants (Kabaija, 1989; King'ang'a, 2005). The main plant materials come from beans, (*Fassiola vulgaris)*, maize, (*Zea mays)* and papyrus reeds (*Cyperus papyrus* and *Typha latifolia* species) among others. Western Kenya is one of the regions where plant derived salts arelargely used with its salt being processed as ashes upon burning some plant materials (King'ang'a, 2005). In Lugari and Busia regions of Western Kenya, unrefined indigenous salts are obtained from papyrus reed plants (Keter *et al.,* 2011). This salt is especially used in foodstuffs like indigenous vegetables, meat, and other meals by the local people and constitutes one of the major ingredients in the local staple.The consumption of unrefined salts with unspecified elemental concentrations can have far reaching health consequences if such salts contain hazardous contaminants.

Several physical and chemical factors affect the micronutrients availability and uptake by plants from the soil. This includes: Soil organic matter, soil clay content, soil, temperature and moisture and soil pH. As soil pH increases, the availability of the micronutrients decreases

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due to the chemical reactions where the micronutrients are complexed. Apart from the total amount of micronutrient in the soil and the soil properties, the plant species and variety can also influence the availability of the nutrients in the growing plant and eventually in the food chain. For instance the availability of iodine as one of the micronutrients, in the absence of dietary seafood sources depends largely on its transfer from soil to food and fodder crops (Johnson *et al.,* 2002; Johnson, 2003). There is therefore a need to increase understanding of iodine behaviour in soils if the resulting implications for transfer to crops, human and livestock are to be understood. The lack of iodine in the soil and water and thus in food, leads to iodine-deficiency disorders, which include goiter and a wide spectrum of mental and intellectual defects with varying degrees of severity. This includes cretinism, paralysis, and deaf-mutism (Fuge, 2007). Iodine Deficiency disorders (IDD) can also lead to stunted growth and development, miscarriages, stillbirths, and infant deaths (Johnson, 2003).

This section of the study was aimed at assessing the level of some essential elements (Na, K, Mg, I and Fe^{2+}) in *Cyperus papyrus* and *Typha latifolia* reed salts. From the findings, values of estimate daily intake of the heavy metals in the salt samples were calculated to estimate the risk to human health. However, lack of knowledge of the elemental constituents of these reed salts often poses danger to consumers as some may contain toxic elements. Also, the dose rate of many of these reed plants is not well defined and left to the judgment of the users. Thus, screening of the elemental composition of these medicinal plants is highly essential. There are limited studies on the micronutrients content of reed salts from Western Kenya. Much focus has been on the status of metal content in edible vegetables, without considering the salt used in these vegetables.

1.2 Purpose of the study

The purpose of this study is to assess the concentration of selected micronutrients (I_2, Na, K, Mg and Fe^{2+}) in soils, plants, Ash and Salt Samples in soil habitats of reed plant species of the indigenous salts used in Lugari and Busia regions of Western Kenya. This is an attempt to fill in the knowledge gap regarding the availability of the micronutrients from the soil to the reed plant and consequently to the salt.

1.3 Materials and Methods

1.3.1 Study Area

The study area comprised of two sites: Lugari and Busia regions of Western Kenya. Two sites were selected from each region, Matete and Lugari villages of Lugari division, in Kakamega region and Ululo and Bidimbidi villages in Matayos division of Busia region of Western Kenya (Figure 1). These regions were chosen based on the common method of processing of unrefined indigenous crystalline salts and the different reed species used in processing of the indigenous salts. Two types of papyrus reeds were used in this study; *Cyperus papyrus* reeds (Matayos) and *Typha latifolia* reeds (Lugari). Lugari district comprises of three administrative divisions Likuyani, Matete and Lugari, with a total area of 670.2 km^2 where Lugari and Matete divisions are selected in Lugari district for study. Lugari lies at an altitude of 1840 m above sea level records a mean annual rainfall range of 900-2200 mm falling within the upper midland (UM) and lower midland (LM) agro-ecological zone. Busia district in Western region covers an area of 1,261.3 km^2, 137 km^2 of which is part of Lake Victoria basin. Busia lies at 1220 m above sea level, has a rainfall range of 1300-1800 mm falling under lower midland agro-ecological zone (AEZ).The district is divided into six administrative divisions, namely Nambale, Butula, Funyula, Budalangi, Township and Matayos. Matayos division was randomly selected for this study in Busia district (Republic of Kenya, 2002-2008a). A Global Positioning System (GPS) was used to obtain the grid references of the location of the study sites.
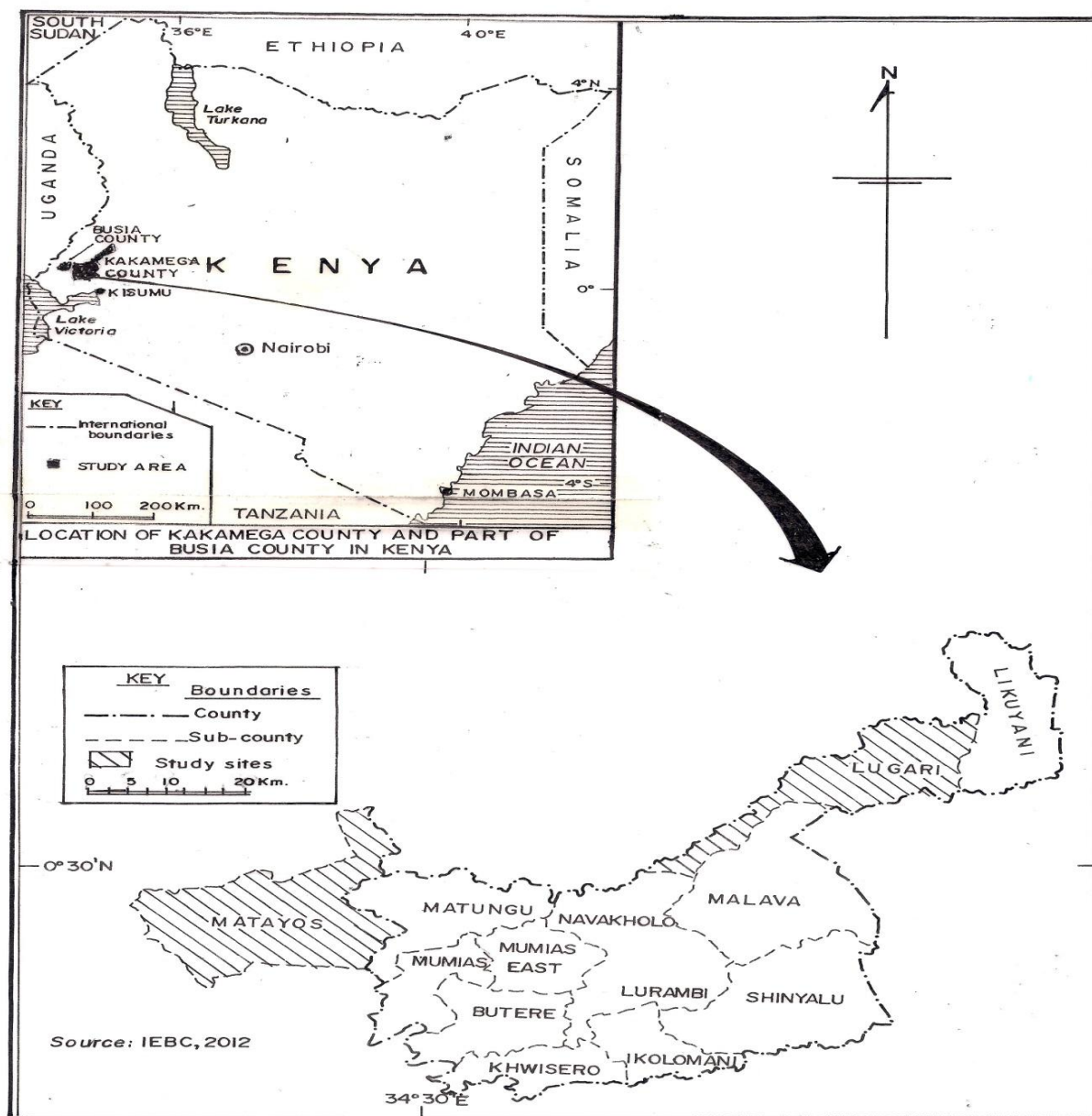
Figure 1: Map of Kenya Showing the sampling areas in Western Province

1.3.2 Sample Collection

Samples were collected from the selected sites in Lugari and Busia regions of Western Kenya, (Figure 1) using randomized method. The samples were collected during both the wet (March-Aug) and dry (Jan-March) periods between January 2012 and December 2013. Soil and plant samples were obtained from randomly selected sites in each region. Top-soil (0-15cm depth) and sub-soil (15-30 cm depth) samples were collected into separate polyethylene plastic bags from randomly selected sampling points within a 10 m square plot of landby the 5 points mixture method from a 10 m square plot of land (Provisional manual for soil survey related to dioxins, 1998). Approximately 0.5 kg (wet weight) of soil samples was scooped using a clean stainless steel auger and a corer for bulk density determination, while a mud (Dutch) auger was used to obtain the wet clay boggy soil for Busia soil samples since the place is swampy. One was taken from the center of the plot, and the others from points between 5 to 10 m in each of four directions, from the same sampling area. They were mixed to form one pooled soil for top-soil (0-15cm depth) and sub-soil (15-30 cm) samples respectively. From each of the above sampling sites used for soils, about 200 kg full growth stage (8 months) fresh reed samples were collected using a stainless steel knife and mixed as well to obtain a 1kg pooled sample per site. The plants were thoroughly washed with tap water to remove surface sand. From the same sampling areas, ash from reeds was collected from randomly selected homes, burnt from the reeds plants obtained from similar sampling sites as mentioned above. The salts were collected together with ash samples from respective study sites with the consent of local people. A total of 18 salt samples were collected from Busia sites and 15 samples from Lugari making a total of thirty three salt samples. The salt samples were collected using standard sampling methods (Gupta and Sinha, 2007) from randomly selected homesteads on burning of the above collected and well prepared reeds. Prepared salt samples were thoroughly mixed to ensure a uniform mixture. These were mixed to form a 500 g composite sample for each respective homestead. The samples were

packed in polythene bags for transportation. The packed soil, plant, ash and salt samples were stored in cool boxes (at 4 ^{o}C) and transported to the laboratory at Egerton University where they were preserved for further analysis.

1.3.3 Preparation and preservation
In the laboratory, portions of the cored soil samples were used for moisture determination. The rest of the soil samples were dried in the open in aluminium trays at ambient temperature for 6 days and gently disaggregated using a pestle and mortar where necessary. Samples were homogenized using the 'cone method'. Sieved soil was poured into a cone-shaped pile and strips from the cone base to the top used to build a new cone and the entire process repeated four times (Schumacher *et al.,* 2010). The homogenised soil samples were crushed and finely ground using a Moulinex coffee and spice mill, model 980. Solid ingredients were mixed using a 5 L ribbon blender from the Department of Soil Science, Egerton University. Finely ground soil samples were sieved through a 2 mm mesh, and then sealed in Kraft paper envelopes prior to analysis.

Plant samples were prepared according to the procedure described by Khan *et al.,* (2006). The plant parts were washed in fresh running water to eliminate dust, dirt, possible parasites or their eggs followed with deionized water. The plants were cut into pieces of about 10 cm^3, air dried in the open for 6 days. The dried plant samples were homogenized by grinding using a Retsch, Model PM400 agate ball miller. Finely ground samples were sieved with 2 mm mesh before being stored in labeled polythene bags at ambient temperature prior to analysis.

Ash samples were prepared by picking the unburned plant material, and packing the rest in polythene backs for further analysis.

1.4 Sample Analysis

The chemicals used during the entire study were of analytical grade. A series of standard metal solutions were prepared, as per the standard methods (AOAC, 1996) by appropriate dilution of the respective stock metal solutions. In general, reagents of the highest purity were used whereas for hydrates, fresh reagents were used.

1.4.1 Determination of pH in Soil and Salt samples
The pH of the soil suspension was measured using a JENWAY pH meter model 3505, at a temperature of 20.8 ^{o}C in triplicate. The pH meter which consisted of a combined glass electrode (Ag/AgCl; PHE 1004), had earlier been calibrated with pH 7 and pH 4 buffers beforethe analysis of the samples was carried out.

1.4.2 Determination of Soil Bulk Density
Using a steel core, an undisturbed flat horizontal surface in the soil was prepared with a spade at the depth of 15 cm and 30 cm. The steel ring was gently hammered into the soil. Excavation was done around the ring without disturbing or loosening the soil it contained and carefully removed with the soil intact. The soil core was weighed as it was found in the field and air dried. This weight was recorded and the core was placed into an oven at 105 ^{o}C to obtain oven dry

(OD) soil. The OD soil was weighed and the water content calculated by the volume of water (cm^3) divided by the total volume of soil (cm^3). Bulk density was calculated by the mass of OD soil (g) divided by the total volume of soil (cm^3). The volume of the ring was determined by measuring the height of the ring with the ruler in cm to the nearest mm, and the diameter of the ring to get the radius. Ring volume (cm^3) = 3.14 x r^2x ring height; (Soil volume = ring volume). To calculate the dry weight of the soil, the ovenproof container was weighed in grams (W_1). The soil was dried for 2 hours in a conventional oven at 105 ^{o}C. The dry soil sample was weighed to give (W_2); (Dry soil weight (g) = ($W_2 - W_1$) and p is the BD, equation 1;
For,

$$\text{Bulk Density} = \frac{(W_2 - W_1)_{(g)}}{(3.14 \text{ x } r^2 \text{ x h})_{(cm^3)}} 1$$

Where $(W2 - W1)(g) = soil \ OD \ (g)$

1.4.3 Determination of Soil Moisture content
The moisture content of the soil as a percentage of the dry soil weight was calculated using equation 2 below:$MC \% = (W_2 - W_1) - (W_3 - W_1)/(W_2 - W_1)X \ 100 \ 2$
Where:
W_1= Weight of tin (g)
W_2= Weight of moist soil + tin (g)
W_3= Weight of dried soil + tin (g)
The same procedure was repeated for salt samples using 5 g of the salt sample.

1.4.4 Determination of Loss on Ignition (LoI)
Triplicate samples of approximately 5 g oven-dried soil samples in silica crucibles were ignited in a muffle furnace for 16 h at 550 ^{o}C Crucibles were re-weighed after cooling and the % LOI was calculated.

### 1.4.5. Determination of Cation Exchange Capacity, CEC, by Direct Method
CEC is determined when 3 g of air dried soil (1 g peat) is leached with 60 mL 1 M NH$_4$OAc, pH 7, to saturate exchange sites with ammonium ions. Excess free ammonium ions are rinsed from the soil with isopropyl alcohol. The remaining ammonium ions held on cation exchange sites are replaced by leaching the soil with successive aliquots of a solution of 10 % KCl acidified to 0.005 N HCl. Ammonium is determined on the KCl leachate by colorimetry on a Lachat QuikChem 8500 Flow Injection Analyzer using the salicylate/nitroprusside method.

1.4.6Determination of the Concentration of Iodine in Soil, Plant, Ash and Salt Samples
Using an electronic analytical balance, (Shimadzu model AUY 120) 5 grams of the samples were weighed into 250 ml beakers. The sample was digested for iodine analysis using the wet digestion method (Błażewicz, 2012; Yadata, 2014). The liberated iodine was titrated with 0.005 M Sodium thiosulphate solution using 1ml of 1 % starch indicator near the end of the titration according to Ann (2012) and Lena, *et al*., (2015). The same procedure was repeated for dried plant samples, ash and salt samples for the determination of the concentration of iodine in plants, ash and salt samples respectively. From the redox reaction, based on the weight of the sample salt, 5 g, used to prepare the salt solution, the

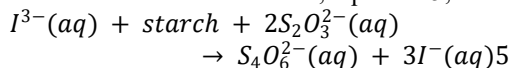iodate content was calculated in mg of iodate per kg of the salt (ppm).

Formation of iodine from the iodate in salt solution, equation 3;

$$IO^{-3}(aq) + 5I^-(aq) + 6H_2O(aq)$$
$$\rightarrow 3I_2(aq) + 9H_2O(l) \quad 3$$
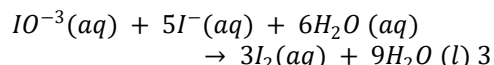
Formation of triiodide and blue complex with starch, equation 4;

$$I_2(aq) + I^- \rightarrow I^{3-}(aq) + starch \rightarrow blue\ complex \quad 4$$
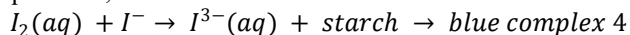
Reduction of iodide with thiosulfate, equation 5;

$$I^{3-}(aq) + starch + 2S_2O_3^{2-}(aq)$$
$$\rightarrow S_4O_6^{2-}(aq) + 3I^-(aq) 5$$

(Blue solution) (Colourless)

The overall reaction is presesnted in equation 6 below;

$$IO^{-3}(aq) + 5I^-(aq) + 6H_3O^+(aq) + 6S_2O_3^{2-}(aq)$$
$$\rightarrow 6\ S_4O_6^{2-}(aq) + 6\ I^-(aq) 6$$
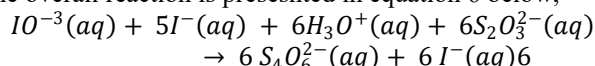
The overall reaction implies that one equivalent of iodate (IO^{3-}) reacts with 6 equivalents of thiosulfate. Therefore, in terms of iodate/iodine weight, one equivalent of thiosulfate means 35.667 grams of potassium iodate (FW KIO_3/6 =214/6 = 35.667), or 21.222 grams of iodine, knowing that potassium iodate contains 59.5 % iodine (35.667 x 0.595 =21.222).

The amount of iodate present in the samples is determined by redox titration using sodium thiosulfate solution, by first reacting the iodate (IO_3^-) with added iodide (I^-), under acid conditions to produce iodine, equation 7:

$$IO^{-3} + I^- + 6H+ \rightarrow 3I_2 + 3\ H_2O \quad 7$$
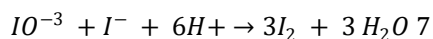
The resulting iodine which is highly soluble is titrated with 0.002 mol L^{-1} thiosulfate using 0.5% starch indicator solution as end-point indicator until the yellow/brown color of iodine becomes pale, equation 8:

$$3I_2 + 2S_2O_3^{2-} \rightarrow 2\ I^- + S_4O_6^{2-} \quad 8$$
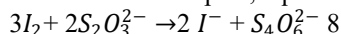
1.4.7 Determination of Na and K metals in Soil, Plant, Ash and Salt samples

5 grams of the sieved soil samples, plant, ash and salt samples were digested for K and Na analysis using the wet digestion method i.e 1:2 ratio of 10 ml of 1:1 HNO_3 and 20 ml of 1:4 HCl, for 30 minutes hot plate until the production of red NO_2 fumes had ceased. The digested samples were filtered using a Whatman No. 1 filter paper and filtrate made to 50 ml mark and kept for analysis. The concentrations of Na and K in soil, plant and ash digests were determined spectrophotometrically, using a corning flame photometer, Corning model 410.

1.4.8 Determination of Iron (II) content in salt samples

Phenanthroline method was used for determination of iron (II) in the salt samples (Lipson et al., 2010). A UV-VIS spectrophotometer, single beam, Nova spec II model was used, at a wavelength of maximum absorbance, λ_{max} =508 nm. A series of standard ferrous ion solutions corresponding to 0.1, 0.2, 03, 0.5, 1.0, 1.5 and 2.0 ppm respectively were

used. The concentration of the samples was determined with the help of the calibration curve.

1.5 Method Validation

1.5.1 Analytical wavelength (nm), detection limits (µg/mL) and regression data.

The analytical wavelength (nm), detection limits (mg/kg), regression equation and correlation coefficient are presented in **Error! Reference source not found.**. The results indicate that linearity for all trace elements was good, with correlation coefficient ≥ 0.9998. Detection limits ranged from 0.0005 to 0.0100 mg/kg.

1.5.2 Accuracy and Precision

In order to verify the accuracy and precision of the method, reed samples were randomly chosen to evaluate the precision of method (n = 6) and the results were given in (**Error! Reference source not found.**). The results indicate good precision under the analytical conditions used since the relative standard deviations were < 5 % and the method was precise.

1.5.3 Recovery of developed method

A recovery work was carried out to demonstrate the validity of the method. *Cyperus papyrus* reed salt was selected to detect the recovery through quantity added. *Cyperus papyrus* reed salt samples were prepared and determined using the recommended procedure. From **Error! Reference source not found.**, the results were considered satisfactory because recovery ranged from 91 to 102.0 %.

1.5.4 Statistical analysis

The data were based on three replicates and subjected to analysis of variance. Statistical analysis was done using SAS, GENSTAT and SPSS 21.0 (SPSS Inc., Chicago, IL, USA). Means were calculated and compared using t-test , standard errors of each individual nutrient of the samples were computed, and variations among the species were evaluated by least significance difference (LSD) at 5 % level of probability (p<0.05). A Randomized Completely Block Design with Analysis of covariance (ANOVA) was done for nutrients iodine, iron, magnesium, potassium and sodium and mean separation done by Fischers protected LSD for significance. A multivariate comparison of means as well as Regression was done to establish each independent variable's contribution to the change in elemental contents of the salts. Correlation was done to establish the relationship between soil-plant-salt elemental concentrations.

1.6 Results

1.6.1 Results of Soil pH, Bulk density, texture and average loss on ignition

Error! Reference source not found., gives results of selected soil properties pH, % moisture, % nitrogen, CEC, soil texture, LOI, phosphorus content and SBD for soil slurries and soil collected from Busia's swamp and the banks of River Nzoia respectively. The soil pH, texture, bulk density and average loss on ignition at depth, 0-15 cm and 15-30 cm respectively, were measured in the samples.

Table 1: Selected soil Properties of Busia and Lugari Soils.

Sampling area	Ululo	Bidimbidi	Lugari	Matete	cv
pH	6.4±0.01 [a]	6.2±0.03 [b]	6.3±0.01 [c]	4.9±0.02 [d]	1.2
% moisture	57.5±0.03 [a]	66.5±0.07 [b]	42.2±0.20 [c]	22.2±0.02 [d]	0.1
% N	0.3±0.01 [a]	0.3±0.002 [b]	0.2±0.01 [a]	0.2±0.01 [b]	27.4
CEC meq/100g	165.0±15.0 [a]	91.0±1.00 [b]	92.0±2.00 [c]	86.8±0.11 [d]	0.1
SBD, g/cm3	0.3±0.01 [a]	0.3±0.02 [b]	0.3±0.01 [c]	0.3±0.01 [d]	0.1
% clay	23.8±3.80 [a]	18.9±0.93 [b]	10.5±0.50 [c]	11.0±1.00 [d]	0.4
% sand	70.3±9.30 [a]	60.9±0.05 [b]	88.8±0.15 [c]	88.9±0.28 [d]	0.1
% silt	5.9±5.50 [a]	19.6±0.20 [b]	1.5±0.09 [c]	1.4±0.02 [d]	1.0
% LOI	59.3±4.30 [a]	61.0±1.00 [b]	41.5±0.50 [c]	42.5±0.50 [d]	0.1
P, mg/kg	16.7±0.79 [a]	12.3±0.01 [b]	18.3±5.79 [c]	6.7±5.79 [d]	0.5

Results are expressed as means ± standard error of the mean (MSE) for 3 determinations. Within rows, means with different alphabets are statistically different at p<0.05 by ANOVA and LSD test. n=12, lsd=0.0836; s.e.d=0.0396;

1.6.2 Concentration of Iodine, K and Na in Soils and Plants Samples

The level of micronutrients (Iodine, Na, K and Fe) were determined in various soil and plant samples collected in Busia and Lugari regions of Western Kenya are presented in Table 2 and

Table 3 respectively.

Table 2: The concentrations of K, Na and Iodine soil samples collected during the dry and wet seasons from Busia and Lugari Regions at varying depths

sampling area	depth cm	DRY SEASON				WET SEASON		
		Concentration, mg/kg						
		pH	K	Iodine	Na	pH	K	Na
Ululo	0-15 cm	6.5± 0.34	640.3±19.85	208.8±0.95	1671.1±24.05	6.9±0.02	269.9±8.24	2025.3±6.25
	15-30 cm	6.4±0.41	560.9±19.85	124.0±1.16	897.3±0.001	6.8±0.03	262.6±0.69	1562.8±2.25
Bidimbidi	0-15 cm	6.2±0.73	680.0±13.23	170.3±5.72	850.6±13.34	6.9±0.01	274.0±2.83	1011.0±0.50
	15-30 cm	6.1±0.67	349.2±19.84	112.7±7.34	470.3±6.67	6.7±0.01	272.7±4.22	1123.8±13.75
Matete	0-15 cm	6.3±0.51	964.4±20.92	139.6±9.15	603.7±42.19	7.1±0.02	266.8±6.46	1060.5±7.00
	15-30 cm	6.3±0.50	640.3±159.76	107.1±4.22	640.4±61.67	7.1±0.03	267.7±7.31	1064.8±11.25
Lugari	0-15 cm	6.1±0.01	964.4±33.08	86.4±0.56	510.3±6.68	6.9±0.02	260.4±0.02	1248.5±3.8
	15-30	4.3±0.02	865.2±33.08	91.1±1.11	470.3±6.67	4.8±1.02	0.25±0.10	24.25±3.08

Results are expressed as means ± standard error of the mean (MSE) for 3 determinations; statistically different at p<0.05 by ANOVA and LSD test. n=12

Table 3: K, Na and Iodine concentrations in plants from Busia and Lugari regions sampled during the dry and wet season, at 95.0 % confidence level.

Sampling Point	Concentration, mg/kg for the wet season			Concentration, mg/kg for the dry season		
	Iodine	K	Na	Iodine	K	Na
Ululo	21.4±5.19	3279.8±9.23	286.8±19.85	21.2±5.64	442.5±4.80	8677.7±7.83
Bidimbidi	22.0±2.00	2055.9±66.15	783.8±13.34	36.8±3.58	292.1±5.81	4024.5±18.05
Matete	27.6±3.83	2452.9±11.79	1235.3±12.15	23.8±3.05	209.6±4.42	1767.3±9.72
Lugari	7.8±5.63	2618.2±60.99	1360.9±9.06	4.2±0.14	263.1±0.002	1085.7±7.43

Results are expressed as means ± standard error of the mean (MSE) for 3 determinations; statistically different at p<0.05 by ANOVA and LSD test. n=12

1.6.4 pH, Moisture, and concentration of Micronutrients (iodine, Na, K) in Salt Samples.

Salt samples were analysed for pH, micronutrients and the heavy metals and the findings are represented in

Table 4 for the wet and dry seasons respectively.

Table 4: Concentration of Micronutrients iodine, Na, K and Fe^{2+} in Salt Samples for the wet and dry seasons

Dry season	Sampling area	pH	% Moisture	iodine	Fe^{2+}	Na	
	Lugari	9.7±0.21	0.5±0.21	1.2±0.50	1.1±0.001	3398.4±43.28	
	Matete	9.8±0.01	1±0.05	1.4±0.60	1.0±0.002	5957.2±24.00	
	Ululo	10.4±0.10	8.2±1.80	0.2±0.10	1.0±0.00	12650.1±47.09	
	Bidimbidi	10.0±0.30	15.6±0.001	1.6±0.90	1.0±0.002	15752±46.60	
Wet season	Sampling area	pH	% Moisture	iodine	Fe^{2+}	Na	K
	Lugari	9.7	0.5±0.25	1.3±0.65	1.1±0.01	3016.8±73.39	4305.2±8.75
	Matete	9.8	1.0±0.05	0.6±0.28	1.0±0.01	3403.3±9.12	4966.7±59.36
	Ululo	10.2	8.7±1.52	1.6±0.79	1.0±0.01	9081.9±26.41	3114.4±36.38
	Bidimbidi	10.5	15.6±4.27	0.1±0.01	1.0±0.01	10419.2±29.35	3809.0±87.51
	Ululo	10.6	11.2±0.22	2.1±1.06	1.0±0.03	10125.6±6.13	3974.4±6.45
	Ululo	10.5	4.9±0.34	2.1±0.65	1.0±0.01	9929.9±10.93	3809.0±7.56
	Bidimbidi	9.6	15.9±2.87	0.4±0.24	1.1±0.01	10517.0±159.79	3974.4±86.45
	Lugari	9.7	0.5±0.25	1.3±0.70	1.1±0.01	3016.8±73.40	4305.2±75.10
	Matete	9.8	1.0±0.21	0.6±0.30	1.0±0.01	3403.3±9.10	4966.7±9.40
	Ululo	10.4±0.10	8.2±1.80	1.9±0.40	1.0±0.01	9636.5±40.34	3632.6±26.20
	Bidimbidi	10.0±0.30	15.6±0.01	0.2±0.10	1.0±0.03	10468.3±15.58	3891.7±13.50

Results are expressed as means ± standard error of the mean (MSE) for 3 determinations; statistically different at p<0.05 by ANOVA and LSD test. n=12;

1.6.5 Comparison of Micronutrients for Reeds and Commercial Salts
Results for reed salts were compared with commercial salts obtained from the supermarket. A total of four types of commercially available table salts were analysed for essential and non-essential elements and micronutrients,

The results are presented in table below

Table 5: Comparison of Typha latifolia salt, Cyperus papyrus Salt and Commercial Salts

	Type of salt					
	T. latifolia salt	*C. papyrus* salt	HSSA	SSSA	KNSA	TCSA
Element	Concentration, mg/kg					
iodine	1.1±0.18	0.9±0.31	19.5±4.79	7.4±0.89	95.6±1.20	69.4±2.39
Fe^{2+}	1.0±0.01	1.0±0.001	2.3±0.03	0.2±0.03	ND	ND
Mg	52.5±3.22	29.2±1.49	156.5±4.48	48.1±0.17	38.9±0.17	15.4±3.45
Na	3943.8±7.34	9969.2±0.01	20099.6±33.54	21285.6±77.20	18913.6±59.07	23855.1±33.94
K	4635.8±0.01	8813.5±7.33	10047.0±13.4	3819.0±0.01	4294±67.19	4769.0±0.01
% Ratio of salt	4.0	0.003				
% Ratio of salt to raw material	10.0	0.125				

Results are expressed as means ± standard error of the mean (MSE) for 3 determinations; statistically different at p<0.05 by ANOVA and LSD test. n=12; ND= Not detected; HSSA= herbal sea salt; SSSA; KNSA= Kensalt; TCSA=Top Chef salt.

1.6.6 Soil-plant transfer coefficient or Bio-accumulation Factor (BAF)
In the present study, the Transfer factors for different heavy metal from soil to reed plants, calculated from equation 3 (section 2.3.4) are presented in Table 6.

Table 6: Transfer factor of micronutrients from soils into reed samples

Transfer factors for respective elements				
Element/sampling point	Iodine	K	Na	Mg
BRPU	0.128	4.294	2.912	1.159
BRPB	0.208	2.980	2.783	1.047
LRPM	0.208	2.489	1.782	1.935

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LRPL		0.068	2.757	2.172	1.882

Results are expressed as means ± standard error of the mean (MSE) for 3 determinations; statistically different at p<0.05 by ANOVA and LSD test. n=12

1.6.7 Estimation of the dietary intake of the selected metals (EDIM)

In the present study, estimation of the dietary intake of the selected metals was calculated from and the results are presented in

Table **7**.

Table 7: Estimation of the dietary intake of the selected metals (EDIM) and the permissible limits

	Mean conc. Mg/kg		DI		PTWs		EDIM	
Plant species	Na	K	Na	K	Na	K	Na	K
Typha latifolia	3732	3734	18660	18670	130619	130689	311	311
Cyperus papyrus	13101	2762	65507	13811	458547	96679	1092	230
HSSA	20100	10047	100498	5235	703486	36646	1675	87
SSSA	21286	3819	106428	1910	744994	13367	1774	32
KNSA	18914	4294	94568	2147	661977	15029	1576	36
TCSA	23855	4769	119276	2385	834930	16692	1988	40
Permissible limits			2300 mg/dy	3500 mg/dy				

[a] WHO/FAO (1999); [b]WHO/FAO Kihampa *et al* (2011);HSSA- Herbal salt; TCSA - Top-chef table salt; KNSA - Kensalt; SSSA - Sea salt naturals;

1.7 Discussion

1.7.1 Selected properties of soil samples

According to the classification of soils on the basis of pH (1:5 soil: water), both *Cyperus P*. and *Typha L*. reeds of Lugari and Busia regions respectively, grow in weak acidic soils of pH range from 4.9-6.5, (**Error! Reference source not found.**). The pH values are in the range of 6.2 - 6.4 with a mean of 6.3 for Busia soils and 4.9-6.3 with a mean of 5.6 for Lugari soils, implying that Busia soils are weakly acidic compared to Lugari soils that are more acidic, although both have an average pH of 6.0. The pH of Busia soil in both sampling points, Ululo (6.5) and Bidimbidi (6.2), was higher than that in Matete (4.9), but almost the same with Lugari (6.3) in Lugari's region. This could probably be due to the presence of the swamps mulching effect and also to the dilution effect during the wet season. From appendix 6, it is clear that pH is dependent on season, depth and location of

Table 1. The % CEC is dependent on % clay and SBD (p$_{values}$ of 0.021 and 0.049 < 0.05) and positively contributes to the CEC in soil (coeff 3.39 and -3532 respectively), App. 32. Busia soils on the other hand, had a bulk density of 0.316-0.322 g/cm^3 with a moisture content of 57.5-66.5 %, while the organic matter content indicated by loss on ignition (LOI) was 59.3-61 %. Lugari samples had a bulk density of 0.315-0.322 g/cm^3 with a moisture content of 22.2- 42.2 % and LOI of 41.5-42.5 %. Organic matter content in Busia soils is higher than that of Lugari due to the presence of increased humus as a result of high plant material decomposition compared to Lugari region.

sampling, p<.0001. pH dramatically affects the CEC of soil by limiting the available exchange sites at low pH. H$^+$ bind to soil particles tighter than other cations, thus, any metal bound to a soil particle will get booted off in the presence of excess H$^+$. At low pH (<6), H$^+$ is in excess and replaces all other cations on the micelle, thus making them bioavailable. At high pH (>7), cations are less bioavailable because they have less competition from H$^+$ for available binding sites. Many cations bind to free hydroxyl groups (OH$^-$) and form insoluble hydrous metal oxides, which are unavailable for uptake, such as CdCO$_3$.

Sand and clay fractions were dominant in both the two regions.Busia soils are sandy loam soils with a texture of a mean range of 18.9 -23.8 % clay, 5.9 -19.6 % silt and 60.9 -70.3 % sand; Lugari soils are sandy loam with 10.5 -11.0 % clay, 1.4 -1.5 % silt and 88.8 -88.9 % sand; classified as Typic Xerofluvent (American Soil Taxonomy),

The results indicate that LOI or organic matter content is a function of % moisture (p$_{value}$=0.001, coeff.= 0.455), % silt (p$_{value}$=0.002, coeff 1.00) and % clay (p$_{value}$=563E-07, coeff 1.40) which have a p$_{value}$<0.05 (

Appendix 4). The higher the % clay content of the soil, the higher the soil organic matter, and therefore higher LOI which agrees with Skaven-Haug (1972). Results of the soils under investigation agree with the previous studies where Skaven-Haug (1972) indicated values of 0.4-1.3 percent for sand and silt and values of 3.9-6.0 % for very fine clay material. This peat, with a Busia and Lugari soils had slightly higher BD than Tie and Kueh (1979) results (LOI of

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95 percent, had bulk densities of 0.15 and 0.13 g/cm^3 at depths of 0-15 and 15-30 cm respectively), implying that these pits are less decomposed and hence the high BD and lowered LOI due to less OM presence. Equally they have a similar trend with higher silt than sand and clay, for sandy loamy soils, although Lugari soils are sandier than Busia samples. The similarity can also be noted in the moisture and LOI which shows that soil texture is dependent on moisture and LOI (organic matter). This is because of the swampy organic rich Busia soils than the Lugari river sediments and or river bank soils with less organic matter for ignition. In this study findings soils in Lugari are more sandy than Busia soils, with a lower BD than that recommended for sandy soils by Grossman (2002), the soil is therefore ideal for root growth. This is also due to increased organic matter accumulation and decomposition rates, evapotranspiration and lateral flow deposition (Tsheboeng *et al.,* 2014).

1.7.2 Ash and Salt's Selected Properties
The pH of Busia's *Cyperus papyrus* salt samples had higher pH values, with an average of 10.53 ranging from 10.23 to 10.55, while Lugari's *Typha latifolia* salt samplesshad an average of 9.66 with a range of 9.56 to 9.76, (**Error!**

Table 4).

From literature, salt contents of plants are generally low. *C. papyrus* contains higher % ratio of salt to ash and to the raw material, 10% for ash and 0.125% for raw material, more than that for T. *latifolia* with 4% of salt in the ash obtained and 0.003% of the raw material. The lowest ratio of salt in reed stems can be explained by the fact that they contain essentially carbohydrates like cellulose which burn in processing for ash production. The high percentage of salt from *C. papyrus* explains why it's still the most traditionally used plant in Busia region to produce indigenous salt. Most of the authors have found the ratio of 0.42% of raw fern, 0.55% of raw vine, 0.55% of raw willow and 0.15% of raw oak (East African Community, 2011). All these data are lower than 1.0 just as the results obtained in this study. It is evident from the regression results that the % CEC increases ten-fold for every one parts increase of % LOI (p_{value}=0.0036, coeff=10.77),

Reference source not found.). This was expected due to the high K and Na concentrations given in (**Error! Reference source not found.**). *Cyperus papyrus* salts reported a mean % moisture content of 10.08% compared to *Typha latifolia* salts with 0.73. Salts from *Cyperus papyrus* species of Busia County had the highest moisture content, ranging from 4.88 % to 15.61% with the highest 15.61 % having been obtained from Bidimbidi village, while those from Lugari County, *Typha latifolia* salts had the lowest moisture content with a range of 0.53 % to 1.03 %, the highest 1.03 % coming from Matete division, **Error! Reference source not found.**. Salts obtained from *Cyperus papyrus* reed plants that thrive in swampy areas have higher moisture contents than those from *Typha Latifolia*. When determined in accordance with ISO 2483, the moisture content of food grade salt shall not be greater than 0.5 % by mass, Lugari samples meet this specification, however, Busia salt has high % moisture content than the recommended one (East African Community, 2013). Evaporation-crystallisation method used in Busia tends to retain more moisture than the one for Lugari region (

Appendix 4 and
Appendix **7**.

1.7.3 Concentration of Iodine, Na, K and Fe^{2+} in Soil
Findings of this study indicate that an increase in Na leads to a decrease in K (r = -0.5815) as well as iodine (
Appendix **7**), which also decreases with depth supported by the regression values, shows the concentration of iodine, Na and K decreased with depth which is in agreement with Whitehead (1978) probably due to soil water dilution and increased leaching as water infiltrates the soil leading to leaching of cations. A positive relation between the concentration K and Mg (p_{value} of 0.0157<.0.05 and coeff of 0.0184) and the pH were observed while that of iodine had a negative relation. For instance, at pH 4.32 the concentration of Mg is 242.49 mg/kg while at a pH of 6.38 their concentrations are 250.57 mg/kg. An increase in K implies an increase of about 2 % in Mg concentration as soil iodine decreases as supported from the value obtained for the correlation coefficient of -0.6521 (

Appendix 4 and
Appendix **7**). These elements tend to complement each other chemically. The concentration of Na was found to decrease with increase in % LOI (p_{value}= 0.040, coeff= -123.7) but with a decrease in % clay (p_{value}=0.0275, coeff=226.11). Equally an increase in Na was observed when the concentration of Cr decreased (p_{value}= 0.0361, coeff=-16.74). There is exchange of ions in the soil through chemical interaction and since Na is higher in reactivity than Cr it is expected that they exchange sites thereby creating this relationship. Results of this study also reveal that the

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concentration of K is linearly related to pH, % moisture, % clay, Fe, and Mg while it is inversely proportional to % N, CEC, % sand, % silt, SBD, % LOI, P, and Pb. However, it is not affected by the increase or decrease of Cd and Cr whose p_{values} are greater than 0.05 (

Appendix 4 and
Appendix **7**).

Top soils, 0-15 cm, contained higher iron and iodine contents than sub-soils 15-30 cm deep (**Error! Reference source not found.**). The presence of high organic matter content (LOI) and the implication that the humus level is higher may have contributed to the assimilation of iodine in the top soil which constitutes the primary reservoir of iodine in most soils. Equally, Metal oxides and hydroxides like $Fe(OH)_3$ may play an important role in controlling iodine behavior in soils, both through adsorption of inorganic iodine and oxidation of iodide (Steinberg *et al.,* 2008a, Steinberg *et al.,* 2008c and Dai *et al.,* 2009). The findings of this study agree with Fuge (2005) who showed that iodine is concentrated in iron-rich soils. Oxidation of I^- to I_2 and then to IO^{3-} has been shown to be a catalyzed reaction with IO^{3-} adsorbing on the metal surface (Gallard *et al.,* 2009). In the presence of humic substances the oxidation to IO^{3-} is limited as I_2 can react to form organic iodine (org-I) species, especially at lower pH (Gallard *et al.,* 2009).

The results also show that the lower the moisture content the lower the iodine level (**Error! Reference source not found.**). Lugari samples have lower iodine concentrations than Busia which has high moisture and organic matter content. The high moisture is due to the high retention of water by the high organic matter present in Busia swamps. These levels are all higher from those found by Whitehead (1978; 1979) in several UK soils that found a range of 0.5 to 98.2 mg kg^{-1} but agrees since they decreased vertically upto 30 cm in depth and with soil type. Yuita and Kihou (2005) also observed higher concentrations in topsoil of three Japanese soils compared to subsoil especially where the

subsoil was more reducing, which agrees with the present findings. However, the present study had significant differences in iodine content in the soil samples analysed. The observed decrease in iodine concentrations with depth in a typical soil could alternatively be a result of reduction of weakly organic-bound iodine to iodide at low redox potentials resulting in the release of iodine from soils into the soil solution. There is a reductive release of soil iodine to soil solution in deep soil horizons agreeing with other studies (Yuita *et al.,* 1991; Yuita and Kihou, 2005; Ashworth and Shaw, 2006; Yamaguchi *et al.,* 2010). Equally, it was found that iodine increases with increase in SBD and % clay (p_{value}= 0.0199 and 0.0229 with coeff of 5650 and 17.25 respectively) since Iodine adsorbs strongly on clay matter (

Appendix 4).

Strong correlations were found between soil iodine, Fe and Na. There was a linear proportionality between iron and iodine since an increase in iodine caused an increase in iron. Soil metal oxides have been shown to oxidize iodide in amounts proportional to their concentration, and inversely proportional to pH, in a reaction that is thermodynamically favorable up to pH 7.5 (Allard *et al.,* 2009 and Gallard *et al.,* 2009). The ultimate fate of iodine in soil appears to be incorporation into solid phase humus via formation of intermediates e.g. HOI or I_2. Abiotic reduction of IO^{3-}, or oxidation of I^- by solid or aqueous organic matter are likely to be the main mechanisms by which these intermediates are formed as the reaction rates observed appear to be too fast for biological processes to play a significant role. Soil pH acts mainly on the initial adsorption of iodate while soil humus appears to control time-dependent sorption. This was further attributed to the scavenging characteristics of soil metal oxyhydroxides for inorganic iodine forms (Dai *et al.,* 2004; Um *et al.,* 2004). The highest iodine concentrations were associated predominantly with iron content rather than with soil organic matter.
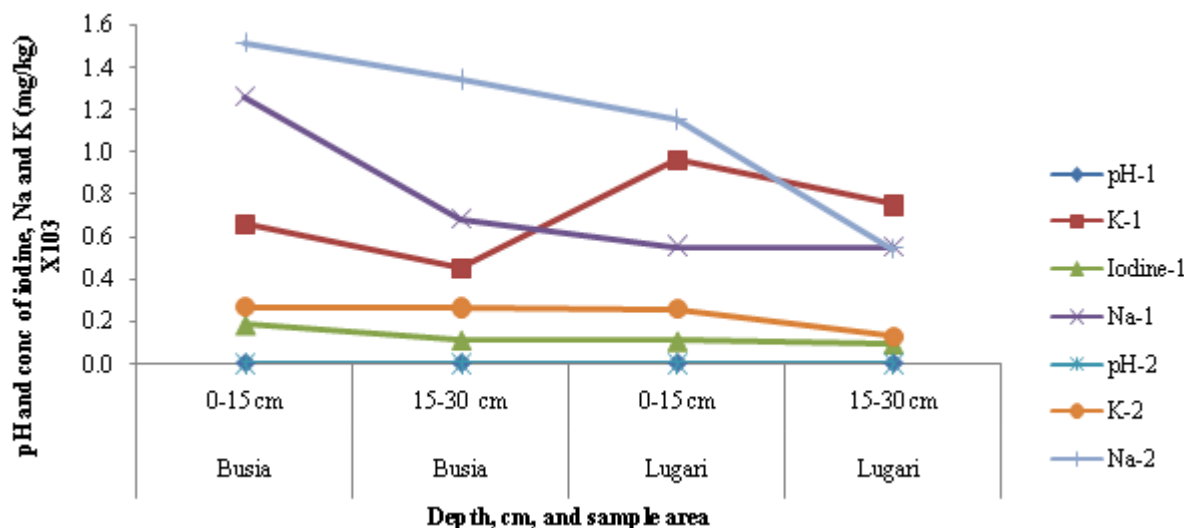
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Figure 2: Effect of depth (cm) and seasonal changes on the Concentration of Iodine, Na and K in soil; for 1=wet season, 2=dry season

1.7.4 Concentration of Iodine, Na, K and Fe^{2+} in Plants

There was higher concentration of iodine in *Cyperus P.* reeds from Bidimbidi than in Ululo for both the wet and dry seasons. In Lugari region, Matete division which is in the lower zone of River Nzoia had the highest iodine content than Lugari division which is in the upper zone of River Nzoia in both seasons (Figure 8).Both the two regions have higher humus content as can be explained by the increase in LOI hence higher organic matter content, which is a great reservoir for iodine. However, there is generally more uptake of iodine by *Cyperus papyrus* reeds than by *Typha Latifolia*, 0.164 versus 0.138 which agrees with findings by Zhu *et al.*, (2004) and Wang *et al.*, (2008). Although this is true from the results, iodine translocation from the soil to the reed plants is generally low due to leaching and sorption to soil surfaces. On the basis of the low uptake as evidenced from the low transfer factors since much is lost in gaseous form through sublimation as well as present as well as previous studies (Smolen and Sady 2011a, Smolen *et al.*, 2011a, 2011b, 2011c) it can be stated that iodine influence on the uptake of mineral nutrients, heavy metals and trace elements by plants depend on numerous factors, including iodine concentration and soil depth but also is affected by variation of plants species in the preference (capacity) towards particular speciation of elements taken from soil. However, Busia reeds have more Na and K than Lugari reeds for both the wet (2871.8 mg/kg > 2519 mg/kg) and the

dry (367 mg/kg > 223 mg/kg) seasons (Figure 6). Iodide may directly interact with clays by forming ion-pairs with like KI which may concentrate within the interlayer space as well as the thin areas surrounding the clay particle. Since the iodine levels in Busia are higher than Lugari it is expected that these elements may be high as well. Findings also revealed an inverse relationship between Iodine and Cr with p_{value}= 0.0024, coeff of -0.0036, (

Appendix 8).The decrease in chromium due to oxidative reactions from Cr (VI) to Cr (III) may cause increased plant-iodine content. While Na was highest in Busia samples than in the Lugari reeds, (2871.8 mg/kg and 2519 mg/kg, and 6351.1 mg/kg and 1596.9 mg/kg) respectively both during the wet and the dry seasons, the amounts differs with finding by Ghani's (Ghani *et al.,* 2012), who reported maximum concentrations (mg/L) of macro elements Na, K as 728 ± 0.60 and 28300 ± 113, respectively in herbal plants. Due to dissolution, there is more loss of K and Na from soil into the soil solution; however, it's notable that the concentrations of K and Na are higher in soils than in plants. The ranking order for TF for Na, Mg, K and iodine in studied reed samples was Na > K > Mg > I for both Busia and Lugari regions (Table 6).
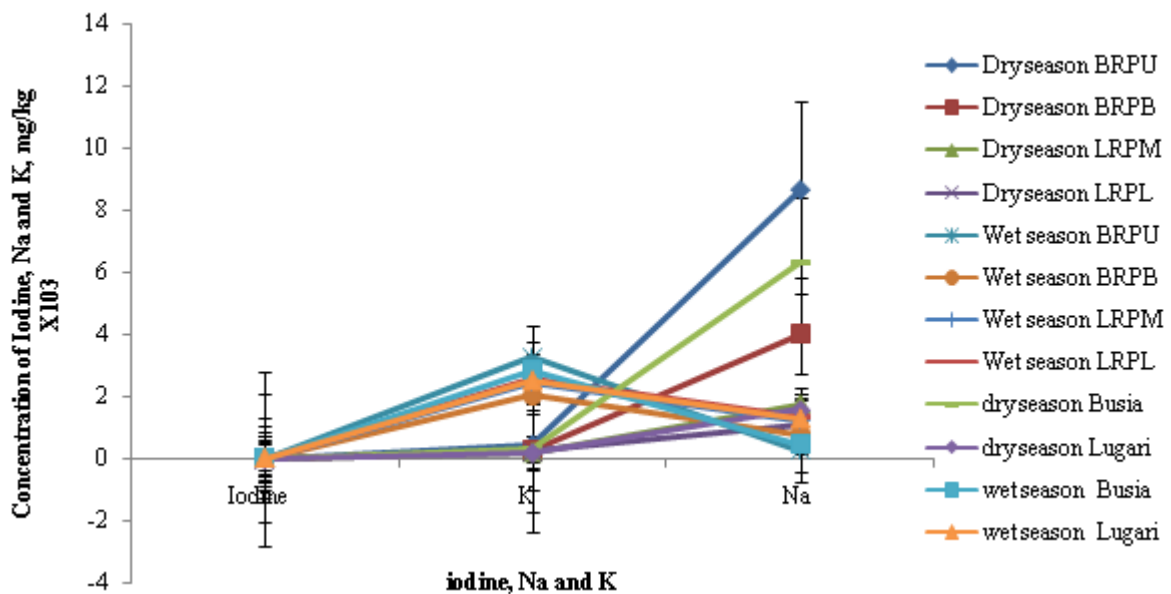
Figure 3: Average concentration of iodine, K and Na, mg/kg, in plants per element per sampling area

1.7.5 Concentration of Iodine, Na, K and Fe^{2+} in Salt

Salt samples analyzed for sodium, potassium and magnesium showed that Na has the highest concentration in salt samples from Busia but generally lower in Lugari compared to potassium, Figure 4. On average, Busia *Cyperus papyrus* salt has higher Na, pH and moisture content but lower K, 11,930 mg/kg, 10.3, 10.1 % and 3,736.2 mg/kg compared to Lugari *Typha latifolia* salt whose Na, K, pH and moisture are 3,943.8 mg/kg, 4,635.8 mg/kg, 9.7 and 0.8 % respectively. From the correlation

Table, the amount of Na will decrease when that of K increases (r = -0.7014) while salt K will increase as that of soil K increases (r= 0.7418, Figure 4). However, Mg is highest in Busia than in Lugari samples, showing a general trend of Na and Mg levels being inversely proportional to K concentrations. Matete and Lugari have lower Na and K levels compared to Ululo and Bidimbidi salts (Figure 4). As reported earlier there is high K and Na contents in Busia than in Lugari plant reeds hence higher Na and K is

expected to be translocated to the salt. This is expected since Busia plants have higher Na and K due to a higher translocation of the same from the soil to the plants as compared to Lugari, as indicated from their TF value where K and Na TF values vary from Ululo> Bidimbidi > Lugari > Matete (

Appendix 1). The amount of K in the salt is found to increase with increase in Mg (p_{value}=0.0475, coeff =74.4),

while that of Na increases as the amount of Fe increases (p_{value}= 0.0475, coeff=180.5). On the other hand an increase in Cd level in the salt causes a decrease in Na content of the salt (p_{value}=0.0403, coeff= -139.6), (

Appendix 6).
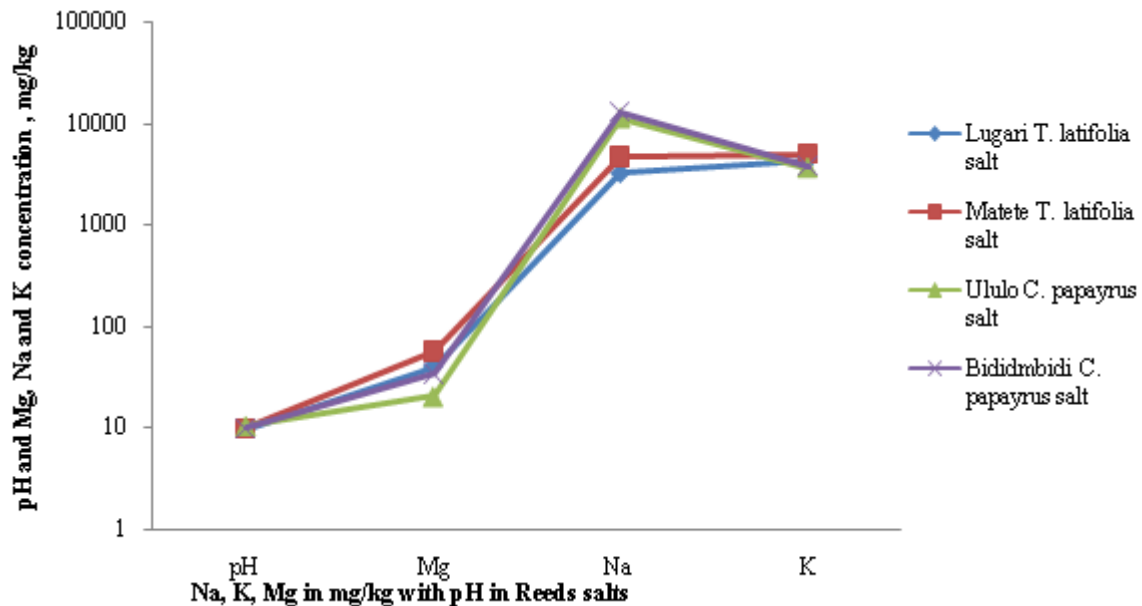
Figure 4: Comparison of the conc. of Na, K, Mg in mg/kg with pH in Reeds salts
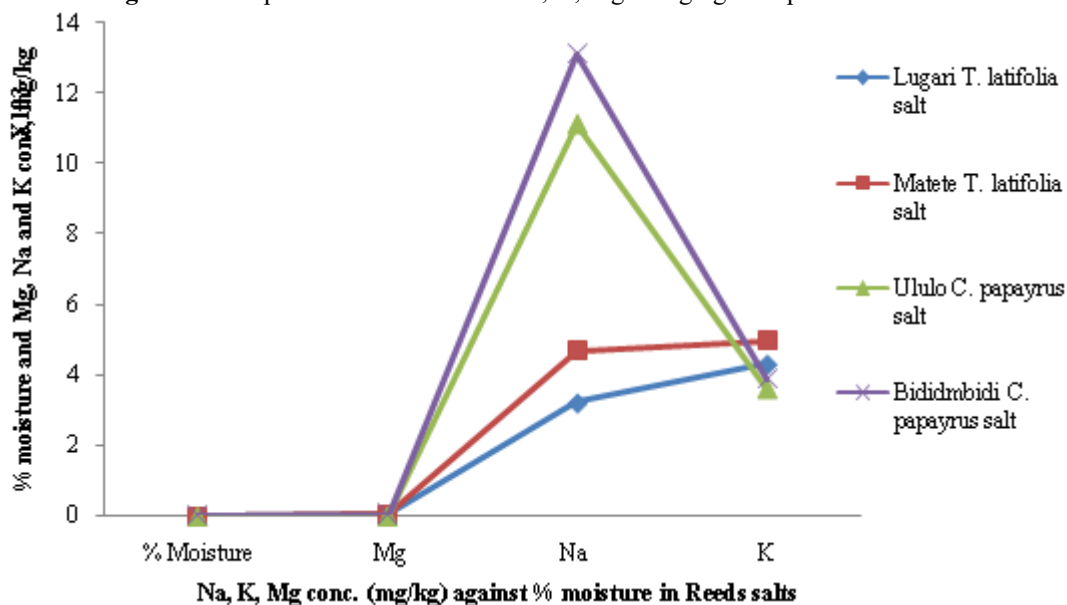
Figure 5: Effect of moisture on the concentration of Na, K, Mg (mg/kg) in reed salts

On the other hand, the Mg content was higher in Lugari *Typha latifolia* salt than in Busia *Cyperus papyrus* salt with Matete >Lugari >Ululo > Bidimbidi. It can be concluded that the higher the Na, pH and % moisture the lower the Mg content and vice versa in reed salts. Equally, *Typha latifolia* reed salt tend to have higher levels of Mg and K than Na which the reverse is true for *Cyperus papyrus* that tends to contain higher Na and lower K and Mg. secondly, *Typha latifolia* salts have a lower pH and moisture content

compared to *Cyperus papyrus* salt. The method used for preparing *Typha latifolia* salt expenses more moisture than that used in Busia on *Cyperus papyrus* salt. Comparing the Na: K ratio of the types of reed salts, *T. latifolia* has 0.85:1 while *C. papyrus* has 3.2:1 compared to 4:1 recommended by WHO 2006. For an ideal food grade salt, *Cyperus papyrus* salt may be better than *Typha latifolia* which is far from the required Na: K ratio, Figure 7. However, *Typha latifolia* salt may be recommended for a Lo-Na salt since its

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Na: K. The trend from the highest to the lowest was Na> K >Mg for Busia while for Lugari it was K >Na >Mg, although the difference between Na and K in Lugari salts was very minimal. Comparing the salt samples' Na/K ratio with the recommended ratio of 2.5:1 and 4:1, it can be observed that Lugari samples are well below the 2.5:1 to 4:1 ratio (mean of Na: K of 0.9) while for Busia salts processed from *C. papyrus* is slightly below the recommended limit of 2.5-4 for Na: 1 for K, with a mean Na:K ratio of 3.2 (**Figure 7**). This suggests that indigenous reed salt from Busia's *C. papyrus* reeds is the more ideal salt for an acceptable Na: K

Table 5 are presented in table belo
Iodine and Fe^{2+} were compared and the reed salts have lower iodine contents as compared to commercial salts while their Fe^{2+} is comparable to the commercial salts. The iodine concentration is of the order Kensalt >Top-chef salt > Herbal sea salt > Sea salt >*Typha latifolia* salt>*Cyperus papyrus* saltwhile for Fe^{2+} is of the order Herbal sea salt >*Typha latifolia* salt = *Cyperus papyrus* salt > Sea salt >Kensalt = Top-chef salt.

Typha L. and *Cyperus P.* salts Na, K, and Mg levels compares well with commercial salts. It is apparent from the results that the sodium levels increased with increase in pH and % moisture of the salt. For instance, Lugari had pH range of 9.56 to 9.76 while Busia's pH range was 10.23-10.55 respectively. From the results in **Figure 6**, the three

ratio as table or common salt, while Lugari's *Typha latifolia* salt could be used as a Lo-Na salt.

Cyperus papyrus is a better bioaccumulator for Na than K and Mg while *Typha latifolia* is better accumulating Mg and K than Na, as is evident from
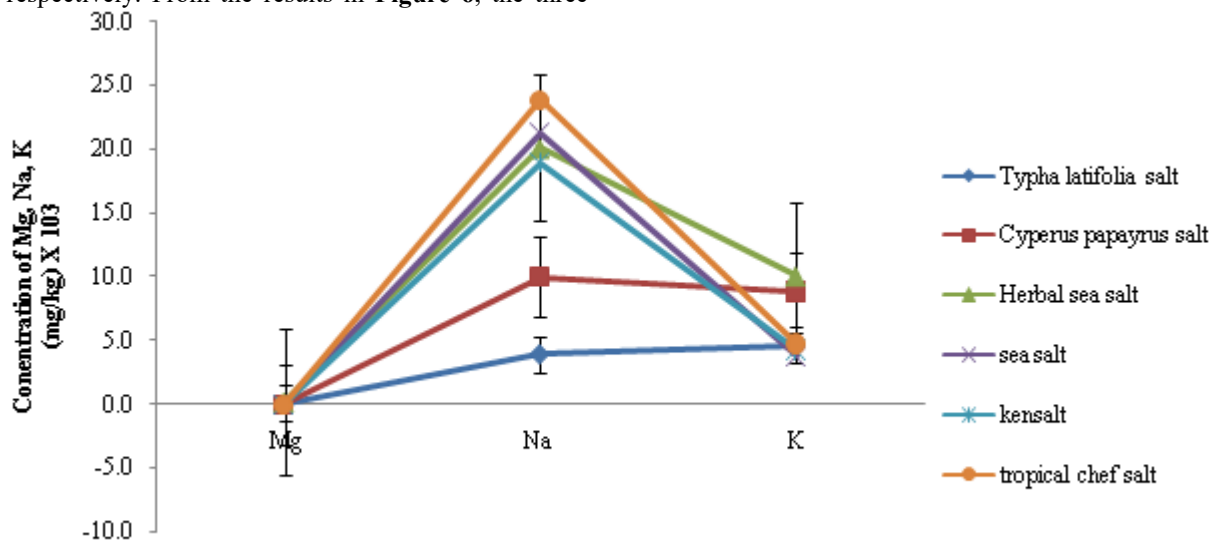
Appendix 6. The chemical composition of the two salts was also compared with that in edible salts obtained from the supermarkets in Western Kenya and the results are presented in w
elements in all salts were of the order Na > K > Mg, with Na being highest in TCSA, 23,855 mg/kg, K and Mg highest in HSSA, 8813.5 mg/kg and 156.5 mg/kg respectively. The Na: K ratio of the salts is such that they fall between 0.9:1 to 5.0:1 (**Figure 7**). Currently dietary guidelines in the US recommend limiting salt intake to 1.5-2.4 grams of sodium per day while the American Heart Association suggests 1.5 gram limit. For a frame reference, one tea spoon of regular table salt contains about 2.3 grams of sodium. Data from around the world suggest that the population average sodium consumption is well above the minimal physiological needs, and in many countries is above the value recommended by the 2002 Joint World Health Organization/Food and Agriculture Organization of the United Nations (WHO/FAO) Expert Consultation (WHO, 2013) of 2 g sodium/day (equivalent to 5 g salt/day) (WHO, 2013).

Figure 6: **A** comparison of the mean concentration of Na, K and Mg in Reed species salts with salts from the market. (HSSA - Herbal salt; TCSA - Top-chef table salt; KNSA - Kensalt; SSSA - Sea salt naturals)

The level of iron (II) is higher than iodine comparatively in all the salts from the two reed species of the two sampled regions respectively. Iodine and Fe^{2+} levels in *Cyperus papyrus* salts from Busia region increased from the dry season to the wet season, from 0.6 to 1.2 mg/kg and 0.9 to 1.0 mg/kg respectively (**Figure 8** and **Figure 9**). On the other hand the iodine content for *Typha latifolia* decreased from 1.3 to 0.9 mg/kg from dry to wet season while that of Fe^{2+} increased from 1.1 to 1.4 mg/kg in the same seasons. However, both Iodine and Iron were higher in *T. latifolia* reeds than *C. papyrus.* since the K content of *T. latifolia* was higher than that of *C. papyrus*, it is expected that iodine

should vary proportionally as supported by the correlation of K to Iodine (r=0.5466), due to their chemical interaction while forming KI compounds . There is a general trend for iodine and Fe^{2+} in these reeds such that while there is an increase in iodine there is a decrease in Fe^{2+}. The amount of iodine increased with increase in K levels, due to the chemical interaction with K than Na. Salt iodine was observed to positively relate with the plant iodine as well as soil iodine (r= 0.5247 and 0.6449;

Appendix 4).

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The mean salt iodine concentrations for Lugari's *Typha latifolia* salts was 1.1 ± 0.18 mg/kg and 0.9 ± 0.31 mg/kg for Busia's *Cyperus papyrus* salts respectively, lower than the worldwide average of 5 mg kg^{-1} (Fleming, 1980; Ure and Berrow, 1982) and the UK average of 9.2 mg kg^{-1} (Whitehead, 1979). There is need to increase the iodine levels in the salts from the two regions of Western Kenya.
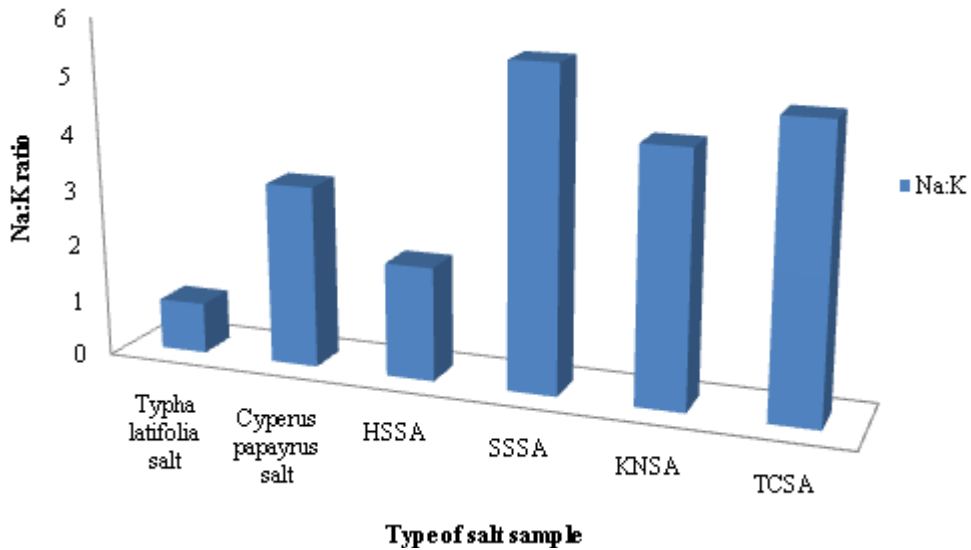
Figure 7: Na: K ratio for *Typha latifolia* and *Cyperus papyrus* and the commercial salts

Iodine concentration varied inversely with pH of the salt. The pH of the salt has insignificant effect on the iodine concentration of the salt. Fe^{2+} levels seemed to generally decrease with increase in pH while there was no significant relationship with % moisture. Results indicate a similar trend in the concentrations of Fe^{2+} in Lugari and Busia counties with a mean of 1.1 ± 0.001 mg/kg and 1.0 ± 0.001 mg/kg respectively.

It is clear that *T. latifolia* salts accumulates more iodine than *C. papyrus* during the dry season than in the wet season probably due to increased oxidation, while the same is true for Fe^{2+}, the variation is minimal (**Figure 8**). The amount of Fe^{2+} seems to increase with a decrease in % moisture content of the salt. Moisture is naturally present in the salt, or is abstracted from the air by hygroscopic impurities such as magnesium chloride. The presence of moisture and some hygroscopic impurities and metal ions impurities such as iron accelerates the loss of iodine (Diosady *et al.,* 1998). As is the case for moisture content, it is clear that the salts from Busia recorded on average the lowest iodate contents, which is true with the moisture contents that were high. It is therefore important to prepare this salt to ensure lower moisture levels so as to have higher iodate contents.

Figure 8: Concentration of Iodine and Fe^{2+}, mg/kg in salt samples from various sites

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Typha latifolia salt is highly related to pH and % moisture content of the salt. Higher pH, lower % moisture, higher Iodine and increased Iron concentration, **Figure 9**. Salt samples from Lugari County had the highest iodate concentration with a mean of 1.0 ± 0.001 mg/kg of the salt, with the highest from Lugari division and the lowest from Matete division, while Busia had a mean of 1.1 ± 0.001 mg/kg of the salt. Iodine availability in the absence of dietary seafood sources depends largely on its transfer from soil to food and fodder crops (Johnson *et al.,* 2002). Transfer of iodine from soil to plants is generally low and locally grown plants often cannot supply a population with the recommended daily intake of iodine (Johnson, 2003). There is therefore a need to increase understanding of iodine behaviour in soils of Lugari and Busia if the resulting implications for transfer to crops and livestock are to be understood. Although some of the plant salts contain iodate the amount is very low compared to the recommended levels and there is need for iodization of the salt as well.

1.7.6 Concentration of Iodine and Iron (II) in reed salts and commercial salts

The concentration of Iodine was highest in KNSA >TCSA > HSSA > SSSA than in the reed salts that recorded < 2.0 mg/kg dry weight as evident from Figure 9. Iodine is low in the reed salts than in the commercially available salts. Fe^{2+} is higher in the reed salts than in the commercially available salts, with *Typha latifolia* having the highest iodine of 43.64 mg/kg as compared to *Cyperus papyrus* with 34.75 mg/kg. There is need to moderate the amounts of iodine and Fe^{2+} in the reed salts probably through salt fortification since these elements are essential in combating goiter and anemia respectively.

The recommended Dietary Allowances (RDA) for iodine and iron are 0.015 mg/kg and 8 mg/kg respectively, with an Upper Limit (UL) of 1.1mg/kg and 45 mg/kg respectively. It therefore shows that *Typha latifolia* and *Cyperus papyrus* reed salts have slightly higher iodine (2.0 mg/kg) than required while that of iron is within the recommended limit. The amount of Mg in the reed salts is comparable to that of the other commercial salts, with *Typha latifolia* and *Cyperus papyrus* reed salts having 21.3 mg/kg and 12.6 mg/kg respectively compared to a range of 15.4-156.5 mg/kg for the selected commercial salts.
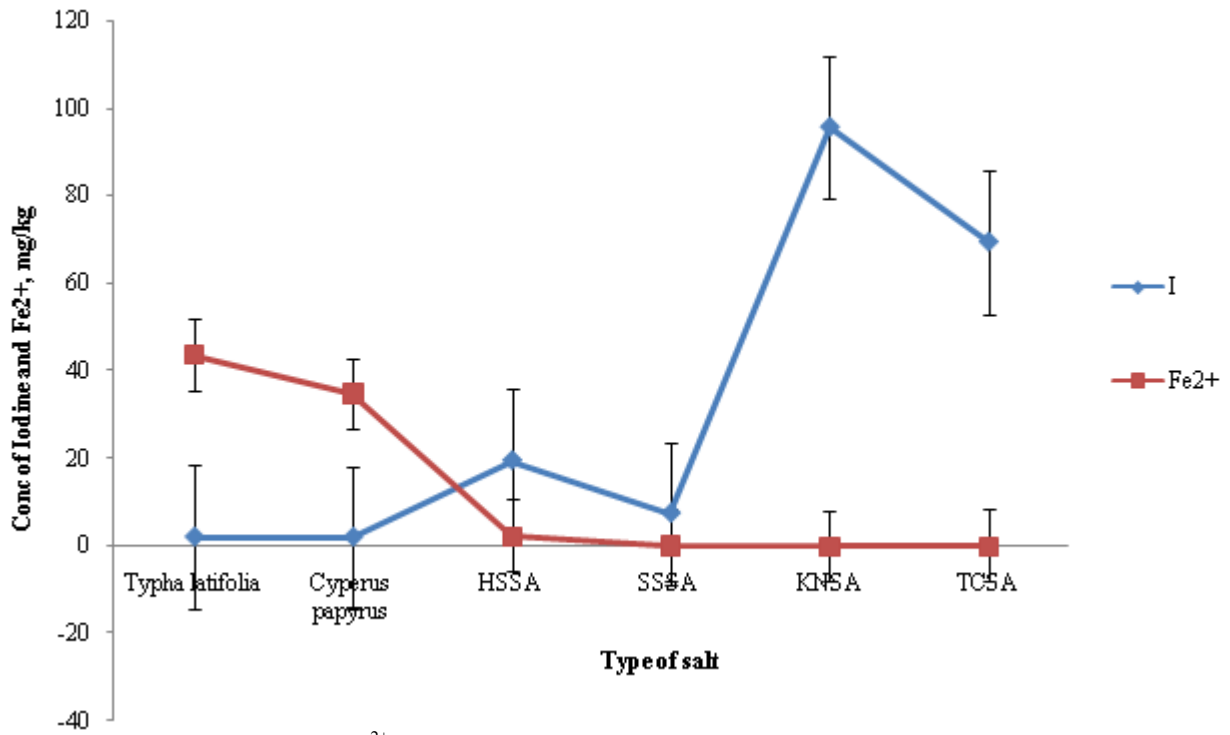
Figure 9: Concentration of Fe^{2+} and Iodine in *Typha latifolia* and *Cyperus papyrus* and Commercial salts

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1.8 Risk Assessment

Risk assessment, as a part of risk analysis, a process of evaluating the possibility of adverse health effects that may occur as a consequence of exposure to a hazard, was evaluated. The health risk of the toxicity associated with the indigenous reeds salt was done by estimating the level of exposure of the heavy metals through the food chain. The

Table 7).

1.8.1 Estimation of the dietary intake of the studied heavy metals (EDIM)

The dietary intake of the studied heavy metals was estimated and their associated risks were studied by comparing to the provisional tolerable weekly intakes (PTWIs). Considering the average daily salt intake to be 5 g/day, PTWI was calculated using the formula provided by *Pourgheysari* 2012; *Lee et al.,* 2006:

Estimated Daily Intake of Metal (EDIM)
The Estimated daily oral intake of metals (EDIM) from soil through the consumption of reed salt in mg was calculated as in equations 9-12 below:

$$Daily\ intake\ of\ heavy\ metals$$
$$= (concentration\ of\ heavy\ metals\ in\ the\ salts)$$
$$* (mean\ salt\ intake\ )\ (g/person)/day)\ 9$$

Table 7). The commercial salts have K range between 36-87 with Herbal sea salt having the highest, whereas T. latifolia has 311 and 230 for *C. papyrus*. On the other hand Na levels in *T. latifolia* and *C. papyrus* are 311 and 1032 respectively while commercial salts range from 1576-1988, which are higher than the reed salts. There is high K and lower Na levels in the reed salts as compared to the Kenya Bureau of statistics certified commercial salts analysed which are in the market. However, from the results of EDIM the

Table 7). The Adequate Intake (AI) for sodium is 1,500 milligrams daily for males and females ages 9-50 (Nguyen *et al*., 2013). This value is less than 1 teaspoon of table salt per day. The maximum recommended level of sodium intake is 2,300 milligrams daily (U.S. Department of Agriculture and U.S. Department of Health and Human Services, 2010). The daily intake for both Busia and Lugari people is higher than the maximum recommended level of sodium intake of 2,300 milligrams daily.

1.8.2 Estimated Health Risk Index (EHRI)

To assess the health risk of persons using these reeds salt in the study area, the daily intake rates of metal (DIM) and the health risk index were estimated. Estimated health risk index (EHRI) is the ratio of estimated daily intake of metal (EDIM) to the reference dose (RD) is which is the maximum tolerable daily intake of a specific metal that does not result

degree of toxicity of heavy metal to human depends on the daily intake. *Typha latifolia* and *Cyperus papyrus* reed salts were selected and their health risk assessment calculated in terms of estimated daily intake of metal (EDIM) and estimated health risk index (EHRI) by considering the intake of metal through the salts by the consumers (

Appendix 2;

$$and$$
$$Weekly\ intake\ of\ heavy\ metals,\ (PTWIs)$$
$$= daily\ intake\ x\ seven\ days$$
$$/\ week\ 10$$
$$Weekly\ intake\ per\ bodyweight\ kg,$$
$$= \frac{PTWIs\ weekly\ intake}{reference\ bodyweight\ 60kg}\ 11$$
$$EDI = CHM\ x\ \frac{WCASS}{BW}\ 12$$

Where CHM (mg/kg, on fresh weight basis) is the concentration of heavy metals in salt; WCASS represents the daily average consumption of salt by consumers in the study areas; and BW is the adult's body weight. The WCASS for this study was taken as 5 g/day. An adult's average body weight of 60 kg was used for the EDI evaluation.

Comparing the calculated daily intake in relation to the commercial salts, both *T. latifolia* and *C. papyrus* salts have higher EDIM values for Na and K (

consumption of reed salt processed from *Cyperus papyrus* is better than for *Typha Latifolia* as the dietary intake of Cr and Fe in adults is lower than the permissible limits (WHO, 1996), while its Pb and Cd EDIM values are higher than for *Cyperus papyrus* reed salt. The daily intake of heavy metals was estimated on the basis of the average consumption and concentration of metal in *Typha latifolia* and *Cyperus papyrus* reed salts. Based on the above concentrations, the estimated daily intake of metal (EDIM) for adults through food chain was calculated (

in any harmful health effects. The HRI has been recognized as a very useful index to evaluate the health risk associated with the consumption of heavy metal contaminated food and food additives (USEPA, 2002; Cui *et al.,* 2004 and Wang *et al.,* 2005). The oral reference dose (RD) for Cd, Pb and Cr are 1.0E-03, 3.5E-03 and 1.5E-00 mg kg^{-1} day^{-1}, respectively given by US-EPA (2002), IRIS (2003). If the value of EHRI is less than one then the exposed population is said to be safe and if greater than one indicating that there is a potential risk associated with that metal (IRIS, 2003). From the estimated Health Risk index (EHRI) (

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Table 7) values obtained it is evident that the exposed population is not safe since the Cd and Pb EHRI values for both salt samples are greater than one indicating that there is a potential risk associated with Cd and Pb metals. The higher the EHRI value, the higher the probability of experiencing long term carcinogenic effects (USEPA, 2002). The order of dominance of HRI index for the metal is Pb > Cd. This clearly shows that the local inhabitants are most likely to be exposed to potential health risk from dietary Pb and Cd.

1.8.3 Soil–Plant Partition Coefficient or Transfer Factor (TF)

To characterize quantitatively the transfer of an element from soil to plant, the soil–plant Partition Coefficient or Transfer Factor (TF) or Concentration Ratio or Biological Accumulation Coefficient (BAC) that expresses the ratio of contaminant concentration in plant parts to concentration in dry soil was determined (Table 6) using methods by Rodriguez et al., 2002; Tome et al., 2003. A prerequisite of the soil–plant transfer factor concept is the presence of a statistically significant relationship between the content of a given element in the soil and plant (Bunzl et al., 2000). Generally, from farming and other human activities, chemicals entering the water system, subsequently, enter the soil. The soil absorbs part of the chemicals which, subsequently, become part of the photosynthetic processes. It was therefore expected that the concentrations of metals in the reed plants would reflect the concentrations in the soil samples. On the basis of transfer factor values the higher the value of transfer factor, the more element would be accumulated by plants.

The correlation between metal contents measured in soils vis-a-vis reeds plants was found to be quite varied (

Appendix 4) K had the highest TF values (10472) in the wet season, while Na was the highest (69) in the dry season. Equally for micronutrients, a sequence of decreasing TF values: Na> K> I> Mg can be generalized for plants in both regions for the dry season, and Mg> K> Na> I for the wet season. It is necessary to take into consideration the fact that the content of metal in plant is influenced by a variety of factors, including: plant species, type of soil and its physico-chemical properties. Also, metals are taken up by plants not only from soil, but also from air deposition and water. Additionally, soil pH, soil texture and BD also have influence on the metal content in plants, since this determines the amount of the metals in the soils thereby affecting the amount translocated to the plant either by increase or decrease of the same.

1.8.4 Ash-Salt Partition Coefficient or Transfer Factor (TF)

The TF values for the dry season are higher than those obtained for the wet season which implies that more metals are present in the environment during the dry season than the wet season (Table 6). There is also dilution factor as a result of the rains runoff, reducing their concentrations.

1.9 Conclusion and Recommendations

1.9.1 Conclusion

Salts from selected reed plants (Typha latifolia and Cyperus papyrus) are used by the inhabitants of the Lugari and Busia counties of Western Kenya. Cyperus P. and Typha L. reeds of Lugari and Busia regions respectively, grow in weak acidic soils of pH range from 4.9-6.5. The concentration of soil-Na was found to be inversely related to t soil- K, Mg and Ca concentrations and SBD, while the Na concentration increased with increase in CEC and % clay in the soil. The concentration of K was found to be linearly related to pH, % moisture, % clay, iodine and Mg while it had a negative relation with % N, CEC, % sand, % silt, SBD, % LOI, P and iodine. The amount of soil nutrients as well as heavy metal content largely depends on soil depth as well as seasonal variation. An increase in depth led to a decrease in iodine level in soil with the top soils, 0-15 cm, recording higher iodine content than sub-soils 15-30 cm deep. Equally, it was found that iodine increases with increase in SBD and % clay. The results also show that the lower the moisture content the lower the iodine level. Fe^{2+} concentration increased with increase in depth in the dry season, with Ululo having the highest iron concentration while the least was Bidimbidi at 15-30 cm depth.

There was higher concentration of iodine in Cyperus papyrus reeds from Bidimbidi than in Ululo for both the wet and dry seasons. Matete division which is in the lower zone of River Nzoia in Lugari region had the highest iodine content than Lugari division which is in the upper zone of River Nzoia in both seasons. However, there is generally more uptake of iodine by Cyperus papyrus reeds than by Typha Latifolia. Findings also revealed an inverse relationship between Iodine and Cr where an increase in iodine contributed to a decrease in Cr and vice versa. However, iodine increased with an increase in Cd and Fe levels. The K content of T. latifolia was higher than that of C. papyrus with K levels increasing with increase in iodine concentration in plants. In the present study, Iodine, K, Na, concentrations increased with ashing process while a decrease in Mg was noted. The process of salt preparation from reeds therefore affects the salt product and hence ashing process is an important step in regard to indigenous reed salt production. From this study, it was noted that Typha latifolia reed ash accumulated less K as compared to Cyperus papyrus ash.

Salts obtained from Cyperus papyrus reed plants that thrive in swampy areas have higher moisture contents than those from Typha latifolia. The order of decreasing concentration of the micronutrients in the salt is of the form Na> K >Mg for Busia while for Lugari it was K >Na >Mg, although the difference between Na and K in Lugari salts was very minimal. On average, Busia Cyperus papyrus salt has higher Na, pH and moisture content but lower K compared to Lugari Typha latifolia salt whose Na, K, pH and moisture and the amount of Na will decrease when that of K increases. Mg content was higher in Lugari Typha latifolia salt than in Busia Cyperus papyrus salt with Matete >Lugari >Ululo > Bidimbidi. Although Na and Mg levels were found to be negatively related to K concentrations in the reed salts,

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Cyperus papyrus salt had higher levels of Mg and K than Na as compared to *Typha latifolia* reed salt. Fe^{2+} levels in the reed salts generally decreased with increase in pH while there was no significant relationship with % moisture.*T. Latifolia* salts prepared during the dry season contained more iodine than *C. papyrus* salt as compared to the one prepared in the wet season. Comparing the salt samples' Na/K ratio with the recommended ratio of 2.5:1 and 4:1, it can be observed that Lugari *Typha latifolia* salt samples had a Na:K of 0.9 while Busia's *C. papyrus* salt had a Na:K ratio of 3.2. The iodine concentration for the analysed salts was of the order Kensalt >Top-chef salt > Herbal sea salt > Sea salt >*Typha latifolia* salt>*Cyperus papyrus* saltwhile for Fe^{2+} is of the order Herbal sea salt >*Typha latifolia* salt = *Cyperus papyrus* salt > Sea salt >Kensalt = Top-chef salt. *Typha latifolia* and *Cyperus papyrus* reed salts have slightly higher iodine (2.0 mg/kg) than the recommended Dietary Allowances (RDA) for iodine (0.015 mg/kg) while that of iron is within the recommended limit (8 mg/kg), with an Upper Limit (UL) of 1.1mg/kg and 45 mg/kg respectively.

The concentrations of K and Na were higher in soils than in plants with a Tf ranking order of Na > K > Mg > I for both Busia and Lugari regions. Correlation analysis done revealed that the presence of iodine in soils and its uptake and accumulation in reed plants largely depends on the presence of K, Na, Mg in soils surrounding the plant and the plant itself. An increase in plant and soil iodine leads to a decrease in plant and soil K, Na, Mg. K interacts positively with Na, and Mg in plants and soil but negatively with Pb in plants and soil. As reported earlier there were high K and Na contents in Busia than in Lugari plant reeds hence higher Na and K translocation to the salt. This was expected since Busia plants contained higher Na and K due to a higher translocation of the same from the soil to the plants as compared to Lugari.

1.9.2 Recommendations

It is recommended that indigenous reed salt be sourced from Busia's*Cyperus papyrus* reeds and obtained from reeds during the wet season. Indigenous reed salt from Busia's *C. papyrus*reeds is more ideal salt for use as table or common salt, since its Na: K ratio is within the recommended 2.5:1 and 4:1 bracket. On the other hand, Lugari's *Typha latifolia* salt could be used as a Low-Na salt. There is need to routinely check for heavy metal contamination of the reed salts in order to make safe for human consumption since the results of this study on *Cyperus papyrus* salt has been shown to contain some considerable levels of heavy metals. It is recommended that further investigations be done to establish the possible sources of these heavy metal contaminants so that they can be eliminated or reduced in the food chain. Meanwhile, people living in this area and other areas with similar activities and plant species are encouraged not to consume large quantities of these salts, so as to minimize or avoid excessive accumulation of heavy metals in their bodies. There is need for a regular and stringent quality control mechanism so that its use in humans and animals is safe.It is therefore recommended that urgent attention is needed to devise and implement appropriate means of monitoring heavy metal concentrations in reed plants used for production of indigenous food additives grown in swampy areas and along river banks, to prevent their excessive build-up in the food chain.

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Appendices

Appendix 1: Tf values for soil-plant for respective samples and sampling sites

Appendix 2: Exposure to selected metals through salt intake- Daily and Weekly intake of metals in the reed salts.

salt type	element	conc, mg/kg	DI, mg/dy/person	PTWIs, mg/pers/wk	EDI, mg/kg/dy	salt type	conc, mg/kg	DI, mg/dy/person	PTWIs, mg/pers/wk	EDI, mg/kg/dy
1	Iod	1.1	0.0055	0.0385	0.0001	4	7.4	0.037	0.259	0.0006
	Fe^{2+}	1	0.005	0.035	0.0001		0.2	0.001	0.007	0
	Mg	52.5	0.2625	1.8375	0.0044		48.1	0.2405	1.6835	0.004
	Na	3943.8	19.719	138.033	0.3287		21285.6	106.428	744.996	1.7738
	K	4635.8	23.179	162.253	0.3863		3819	1.9095	13.3665	0.0318
2	Iod	0.9	0.0045	0.0315	0.0001	5	95.6	0.478	3.346	0.008
	Fe^{2+}	1	0.005	0.035	0.0001		ND	ND	ND	ND
	Mg	29.2	0.146	1.022	0.0024		38.9	0.1945	1.3615	0.0032
	Na	9969.2	49.846	348.922	0.8308		18913.6	94.568	661.976	1.5761
	K	8813.5	44.0675	308.4725	0.7345		4294	2.147	15.029	0.0358
3	Iod	19.5	0.0975	0.6825	0.0016	6	69.4	0.347	2.429	0.0058
	Fe^{2+}	2.3	0.0115	0.0805	0.0002		ND	ND	ND	ND
	Mg	156.5	0.7825	5.4775	0.013		15.4	0.077	0.539	0.0013
	Na	20099.6	100.498	703.486	1.675		23855.1	119.2755	834.9285	1.9879
	K	10047	5.235	36.645	0.0873		4769	2.3845	16.6915	0.0397

1= Typha latifolia salt; 2= Cyperus papyrus salt; 3 = HSSA; 4= SSSA; 5= KNSA; 6= TCSA

Appendix 3: Regression table for Salt variables in wet and dry seasons

Dry season -salts			Coefficients	Standard Error	t Stat	P-value	Lower 95%	Upper 95%	R^2
pH	% Moisture		0.039915	0.018032	2.213537	0.091266	-0.01015	0.089981	
	iodine		-0.23988	0.298963	-0.80237	0.569526	-4.03856	3.5588	
	Fe^{2+}		-11.533	11.30063	-1.02056	0.493522	-155.121	132.0551	
	Mg		-0.03162	0.006079	-5.20208	0.120903	-0.10886	0.045616	
	Na		2.48E-05	4.68E-06	5.30966	0.11851	-3.5E-05	8.42E-05	
% Moisture	iodine		0.52635	1.730436	0.304172	0.812019	-21.4609	22.51363	
	Fe^{2+}		-232.083	65.40961	-3.54814	0.174887	-1063.19	599.0251	
	Mg		-0.00547	0.41686	-0.01312	0.991646	-5.30218	5.291239	
	Na		0.001273	0.000321	3.969967	0.157091	-0.0028	0.005348	
	pH		13.79299	6.2312	2.213537	0.091266	-3.50759	31.09358	
iodine	Fe^{2+}		-16.5569	33.2658	-0.49772	0.705997	-439.239	406.1251	
	Mg		0.091696	0.021679	4.229783	0.147795	-0.18376	0.367148	
	Na		0.000148	4.6E-05	3.222086	0.191579	-0.00044	0.000732	
	pH		-2.89037	1.121377	-2.57751	0.235609	-17.1388	11.35808	
	% Moisture		0.01134	0.048739	0.232674	0.827435	-0.12398	0.146661	
Fe^{2+}	Mg		-9.37061	23.20522	-0.40381	0.755671	-304.221	285.4797	
	Na		-0.0189	0.01906	-0.99168	0.425866	-0.10091	0.063108	
	pH		144.0005	81.31302	1.77094	0.218585	-205.861	493.8622	
	% Moisture		14.36987	13.05655	1.100587	0.385836	-41.8079	70.54769	
	iodine		-30.2632	47.72457	-0.63412	0.57105	-182.144	121.6176	
	Fe^{2+}		-166.75	1504.587	-0.11083	0.918751	-4955.02	4621.518	
Mg	pH		-7.22944	3.198291	-2.26041	0.265161	-47.8676	33.4087	
	% Moisture		-0.31885	0.181799	-1.75387	0.329893	-2.62883	1.991127	
	iodine		4.806491	1.219403	3.941675	0.158173	-10.6875	20.30048	

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		Coefficients	Standard Error	t Stat	P-value	Lower 95%	Upper 95%	R²
	Na	-0.00046	0.000589	-0.78835	0.474588	-0.0021	0.001171	
Na	pH	3063.164	4178.567	0.733066	0.59729	-50030.6	56156.89	
	% Moisture	613.4117	237.5208	2.58256	0.235189	-2404.58	3631.4	
	iodine	-189.483	1593.15	-0.11894	0.924637	-20432.4	20053.41	
	Fe²⁺	-20725.7	50917.68	-0.40704	0.753906	-667696	626244.8	
	Mg	-289.551	367.2887	-0.78835	0.474588	-1309.31	730.2062	
wet season -salts		Coefficients	Standard Error	t Stat	P-value	Lower 95%	Upper 95%	R²
pH	% Moisture	0.034592	0.013116	2.637403	0.23072	-0.13206	0.201246	
	iodine	0.38267	0.098043	3.903106	0.159671	-0.86308	1.628418	
	Fe²⁺	-6.08689	3.707452	-1.6418	0.348279	-53.1945	41.02076	
	Mg	-0.00649	0.047732	-0.13606	0.913908	-0.61299	0.600002	
	K	-0.00067	0.001348	-0.49523	0.707267	-0.0178	0.016463	
	Na	8.56E-05	3.41E-05	2.510092	0.086931	-2.3E-05	0.000194	
% moisture	pH	5.662921	8.582161	0.659848	0.556487	-21.6493	32.97519	
	iodine	-13.0992	9.048751	-1.44763	0.384846	-128.075	101.876	
	Fe²⁺	-58.9785	166.1199	-0.35504	0.782815	-2169.73	2051.775	
	Mg	-0.05225	0.513923	-0.10167	0.935496	-6.58226	6.477761	
	K	0.006047	0.031425	0.192432	0.878974	-0.39324	0.405338	
	Na	0.001843	0.002095	0.879803	0.540651	-0.02478	0.028465	
iodine	pH	2.00103	0.618854	3.233446	0.083799	-0.66168	4.663742	0.853572
	% Moisture	-0.08467	0.038905	-2.17627	0.161493	-0.25206	0.082727	
	Fe²⁺	1.292954	17.00134	0.07605	0.951678	-214.73	217.3154	
	Mg	0.039637	0.174471	0.227184	0.857784	-2.17723	2.256501	
	K	-0.00176	0.001588	-1.10778	0.383346	-0.00859	0.005072	
	Na	-0.00016	0.000226	-0.68909	0.561973	-0.00113	0.000818	
Fe²⁺	pH	-0.11983	0.072988	-1.6418	0.348279	-1.04723	0.807568	
	% Moisture	0.003944	0.003374	1.168892	0.450526	-0.03893	0.04682	
	iodine	0.044219	0.033419	1.323179	0.412004	-0.3804	0.468842	
	Mg	0.002778	0.002982	0.931368	0.522613	-0.03512	0.040671	
	K	-3E-05	8.42E-05	-0.3532	0.783854	-0.0011	0.001041	
	Na	-2.1E-06	3.04E-06	-0.70521	0.5315	-1.2E-05	7.52E-06	
Mg	pH	56.86231	37.65514	1.510081	0.372369	-421.592	535.3162	
	% Moisture	-5.10605	1.740882	-2.93302	0.209184	-27.2261	17.01396	
	iodine	-47.2214	17.24096	-2.73891	0.222862	-266.289	171.8458	
	Fe²⁺	53.34409	390.5695	0.13658	0.913585	-4909.31	5016	
	K	0.056308	0.016858	3.340021	0.079144	-0.01623	0.128844	
	Na	0.00225	0.002404	0.93588	0.448132	-0.00809	0.012594	
K	pH	835.8691	245.8074	3.400504	0.18208	-2287.41	3959.149	
	% Moisture	-106.003	11.36423	-9.32774	0.06799	-250.399	38.39363	
	iodine	-853.994	112.5465	-7.58792	0.083418	-2284.03	576.0453	
	Fe²⁺	2577.298	3208.713	0.803219	0.569199	-38193.3	43347.86	
	Mg	74.38419	5.664941	13.13062	0.04839	2.404281	146.3641	0.998876
	Na	-0.12106	0.043511	-2.7823	0.068859	-0.25953	0.017411	
Na	pH	5902.382	2524.03	2.338476	0.257255	-26168.5	37973.22	
	% Moisture	360.0614	116.6916	3.085581	0.199521	-1122.65	1842.769	
	iodine	-19.557	1155.664	-0.01692	0.989228	-14703.7	14664.55	
	Fe²⁺	-100852	9624.899	-10.4783	0.060573	-223148	21443.64	
	Mg	-851.603	189.6096	-4.49135	0.139469	-3260.82	1557.615	
	K	-5.95325	2.139685	-2.7823	0.068859	-12.7627	0.856182	

Appendix 4: Regression table for salt-plant-soil elemental concentrations

			Coefficients	Standard Error	t Stat	P-value	Lower 95%	Upper 95%	R²
wet season	iodine	plant	-0.00321	0.018245	-0.17588	0.876583	-0.08171	0.075291	0.091664
		soil	0.005337	0.015259	0.349781	0.759902	-0.06032	0.070993	0.091664
	K	plant	0.259556	0.494584	0.524796	0.652095	-1.86847	2.38758	0.445251
		soil	78.36655	62.09895	1.261963	0.334198	-188.824	345.5568	0.445251
	Na	plant	-9.7033	4.010241	-2.41963	0.13665	-26.958	7.551371	0.805746
		soil	-5.18269	4.924235	-1.05249	0.402972	-26.37	16.00458	0.805746
Dry season	iodine	plant	-0.00177	0.026999	-0.06545	0.95193	-0.08769	0.084156	0.416709

		soil	0.02096	0.024578	0.852806	0.456442	-0.05726	0.099178	0.416709
	K	plant	0.026044	0.935007	0.027855	0.979527	-2.94956	3.001652	0.550337
		soil	1.532324	0.836049	1.832817	0.164208	-1.12836	4.193005	0.550337
	Na	plant	0.338841	1.112825	0.304488	0.780657	-3.20266	3.880346	0.033031
		soil	-1.15541	9.249791	-0.12491	0.908493	-30.5924	28.28155	0.033031

Appendix 5: Correlation coefficients for respective elements in plant samples

			Iodine/K	Iodine/Na	K/Na	K/Mg	Na/K	Na/Mg	Mg/Iod	Mg/K
Soils	Busia	BRPU	-0.6174	0.6645	0.2322	1.3336	0.1161	-0.6572	-0.9791	0.6668
		BRPB	-0.7859	0.3489	0.4320	1.7528	0.2160	-0.2666	-0.9673	0.8764
	Lugari	LRPM	-0.9294	-0.8680	1.9771	1.9936	0.9885	0.9763	-0.9523	0.9968
		LRPL	-0.9085	-0.8424	1.9762	1.9284	0.9881	0.9538	-0.8222	0.9642
	BUSIA		-0.9262	-0.7504	1.8302	0.7919	0.9151	0.0177	-0.4943	0.3959
	LUGARI		-0.8849	-0.5248	1.6186	0.6596	0.8093	-0.2673	-0.5573	0.3298
Plants	Busia	BRPU	-0.1773	0.3740	1.5401	-0.5474	0.7739	-0.8227	-0.5548	-0.3266
		BRPB	-0.3056	0.5892	0.7966	-0.0169	0.3983	-0.8892	-0.6026	-0.0085
	Lugari	LRPM	0.7305	0.7780	1.5835	1.6497	0.7918	0.3266	0.5384	0.8248
		LRPL	0.8256	0.9252	1.7039	1.7873	0.8519	0.5328	0.5917	0.8937
	BUSIA		0.9978	0.9527	1.8611	1.8018	0.9306	0.6794	0.8702	0.9009
	LUGARI		1.0000	1.0000	2.0000	1.9999	1.0000	1.0000	0.9999	1.0000

Appendix 6: Correlation table for element concentration in salt versus its presence in plant and soil

	salt-I	plant-I	soil-I	salt-K	plant-K	soil-K	salt-Na	plant-Na	soil-Na
salt-I	1.0000								
plant-I	0.5247	1.0000							
soil-I	0.6449	0.8380	1.0000						
salt-K	0.5052	-0.0396	-0.2681	1.0000					
plant-K	-0.2011	-0.4570	-0.4566	0.2164	1.0000				
soil-K	0.0707	-0.5555	-0.6521	0.7418	0.2778	1.0000			
salt-Na	0.0318	0.5528	0.7079	-0.7014	-0.0082	-0.8742	1.0000		
plant-Na	-0.6355	-0.2595	-0.3533	-0.3472	0.3201	-0.4198	0.1673	1.0000	
soil-Na	-0.8486	-0.1727	-0.3432	-0.5815	-0.2633	-0.3596	0.0561	0.6554	1.0000

Appendix 7: Correlation table for various soil properties in the soils samples

wet season	depth, cm	pH	% moisture	%N	CEC meq/100g soil	% sand	%silt	SBD, g/cm3	% LOI	% clay	P, mg/kg	Iod mg/kg	K mg/kg	Na mg/kg
depth, cm	1.000													
pH	-0.308	1.000												
%moisture	0.417	-0.653	1.000											
%N	0.344	-0.621	0.717	1.000										
CEC meq/100gsoil	-0.215	-0.325	0.486	0.470	1.000									
%sand	-0.444	0.862	-0.801	-0.795	-0.367	1.000								
%silt	0.537	-0.795	0.689	0.607	-0.041	-0.907	1.000							
SBD, g/cm3	0.645	0.406	-0.339	-0.283	-0.715	0.337	-0.094	1.000						
%LOI	0.307	-0.847	0.831	0.808	0.610	-0.960	0.763	-0.511	1.000					
%clay	0.260	-0.757	0.755	0.835	0.719	-0.897	0.627	-0.519	0.974	1.000				
P, mg/kg	0.311	-0.029	-0.351	-0.414	-0.046	0.230	-0.254	0.388	-0.201	-0.159	1.000			
Mg mg/kg	-0.131	0.900	-0.388	-0.571	-0.473	0.705	-0.526	0.467	-0.754	-0.750	-0.218			
Ca mg/kg	-0.138	0.080	0.397	-0.259	-0.018	0.069	0.054	-0.203	-0.049	-0.191	-0.350			
Iod mg/kg	-0.145	0.772	-0.135	-0.252	-0.286	0.570	-0.460	0.310	-0.582	-0.572	-0.465	1.000		
K mg/kg	-0.049	0.489	0.005	-0.268	-0.441	0.158	0.066	0.197	-0.279	-0.362	-0.573	0.673	1.000	
Na mg/kg	-0.306	-0.385	0.335	0.360	0.928	-0.234	-0.147	-0.715	0.486	0.585	0.123	-0.394	-0.681	1
dry season	depth, cm	pH	% moisture	%N	CEC meq/100g soil	% sand	% silt	SBD, g/cm3	% LOI	% clay	P, mg/kg	Iod mg/kg	Na, mg/kg	
depth, cm	1													
pH	-0.312	1												
%moisture	0.000	0.254	1.000											
%N	0.055	0.156	0.767	1.000										
CEC meq/100gsoil	-0.098	0.441	0.394	0.438	1.000									
%sand	-0.150	-0.141	-0.828	-0.762	-0.295	1.000								

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%silt	0.150	0.002	0.750	0.601	-0.058	-0.931	1.000						
SBD, g/cm3	0.557	-0.200	-0.239	-0.237	-0.622	0.273	-0.088	1.000					
%LOI	0.097	0.227	0.843	0.786	0.526	-0.967	0.815	-0.420	1.000				
%clay	0.118	0.283	0.767	0.815	0.667	-0.897	0.674	-0.444	0.971	1.000			
P, mg/kg	-0.018	0.073	-0.002	-0.070	0.051	0.147	-0.183	0.323	-0.113	-0.075	1.000		
Mg, mg/kg	-0.262	0.403	-0.068	-0.129	0.066	-0.094	0.078	-0.404	0.090	0.095	-0.344		
K, mg/kg	-0.218	0.256	-0.534	-0.473	-0.192	0.498	-0.460	-0.040	-0.506	-0.453	-0.035		
Iod mg/kg	0.271	0.360	0.561	0.670	0.433	-0.587	0.413	0.147	0.617	0.695	0.035	1.000	
Na, mg/kg	-0.308	0.383	0.438	0.247	0.886	-0.206	-0.075	-0.590	0.424	0.509	0.205	0.327	1

Appendix 8: Regression table for chemical characteristics of the reed Plants

plants-dry season							
Dry season		Coefficients	Standard Error	t Stat	P-value	Lower 95%	Upper 95%
iodine	Na mg/kg	0.00682	0.001788	3.813843	0.163249	-0.0159	0.029542
	K mg/kg	-0.06924	0.031522	-2.19651	0.27198	-0.46977	0.331288
Na	K mg/kg	10.24321	3.391211	3.020516	0.203535	-32.8462	53.33262
	Iod mg/kg	137.1926	35.97227	3.813843	0.163249	-319.878	594.2635
K	Iod mg/kg	-11.9632	5.446435	-2.19651	0.27198	-81.1667	57.24035
	Na mg/kg	0.087982	0.029128	3.020516	0.203535	-0.28213	0.458091
plants-wet season		Coefficients	Standard Error	t Stat	P-value	Lower 95%	Upper 95%
Iodine	Mg mg/kg	1.191945	7.222694	0.165028	0.884094	-29.8848	32.26869
	K mg/kg	-0.01474	0.022226	-0.66309	0.543532	-0.07645	0.046971
	Na mg/kg	-0.02025	0.028184	-0.71844	0.512215	-0.0985	0.058003
Mg	Iod mg/kg	-0.06334	0.165562	-0.38259	0.767371	-2.167	2.040319
	K mg/kg	0.001622	0.001262	1.284973	0.268162	-0.00188	0.005126
	Na mg/kg	-0.0007	0.0016	-0.4384	0.683731	-0.00515	0.003742