ESSENTIAL TRACE ELEMENT LEVELS IN *Sesuvium portulacastrum*,
SOIL AND WATER ALONG KWALE COUNTY COASTLINE AND
COMMUNITY UTILIZATION OF THE PLANT

By

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of the Degree of Master of Science in Applied Analytical Chemistry in the
School of Pure and Applied Sciences of Kenyatta University

February 2013
DEDICATION

This thesis is dedicated to my beloved daughter Carolyne, my sister Veronicah and her family.

DECLARATION

I hereby declare that this is my own original work and has not been presented for the award of a degree in any other University.

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May God bless you all.
# TABLE OF CONTENTS

DECLARATION ................................................................. Error! Bookmark not defined.
DEDICATION .............................................................................. ii
ACKNOWLEDGEMENTS .................................................................. iii
TABLE OF CONTENTS .................................................................. iv
LIST OF TABLES ......................................................................... ix
LIST OF PLATES .......................................................................... x
ABBREVIATIONS AND ACRONYMS ........................................... xi
ABSTRACT ................................................................................. xiii

## CHAPTER ONE ........................................................................... 1

1.0 INTRODUCTION ....................................................................... 1
  1.1 Background Information .......................................................... 1
  1.2 Problem Statement and Justification ........................................... 7
  1.3 Hypotheses ............................................................................. 8
  1.4 Objectives ............................................................................. 9
    1.4.1 Main Objective ................................................................. 9
    1.4.2 Specific Objectives ........................................................... 9
  1.5 Significance of Study and Anticipated Output .......................... 9
  1.6 Scope and Limitations .............................................................. 10

## CHAPTER TWO ........................................................................... 11

2.0 LITERATURE REVIEW .......................................................... 11
  2.1 Trace Elements .................................................................... 11
  2.2 Essential Trace Elements ....................................................... 11
  2.3 Health Effects of Essential Trace Elements ............................. 14
  2.4 Chromium .......................................................................... 16
    2.4.1 Introduction .................................................................... 16
2.4.2 Benefits and Uses of Chromium ......................................................... 17
2.4.3 Chromium Deficiency ........................................................................ 18
2.4.4 Sources and Studies of Chromium ..................................................... 19
2.5 Iodine ..................................................................................................... 20
  2.5.1 Introduction ...................................................................................... 20
  2.5.2 Benefits and Uses of Iodine .............................................................. 20
  2.5.3 Iodine Deficiency ............................................................................ 24
  2.5.4 Sources and Studies on Iodine ......................................................... 26
2.6 Selenium ................................................................................................ 28
  2.6.1 Introduction ...................................................................................... 28
  2.6.2 Benefits and Uses of Selenium ........................................................ 28
  2.6.3 Selenium Deficiency ....................................................................... 32
  2.6.4 Sources and Studies on Selenium ................................................... 34
2.7 Vanadium ............................................................................................... 34
  2.7.1 Introduction ...................................................................................... 34
  2.7.2 Benefits and Uses of Vanadium ....................................................... 35
  2.7.3 Vanadium Deficiency ...................................................................... 38
  2.7.4 Sources and Studies on Vanadium ................................................. 38
2.8 Zinc ........................................................................................................ 39
  2.8.1 Introduction ...................................................................................... 39
  2.8.2 Benefits and Uses of Zinc ................................................................. 40
  2.8.3 Zinc Deficiency ............................................................................... 44
  2.8.4 Sources and Studies on Zinc ............................................................ 47
2.9 Sesuvium portulacastrum (L.)L. (“Mboga ya Pwani”) .......................... 50
  2.9.1 Description of S. portulacastrum (L.)L. ........................................... 50
  2.9.2 Previous Research on S. portulacastrum ......................................... 55
  2.9.3 S. portulacastrum as a Halophyte .................................................... 56
  2.9.4 Health Importance of Halophytes to Man ...................................... 59
3.9 Validation of Method for Metal Analysis .......................................................... 79
3.10 Statistical Data Analyses .................................................................................. 80

CHAPTER FOUR ........................................................................................................ 81

4.0 RESULTS AND DISCUSSION ........................................................................... 81

4.1 Introduction ......................................................................................................... 81
4.2 Local Community Utilization of *Sesuvium portulacastrum* .............................. 81
4.3 Levels of Essential Trace Elements in Stem, Leaves, Soil and Water Samples .......................................................... 85
  4.3.1 Introduction .................................................................................................. 85
  4.3.2 Levels of Chromium in the Stem and Leaves of *S. portulacastrum*, Soil and Water Samples .......................................................... 85
  4.3.3 Levels of Iodine in the Stem and Leaves of *S. portulacastrum*, Soil and Water Samples .......................................................... 90
  4.3.4 Levels of Selenium in the Stem and Leaves of *S. portulacastrum*, Soil and Water Samples .......................................................... 93
  4.3.5 Levels of Vanadium, µg/g, in the Stem and Leaves of *S. portulacastrum*, Soil and Water Samples .......................................................... 96
  4.3.6 Levels of Zinc in the Stem and Leaves of *S. portulacastrum*, Soil and Water Samples .......................................................... 99
4.4 Summary of Essential Trace Element Levels in the Stem, Leaves, Soil and Water Samples .......................................................... 103
  4.4.1 Mean distribution of Elements in *S. portulacastrum* .................................. 103
  4.4.2 Seasonal and Regional Variation of Essential Trace Element Levels in *S. portulacastrum* .......................................................... 105
  4.4.3 Levels of Essential Trace Elements in the Soil and Water .......................... 106
  4.4.4 Correlation between Levels of Essential Trace Elements in Water, Soil and the Plant .......................................................... 108
CHAPTER FIVE ........................................................................................................... 110

5.0 CONCLUSIONS AND RECOMMENDATIONS .............................................. 110

5.1 Conclusions ........................................................................................................ 110

5.2 Recommendations ............................................................................................ 112

5.2.1 Recommendations from the study ................................................................. 112

5.2.2 Recommendations for Further Research ...................................................... 113

REFERENCES ........................................................................................................ 116

APPENDICES ......................................................................................................... 129

APPENDIX I : Questionnaire to Assess the Level of Community
Utilization of S. portulacastrum in the Sampling Regions . 129

APPENDIX II : Questionnaire Results for Level of Community Utilization
of S. portulacastrum in the Sampling Regions ....................... 131

APPENDIX III : Calibration Curve for Chromium................................. 134

APPENDIX IV : Calibration Curve for Selenium................................. 134

APPENDIX V : Calibration Curve for Vanadium............................... 135

APPENDIX VI : Calibration Curve for Zinc......................................................... 135

APPENDIX VII : Concentration of Chromium in the Stem, Leaves, Soil and
Water Samples at the Regions in Dry and Wet Seasons..... 136

APPENDIX VIII : Concentration of Iodine in the Stem, Leaves, Soil and
Water Samples at the Regions in Dry and Wet Seasons..... 136

APPENDIX IX : Concentration of Selenium in the Stem, Leaves, Soil and
Water Samples at the Regions in Dry and Wet Seasons..... 137

APPENDIX X : Concentration of Vanadium in the Stem, Leaves, Soil and
Water Samples at the Regions in Dry and Wet Seasons..... 137

APPENDIX XI : Concentration of Zinc in the Stem, Leaves, Soil and Water
Samples at the Regions in Dry and Wet Seasons .......... 138

APPENDIX XII : Comparison of Elemental Levels in S. portulacastrum
with other Samples............................................................ 139

APPENDIX XIII : Concentration of Elements in Natural Sea Water .......... 140
LIST OF TABLES

Table 2.1: The AAS Working Conditions ............................................................ 65
Table 3.1 Comparison of Zinc Levels in the Samples by AAS and EDXRF ....... 79
Table 3.2: Regression Coefficient of the Essential Trace Elements by AAS .... 80
Table 4.1: Percent Level of Community Awareness and Utilization of
S. portulacastrum and its Specific Uses at the Regions ..................... 82
Table 4.2: Concentration of Chromium in the Stem, Leaves, Soil and Water
Samples at the Regions in Dry and Wet Seasons ............................ 86
Table 4.3: Concentration of Iodine in the Stem, Leaves, Soil and Water
Samples at the Regions in Dry and Wet Seasons ......................... 90
Table 4.4: Concentration of Selenium in the Stem, Leaves, Soil and Water
Samples at the Regions in Dry and Wet Seasons .......................... 93
Table 4.5: Concentration of Vanadium in the Stem, Leaves, Soil and Water
Samples Showing Regional and Seasonal Variation ...................... 96
Table 4.6: Concentration of Zinc in the Stem, Leaves, Soil and Water Sample
at the Regions in Dry and Wet Seasons ........................................... 99
Table 4.7: Mean Distribution of Elements in the Leaves and Stems of
S. portulacastrum ............................................................................... 104
Table 4.8: Seasonal Variation of Essential Trace Element Levels in
Leaf and Stem Samples of S. portulacastrum at the Regions .......... 105
Table 4.9: Mean Distribution of Essential Trace Elements in the Soil and
Water ............................................................................................. 107
Table 4.10 Correlation Coefficient Values (r*) for Essential Trace Elements
in Different Sample Matrices ............................................................... 108
LIST OF PLATES

Plate 2.1:  S. portulacastrum (L.) L. (Mboga ya Pwani) ........................................ 51
Plate 2.2:  A sampling station in Vanga region with S. portulacastrum growing at the beach .......................................................... 53
Plate 2.3:  A sampling station in Wasini region with S. portulacastrum growing amidst corals and submerged in seawater at high tide ...................... 53
Plate 3.1:  Map of Study Area.............................................................................. 69
### ABBREVIATIONS AND ACRONYMS

<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Description</th>
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<tbody>
<tr>
<td>AAS</td>
<td>Atomic Absorption Spectroscopy</td>
</tr>
<tr>
<td>AIDS</td>
<td>Acquired Immune Deficiency Syndrome</td>
</tr>
<tr>
<td>ANOVA</td>
<td>Analysis of Variance</td>
</tr>
<tr>
<td>APC</td>
<td>Adenomatous Polyposis Coli</td>
</tr>
<tr>
<td>APDC</td>
<td>Ammonium Pyrrolidine Dithiocarbamate</td>
</tr>
<tr>
<td>APHA</td>
<td>American Public Health Association</td>
</tr>
<tr>
<td>ART</td>
<td>Antiretroviral Treatment</td>
</tr>
<tr>
<td>ATPase</td>
<td>Adenosine Triphosphatase</td>
</tr>
<tr>
<td>AWWA</td>
<td>American Waste Water Association</td>
</tr>
<tr>
<td>CCA</td>
<td>Chromated Copper Arsenate</td>
</tr>
<tr>
<td>DNA</td>
<td>Deoxyribonucleic Acid</td>
</tr>
<tr>
<td>DRI</td>
<td>Dietary Reference Intake Values</td>
</tr>
<tr>
<td>EDXRF</td>
<td>Energy Dispersive X-ray Fluorescence</td>
</tr>
<tr>
<td>FDA</td>
<td>Food and Drugs Administration</td>
</tr>
<tr>
<td>GRAS</td>
<td>Generally Recognized as Safe</td>
</tr>
<tr>
<td>GSH-Px</td>
<td>Glutathione Peroxidase</td>
</tr>
<tr>
<td>GTF</td>
<td>Glucose Tolerant Factor</td>
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<tr>
<td>HDPE</td>
<td>High Density Polyethylene</td>
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<tr>
<td>HGT</td>
<td>Hydride Generation Technique</td>
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<tr>
<td>Acronym</td>
<td>Full Form</td>
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<td>----------</td>
<td>-----------------------------------------------</td>
</tr>
<tr>
<td>HIV</td>
<td>Human Immunodeficiency Virus</td>
</tr>
<tr>
<td>LDL</td>
<td>Low Density Lipids</td>
</tr>
<tr>
<td>MAC</td>
<td>Maximum Acceptable Concentration</td>
</tr>
<tr>
<td>MDG</td>
<td>Millennium Development Goals</td>
</tr>
<tr>
<td>MIBK</td>
<td>Methyl Isobutyl Ketone</td>
</tr>
<tr>
<td>NASCOP</td>
<td>National AIDS and STI Control Program</td>
</tr>
<tr>
<td>NRC</td>
<td>National Research Council (United States)</td>
</tr>
<tr>
<td>PLWHA</td>
<td>People Living With HIV and AIDS</td>
</tr>
<tr>
<td>RDA</td>
<td>Recommended Daily Allowance</td>
</tr>
<tr>
<td>RNA</td>
<td>Ribonucleic Acid</td>
</tr>
<tr>
<td>SOD</td>
<td>Superoxide Dismutase</td>
</tr>
<tr>
<td>STI</td>
<td>Sexually Transmitted Infections</td>
</tr>
<tr>
<td>T3</td>
<td>Triiodothyroxine</td>
</tr>
<tr>
<td>TICAH</td>
<td>Trust for Indigenous Culture and Health</td>
</tr>
<tr>
<td>TSH</td>
<td>Thyroid Stimulating Hormone</td>
</tr>
<tr>
<td>UNICEF</td>
<td>United Nations Children’s Fund</td>
</tr>
<tr>
<td>WEF</td>
<td>World Environmental Federation</td>
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<td>WHO</td>
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ABSTRACT

Many underutilized indigenous foods contain high levels of essential trace elements some of which have immunological effect, and play important roles in many metabolic and enzymatic functions in man. Such elements include zinc, vanadium, selenium, chromium and iodine among others. If sustainably exploited, they would cost-effectively promote good health and thus reduce the medical bills. There is need therefore to analyze for these essential trace elements in foods, and especially the indigenous vegetables which have not been fully exploited. These would not only serve as nutrient source but also as a source of food for food security. This study therefore aimed at assessing the level of utilization of an indigenous marine halophytic vegetable *Sesuvium portulacastrum* (L) L. locally known as ‘Mboga ya Pwani’ that grows along the Kenyan Kwale Coastline and analyze the content of selected essential trace elements in it. The level of utilization was assessed through a questionnaire distributed among the local communities of Vanga, Funzi and Wasini regions along the coastline. The leaves and stems of the vegetable, and water and soil supporting its growth were sampled from the same regions and analyzed for vanadium, zinc, chromium and selenium using Atomic Absorption Spectroscopy (AAS), and iodine by iodimetric titration. The data collected was statistically analyzed using analysis of variance (ANOVA). The results showed Wasini region to have the highest utilization at 83.3%, followed by Funzi with 26.7% and finally Vanga with 13.3%. The major specific use as food ranged from 10.0% to 73.3%, and the minor use as medicine from 3.3% to 10.0% across the regions. The Atomic Absorption Spectroscopy method was validated using the Energy Dispersive X-ray Fluorescence method. The results showed the soil to contain the highest mean levels of the metals, followed by stems, leaves and water. Zinc was the most abundant with levels ranging from 0.72±0.01 to 21.26±0.85 µg/g, followed by vanadium from 2.44±0.05 to 11.03±0.24 µg/g, chromium 0.29±0.00 to 7.16±0.22 µg/g and selenium from 0.23±0.01 to 1.37±0.07 µg/g respectively. Iodine was relatively abundant in all the samples, ranging from 9.55±0.38 µg/g in the leaves to 14.59±0.43 µg/g in the stems. Zinc, vanadium and iodine levels were relatively high in all the samples. A positive r-correlation was observed between the level of all elements in the plant and the soil, while only iodine and zinc in the soil showed significant but negative correlation to their levels in the water. The results of present study suggest that the communities should be sensitized to the existence and nutritional value of the plant, and thus enhance utilization. The results will also provide a database for further research on the plant and will be availed to relevant stakeholders for appropriate action.
CHAPTER ONE

1.0 INTRODUCTION

1.1 Background Information

Throughout the world today man is faced with the great challenges of containing persistent health condition and diseases that are resisting effective management and cure by conventional medicine, most of which have been associated with compromised body immune system (National AIDS and STI Control Program (NASCOP), 2008). For this reason many people and health organizations today have become increasingly interested in preventive health care that aims at boosting the body’s immune system. There is a close relationship between good food and good health; hence one economical and viable way is by advocating the consumption of locally available natural indigenous foods that contain immune boosting and curative ingredients like essential trace elements and vitamins (O’Shea, 2002).

Nutrition has now been recognized as a key component in the management and care for people living with HIV/AIDS (PLWHA) (NASCOP, 2008). As an essential complementary intervention to antiretroviral treatment (ART), nutrition enhances rehabilitation, immunity and adherence to ART. Malnutrition and associated deficiency in specific micronutrients among PLWHA manifests itself most commonly in weight loss, wasting in adults and children and faltering linear growth (stunting) in children (NASCOP, 2008). The intake of foods rich in
essential trace metals improves their nutritional status and thus delays the progression of their status into full blown AIDS (NASCOP, 2008).

The supporting roles of vitamins and mineral have gone largely unnoticed, and due to the fact that such small amounts of these nutrients are found in the body, their function has only been elaborated by research technology (McDonald, 1997). Minerals in food are bound to organic molecules during normal metabolic processes, after being absorbed in ionic or chelated state (O’Shea, 2002). In man, mineral deficiency is a result of consumption of processed food deprived of important trace elements or diet with insufficient minerals such as lacking in vegetables and fruits. Lack of necessary elements may lead to wastage of consumed food if it is not broken down due to lack of necessary enzyme activity catalyzed by a particular mineral supplied by a certain type of food (O’Shea, 2002). Foods low in fats and refined sugar, and high in fiber are richest in vitamins and mineral, and include vegetables, fruits and whole grains (McDonald, 1997). Being the major sources of most nutrients these foods are linked to protection against diseases. Vegetables in particular have more insoluble fiber that may protect the colon from cancer (McDonald, 1997).

Most old people lived the vast majority of their years eating far less adulterated, denatured and demineralised food than young people today. They boast of quality life with less or no incidence of chronic and degenerative disease during their
lifespan (O’Shea, 2002). Studies have shown that mineral deficiency is being suffered by a vast majority of the population, with chromium deficiency leading at 87%, while Zn, Se, Fe, Cu and Mg deficiency are observed in 67%, 60%, 58%, 81% and 75% of the population, respectively (O’Shea, 2002). Marginal or severe essential trace element imbalances can be considered risk factors for several disease of public health importance. Particular essential trace elements have been associated with specific health benefits. Zinc is essential for many metabolic and enzymatic functions in man and is noted to promote wound healing, sexual development and gaining height. Thus, it prevents infertility, dwarfism, some form of night blindness and dermatitis. Chromium increases the body’s sensitivity to insulin thus increasing glucose tolerance which protects the body against diabetes (Paraphona, 2004; Morel, 1983), and also prevents kwashiorkor which accompanies glucose intolerance (Horrobin, 1981).

Vanadium promotes the immune system, mimics insulin and thus also controls diabetes. It protects against tooth decay (Harrison and Mora, 1996) and inhibits cholesterol biosynthesis therefore reducing chances of heart disease, hypertension and arteriosclerosis (Hamel and Duckworth, 1995). Selenium is a strong antioxidant hence an anticarcinogen that protects against breast and skin cancer. It stimulates the immune system and protects the body against degenerative diseases and thus prevents premature ageing (Paraphona, 2004). Deficiency in animals affects fertility, and produces muscular dystrophy, leukocyte inefficiency, liver
necrosis and endemic cardiomyopathy (Taylor and Sinkiss, 1984). Iodine is important for development and function of the thyroid gland and protects against goiter and cretinism in children (Stobark, 1985). In pregnant women, it prevents gestosis, premature birth, miscarriages and birth of mentally retarded or borderline intellect babies (UNICEF, 2005).

It is quite evident therefore, that trace elements, along with other nutrients like vitamins and proteins are key to good health in man. It has been shown that the sure way to recover from an illness is when the immune system overcomes the problem (O’Shea, 2002). Thus a sure way to better health is to do everything possible to build up our natural immune system. One effective way is through nutritional supplementation. It may not be dramatic but daily deposit to the immune system bank account will pay off down the road. Healthy people don’t get sick (O’Shea, 2002). It need not cost money and it often saves money to prevent illness or treat it early, rather than wait until the services of a physician or healer are necessary. Adequate knowledge and experience in the field of traditional food science show that there is potential of food and herbal medicine in contributing to good health (Mutisya, 2009). Previous local communities have identified locally affordable and accessible nutrition and herbal care to manage common health complaints. Some have been documented in the book “Using our Traditions: A Herbal and Nutritional Guide for Kenyan Families” (Mutisya, 2009).
Foods are preferred as a primary source of nutrients as opposed to conventional supplements because it is difficult to get too much or an overdose of minerals from foods as would happen with a mineral supplementary pill (McDonald, 1997). However, to ensure food nutrition and good health, all essential nutrients must be supplied in adequate amounts. Many elderly people do not eat well because of economic problems, loneliness, physical handicap or reduced mobility (McDonald, 1997). This may lead them to suffering from nutrient deficiency conditions, and many are known to dislike and refuse conventional medication. To avoid the incidence of having to dispense mineral supplements, a balanced diet containing foods rich in essential trace elements would be recommended for such people in order to keep them in good health. Athletes may also benefit from higher intake of foods containing nutrients that are antioxidants because they are exposed to large volumes of oxygen during exercise (McDonald, 1997).

Food sources rich in nutrients or essential trace elements include terrestrial plants, halophytes as well as the less familiar aquatic plants (McHugh, 1988). Among the latter are seaweeds and marine algae which have been used as human foods by the Chinese for many centuries, and in significant amounts by Japanese communities (McHugh, 1988). However in the tropics these and other aquatic plants have not been popular as food, except among few indigenous and conservative communities. Along the Kenyan Coast there is such a halophytic vegetable plant locally known as “Mboga ya Pwani” (Local Community, Personal
Communication). Its botanical name is *Sesuvium portulacastrum* (L) L. and goes by the common name shoreline sea purslane (Gilman, 1999). It is a widespread succulent perennial herb or vine known to be an edible wild plant in tropical coastal areas of the US and Caribbean (McHugh, 1988). It is however cultivated and consumed as a vegetable in India, Indonesia and Southern China and is also known to have some medicinal value (McHugh, 1988).

The marine halophytes are nourished by soils that are consistently exposed to the highly mineralized sea water, on which the marine algae and seaweed also thrive. The latter are known to contain carbohydrates, some of which are useful in the food and pharmaceutical industries as stabilizers and as binders in confectionary, fish food and release tablets (McHugh, 1988). Seaweeds in particular are of important nutritional value, containing less than 1% fats and a high content of minerals (Milan *et al*., 1998). They have been harvested for food, fodder, fertilizer and medicine (White and Keleshian, 1994). Seafood and seaweeds are also a good source of iodine (Paraphona, 2004). It is for this reason that “Mboga ya Pwani” may contain substantial amounts of iodine and immune boosting trace metals since it thrives on a marine environment similar to the seaweeds (McDonald, 1997).
1.2 Problem Statement and Justification

In many parts of the world people are going hungry due to limited food supply. Many leafy vegetables in the tropics grow wild and are not even known to health educators (Paraphona, 2004) and other stakeholders, may be due to their unfamiliar habitat. Consequently, they are of not much interest to researchers and they almost go unnoticed due to lack of documented information and data, yet they are highly beneficial to man. A significant positive correlation has been reported between indigenous knowledge and consumption patterns of African leafy vegetables in Western Kenya (Nyakabo, 2011). Culture was thought to play a great role in consumption of such vegetables, which potentially have health implications especially for life threatening non-communicable but degenerative diseases such as cancer, diabetes, and heart disorders. Most indigenous foods contain essential trace elements like zinc, chromium, vanadium, selenium and iodine which have an immune boosting effect in the body and should be highly recommended for use by majority of the population especially the poor. This would provide an equally effective alternative source of food and medicine within their means, since they are cheap and easily available.

*S. portulacastrum* is one such natural green vegetable which may have preventive and curative effects that promote the body immune system, leading to less infections and quick recovery from common ailments. The plant grows in sea shore soils supposedly rich in trace elements supplied by the tidal mineral-rich
ocean water (McHugh, 1988). Being a leafy succulent vegetable, it could contain essential nutrients in its leaves and stem accumulated from its mineral-rich marine habitat. Most people along the Kenyan coast are not even aware of its existence (Kwale Community, personal communication) but a local entrepreneur is cashing in on it as a tourist delicacy at Kisite Mpunguti Hotel on Wasini Island.

It is therefore necessary to assess the level of utilization of *S. portulacastrum L. L.* by the Kwale communities and to determine the level of selected essential elements in this indigenous vegetable in order to document its potential nutritive benefit, and create awareness among the various stakeholders and consequently enhance its utilization. Since elements are known to move in geological circles, it is also important to determine the level of the same elements in the soil and water supporting the plant growth in order to establish any such correlations.

1.3 Hypotheses

(i) The local community does not know the nutritional value and uses of *Sesuvium portulacastrum* (‘Mboga ya Pwani’).

(ii) The *Sesuvium portulacastrum* does not contain substantial amounts of essential trace elements.

(iii) The level of essential trace elements in the leaves and stems of *Sesuvium portulacastrum* is not directly related to the soil and water on which it grows.
1.4 Objectives

1.4.1 Main Objective

To assess the extent of utilization of *Sesuvium portulacastrum* by the Kwale community and to determine the levels of selected essential trace elements in the plant, soil and water on which it grows.

1.4.2 Specific Objectives

(i) To assess the level of utilization of *Sesuvium portulacastrum* by the Kwale community using a questionnaire.

(ii) To determine the concentration of essential trace elements chromium, iodine, selenium, vanadium and zinc during both wet and dry season in Vanga, Funzi and Wasini in:-

   (a) Leaves and stems of *Sesuvium portulacastrum*.

   (b) Soil and water on the shores of the Indian Ocean on which *Sesuvium portulacastrum* grows.

1.5 Significance of Study and Anticipated Output

This study is important as it seeks to establish the potential nutritive value of the plant with respect to essential trace elements. The study will promote awareness of the plant as a potential cheap and locally available natural food source or nutrient supplement. Sustainable utilization of this vegetable will help meet some millennium development goals (MDGs) of providing food and promoting good
health, thus alleviating poverty and the incidence of child mortality among the poor Kwale community. Large scale exploitation of the plant will lead to job creation and a source of income for the Kwale communities thus promoting their livelihood. The analytical results will provide important baseline data on the plant. This will lay a foundation for further analysis on essential micronutrients on the plant and its environment. Thus analytical chemistry will be seen to aid in developing the information base to support rational decision making on utilization, conservation and development of the nation’s and coastal resources, as well as ensure that critical knowledge gaps are addressed (Borman, 1983).

1.6 Scope and Limitations

This study covered only specific areas on the coastline of Kwale County of Coast Province namely Funzi, Vanga and Wasini, since they were the easily accessible habitats of *Sesuvium portulacastrum*. The varieties of the plant were not considered. Seasonal variations were considered while tidal variations were not.
CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 Trace Elements

Trace elements are those that naturally occur in extremely small quantities of a few parts per million (ppm), and reside in or are present in animal and plant cells and tissue. They are needed in the body in organic form and absorbed as ions. Trace elements are classified as essential or non-essential. The non-essentials have no known value to organisms. They are non-biodegradable and hence bio-accumulative. They are toxic to organisms even at low levels and include lead, cadmium and mercury (Tyagi and Mehra, 1990). The essential trace elements are of nutritional value and promote growth and reproduction in an organism, although they may be toxic if taken up in excessively high concentrations at once. Inadequate intake of these elements affects various body functions, and the body may require supplementation. A dietary supplement, also known as food supplement or nutritional supplement is a preparation intended to provide the essential elements that are missing or are not consumed in sufficient quantity in a person’s diet.

2.2 Essential Trace Elements

An element is considered essential to an organism when reduction of exposure to it below a certain limit would result consistently in a reduction of a physiologically important function, or when the element is an integral part of an
organic structure with a vital function in that organism (Weisell, 1999). They form an essential part of every tissue in the body and dominate the harder structures such as bones, and are the chief factors in maintaining the normal alkalinity of the body and informal specific gravity. They are the constituents of the body’s secretions and a lack of them in the diet produces a lack of secretions. They act as detoxifying agents by neutralizing the acid waste from the cells that causes acidosis. In the blood and lymph they help maintain a proper osmotic equilibrium. They form catalysts for most biological reactions whose functions include solutes and electrolytes balance in the blood, enzyme action, energy production from food breakdown, nerve transmission and muscle action (O’Shea, 2002). Some trace elements currently considered essential include Cr, V, Se, Zn, I, Co, Cu, F, Fe, Mo, Cl and Mn (Booth, 2005). Today seventeen minerals are recognized as essential elements for humans, and the list is growing.

Most essential trace elements are found in foods. Some elements that have been thought to be contaminants have been proved to be essential, but only if taken in certain limited amounts. They form a necessary part of good nutrition and are depleted through the expenditure of energy by a living organism. They are replenished in animals by eating plants and replenished in plants through the uptake of nutrients from the soil in which they grow. Thus essential trace elements are known to circulate in geological circles. Primarily, all our foods are derived from the vegetable kingdom, for no animal has the capacity of associating
trace elements and forming them into food the way plants do. The earth contains a perfect balance of all the nutrients humans need to be healthy and happy. However the problem of soil-nutrient depletion has emerged. Over the years, soil erosion and aggressive farming practices have depleted the essential nutrients in crops and human nutrition has suffered. According to Aswathanarayana (1994) ‘When people consume a diet derived from crops grown in nutrient-deprived soil, their intake of essential elements becomes inadequate. This leads to the impairment of relevant physiological functions and causes disease’.

Essential trace elements may occur in clusters in the diet and function interactively. If in the right proportions, they act synergistically to positively alter physiological variables in the body such as blood pressure (Reusser and McCarron, 1994). They are required by man in amounts ranging from 50 µg to 15 mg per day (NASCOP, 2008). Plants with adequate trace elements have therefore been used as medicinal herbs and for production of metal-based drugs, as well as a source of food.

Many common health problems like deficiency diseases can be prevented or alleviated with a healthy diet. Serious health threatening conditions like obesity and metabolic syndrome, common chronic systematic diseases such as cardiovascular diseases, diabetes and osteoporosis may result due to lack of essential trace elements. Consumption of whole-plant foods slows digestion and
allows better absorption and a more favorable balance of such elements as opposed to the processed foods. This results in better management of various body functions.

2.3 Health Effects of Essential Trace Elements

Trace elements and mineral nutrition affect various disease states including genetic, endocrine, skeletal, cardiovascular, kidney, gastrointestinal, surgical and ophthalmologic disorders (Booth, 2005). They have the benefit of stimulating and boosting the body’s immune mechanism and have therapeutic effects for such conditions as diabetes, infertility and heart diseases. Inorganic elements in the body fluids help in maintaining acid-base balance and water balance. Some are essential for normal responses of nerves and muscles to stimuli, while others are important regulators of body chemistry and normal enzyme action. They act as catalysts or structural components of larger molecules with specific function and are therefore indispensable in life (NASCOP, 2008).

As the science of chemistry developed in the 18th and 19th centuries, so did procedures to analyze what we eat. By the later part of the 19th century, the English Physician William Prout proposed that an “adequate diet” had to include inorganic elements in form of minerals which include essential trace elements in appropriate amounts (O’Shea, 2002). The two-time Nobel Prize Winner Linus Pauling once said: “You can trace every sickness, every disease and ailment to
mineral deficiency” (O’Shea, 2002). Essential trace element deficiency means some work is not done in the body and this elicits non-specific symptoms such as reduced growth and development, premature aging and cell break down (O’Shea, 2002), which are not easily recognized (Weisell, 1999).

Essential trace elements have been directly associated with the immune function. The sensitivity of the immune system is one function that declines with age. Since the system fights off tumors as well as infection, its decline leaves a person more vulnerable not only to colds but to cancer (McDonald, 1997). A declining immune system can also sap ones’ energy. Since immunity declines with age, older adults over 50 years usually benefit more than young adults from immune boosting nutrients. Antioxidants are important for preserving immune function because the inflammation process causes the production of free radicals by immune cells in the act of fighting bacteria or other foreign substances. When immune cells are called into action by the presence of bacteria, viruses, tumor cells or other foreign substances in the system, they must increase their numbers to challenge these substances successfully. Our bodies must be able to maintain a properly functioning immune system that will not only fight off the pathogens but also destroy cancer cells in the early stages of the disease (McDonald, 1997).

Diet among many things can affect how well the immune system operates. While some vitamins are necessary for immune function, several essential trace elements
are also needed to ensure optimal function of the system. These include Fe, Zn, Cu, Cr, Se, V, I, Co and Mn among others. Most of these are supplied in differing proportions from the different types of foods we eat. Fruits and vegetables protect us against diseases due to their antioxidant properties, besides having a low fat content (McDonald, 1997). It is in this context that the locally and wildly growing coastal vegetable *Sesuvium portulacastrum*, locally known as “Mboga ya Pwani” is very significant in this study. This is because, being a marine halophyte, the environment in which it grows is mineral rich from the constant exposure to seawater, and hence it could be accumulating adequate levels of the essential trace elements. A few essential trace elements that are of interest in this study have been discussed in the following section.

2.4 Chromium

2.4.1 Introduction

Chromium is abundant in the earth’s crust with an average concentration of 100 ppm. Chromium containing compounds in the environment are due to erosion of chromium-containing rocks and volcanic eruptions. Chromium is an important essential trace element that is frequent in the environment and in food as Cr$^{3+}$ (Bowen, 1984). The concentration range in the soil is between 1 and 3000 mg/kg, in seawater 5 to 800 µg/L and in rivers and lakes 26 µg/L to 5.2 mg/L (Kotas and Stasicka, 2000). The relationship between Cr$^{3+}$ and Cr$^{6+}$ strongly depends on pH and oxidative properties of the location, but mostly Cr$^{3+}$ is the dominating species
(Kotas and Stasicka, 2000). Water insoluble Cr\textsuperscript{+3} compounds and chromium metal are not considered a health hazard, but Cr\textsuperscript{+6} is toxic and carcinogenic (Barceloux and Barceloux, 1999). Because of the specific transport mechanisms, only limited amounts of Cr\textsuperscript{+3} enter the cells. In man the highest concentrations of chromium in the body are found in the liver, kidney, spleen and bone.

2.4.2 Benefits and Uses of Chromium

Chromium uptake in man is known to positively influence diabetes condition by aiding sugar and lipid metabolism (Mertz, 1993). Trivalent chromium in combination with nicotinic acid forms a constituent of an organic compound known as glucose tolerant factor (GTF) which regulates the metabolism of glucose in the body by primarily potentiating the action of insulin (Horrobin, 1981; McDonald, 1997). GTF increases glucose tolerance by enhancing the hormone insulin through increasing the body’s sensitivity to it which results in sugars passing quicker into the cells and hence removal from the bloodstream leading to stabilized blood sugar levels (McDonald, 1997). Chromium is also required for fat metabolism, thus assists in regulating cholesterol in the blood. Kwashiorkor, which is usually accompanied by impaired glucose intolerance, also improves with the administration of chromium (Horrobin, 1981). Natural chromium levels decline with age and so does the action of GTF (McDonald, 1997), hence the great need to eat natural foods rich in essential trace elements.
particularly vegetables. The GTF also contains niacin, vitamin B₃, glycine, cysteine, glutamic acid among other constituents (McDonald, 1997).

Chromium is normally added to dietary supplements as CrCl₃, chromium (III) picolinate, chromium (III) polynicotinate, or amino acid chelate such as chromium (III) D-phenylalanine (Heimbach, 2005; Vincent, 2007). Several in vitro studies indicated that high concentrations could lead to DNA damage (Eastmond et al., 2008). Acute oral toxicity ranges between 1500 to 3300 µg kg⁻¹ for Cr⁺³ and 50 to 150 µg kg⁻¹ for Cr⁺⁶ (Katz and Salem, 1992). While it is easily excreted from the body, it has strong oxidation properties through which it damages blood cells, the kidneys and liver resulting into haemolysis, renal and liver failure respectively. This condition can only be improved by aggressive dialysis (Dayan and Paine, 2001). Chromates cause allergic contact dermatitis and irritant dermatitis resulting in ulceration of the skin or “chrome ulcers”, a condition common with workers in electroplating, tanning and chrome-producing factories (Basketter et al., 2000). In some parts of Russia, pentavalent chromium was reported as one of the causes of premature dementia.

2.4.3 Chromium Deficiency

Deficiency of chromium leads to symptoms such as anxiety, fatigue, glucose intolerant (especially in people with diabetes), inadequate metabolism of amino acids and increased risk of arteriosclerosis. A group of people with special
chromium requirement include the overweight, those with high cholesterol levels, those exercising heavily and those with sugar cravings.

2.4.4 Sources and Studies of Chromium

In general food appears to be the major source of intake in form of fresh fruit, vegetables, eggs, wheat germ, beef and brewers’ yeast. Very little is found in refined foods (McDonald, 1997). Daily dietary requirements range between 0.01 to 0.03 mg Cr per day (Bowen, 1984). Elsewhere it has been suggested that safe and adequate range of intake of chromium is 0.05 to 0.2 mg per day (McDonald, 1997) and an RDA value placed at 0.12 mg per day (McDonald, 1997). The United States dietary guidelines for daily chromium intake are 0.035 mg for adult male and 0.025 mg for adult female (Vincent, 2007).

Mbovu (2002) reported mean chromium levels in river Migori to be 6.04 mg/L. Elsewhere, chromium in different selected samples was reported to be within the following ranges: seeds 5.00 to 6.2 µg/g; spices 1.76 to 12.8 µg/g; grains 2.24 to 5.86 µg/g (Muchemi, 2006). Sesuvium portulacastrum samples from India gave a range of 0.48 µg/g chromium in the stems to 7.44 µg/g in the leaves (Vardanyan and Ingole, 2004).
2.5 Iodine

2.5.1 Introduction

Iodine occurs naturally in the environment chiefly as dissolved iodide in seawater, although it is also found in some minerals and soils (Dissanayake et al., 1999). It does not occur naturally in a free state but as iodides that are very soluble in water, but when freed from its compounds it forms diatomic molecules ($I_2$). It is concentrated in seawater and is required in trace amounts by all animals and some plants (McMaster and Enemark, 1998; Hille, 2002).

2.5.2 Benefits and Uses of Iodine

Iodine is beneficial to man and is found in the thyroid gland in very minute quantities. It helps in the production of thyroxine, an internal secretion of the thyroid, which regulates the rate at which energy producing nutrients are oxidized or burned in the cells. Of the 25 mg of iodine in the body, almost half of it is found in the thyroid gland (McDonald, 1997). The two main thyroid hormones, thyroxine and tri-iodothyronine, are synthesized by the body from iodine and the amino acid tyrosine. Thyroxine controls energy metabolism in the body by regulating the conversion of fat to energy thus stabilizing body weight and controlling cholesterol levels. It therefore influences vital functions such as normal body temperature, basal metabolic rate, reproduction and growth, all of which are life-sustaining (McDonald, 1997). Hormones help to form bones, keep skin, nails, hair and teeth healthy and prevent cancer of the breast and womb.
Shortage of hormones leads to constipation, obesity, weaknesses, mental slowness and other mental problems.

Iodine protects against goiter (Storbark, 1985), a condition that causes thyroid gland to enlarge beyond its normal size and can be as big as one’s head (McDonald, 1997). This is the body’s attempt to maximize the amount of iodine to be extracted from the blood. Certain substances called goitrogens can induce goiter when iodine intake is low by interfering with iodine. However, they are destroyed by heat hence their potential danger is avoided by not eating large amounts of raw foods such as cabbage, peanuts and cauliflower (McDonald, 1997).

Iodine has an important function in the immune system. The high iodide-concentration of thymus suggests an anatomical rationale for this role of iodine in the immune system (Marani et al., 1985; Venturi et al., 1993; Ma et al., 2002; Venturi and Venturi, 2009A). In tropics, antioxidant and opoptosis-inductor actions and the presumed anti-tumour activity of iodides might also be important for prevention of oral and salivary glands diseases (Bartelstone et al., 1951; Banerjee et al., 1985; Banerjee and Datta, 1986; Bahar et al., 2007; Venturi and Venturi, 2009B). Laboratory evidences demonstrate that iodine inhibits breast cancer through modulation of the estrogen pathway, this being independent of the thyroid function. Research has reported a decrease in death rate from stomach
cancer after implementation of an effective iodine-prophylaxis, where iodine functions in the gastric mucosa as an anti-oxidant to detoxify it of destructive species like hydrogen peroxide (Venturi et al., 1993).

In an official report given in 1924, Dr. Baruaze, an English medical officer, summarized the role of iodine in the human body as follows (Venturi and Venturi, 2009A): ‘Iodine is necessary for effective body metabolism which promotes respiratory exchanges and physical growth. It promotes efficient mental capacity thus preventing cretinism that results from severe shortage before birth, hence is needed in pregnant mothers. At the adolescence age it is required for the development of reproductive organs particularly in the female where the change-over takes place more elaborately than in males. It keeps the skin and its appendages in a healthy condition thus preventing frequent hair fall associated with thyroid deficiency. It is required for the digestion, assimilation and combustion of fats, thus preventing obesity. It is required for metabolism of calcium and helps the body resist invasion of microbes by rendering harmless the toxins they produce’.

Iodine protects the thyroid from the effects of radiation. The Polish government gave iodine tablets in form of potassium iodide to its populations after they got exposed to nuclear fission radiation from the accidental Chernobyl nuclear explosion, thus protecting them from many harmful late-cancer effects of nuclear
fallout. Due to preferential uptake of iodine by the thyroid, I-131 which has a short half-life is used for thyroid ablation where it is administered intravenously or orally to destroy remnant tissues after thyroid cancer surgery. Iodine containing compounds are sometimes used to disinfect daily equipments while iodine-containing feed is fed to dairy cattle. These two sources contribute to increase in the amount of iodine in milk and diary products. It is also found in dough conditioners used by bakeries and in food colorings (McDonald, 1997). High-iodine content eggs have also been developed to offset the high cholesterol content of the yolk whereby the iodine, through the thyroid hormones increases cholesterol metabolism (McDonald, 1997).

When iodine in the soil is not excessive, the concentration of I$_2$ in vegetables (radial spinach and Chinese cabbage) was found to increase as the content of I$_2$ in the soil increases (Weng et al., 2003). The absorbability and enrichment degree of I$_2$ in various vegetables and in various parts of the same vegetables are different, which explains why the concentration of I$_2$ in plants is determined by the plant type and the physiological action of plant (Weng et al., 2003).

Iodine has several other applications. Tincture of iodine (3% elemental iodine in water/ethanol base) is an essential component of any emergency survival kit, used both to disinfect wounds and to sanitize surface water for drinking (3 drops per liter). Iodine crystals have also been used to disinfect certain portable and
swimming pool waters (APHA et al., 1995). It lessens eye burn among swimmers and provides a stable disinfectant residue that is less affected by adverse environmental conditions (APHA et al., 1995). Radioactive iodine has been used for treatment for hyperthyroidism (Graves’ disease). The artificial radioisotope I-131, with a half-life of 8 days, has been used to treat the thyroid gland. In the 1970’s, imaging techniques were developed to employ radioiodine in diagnostics for renal hypertension. Iodides together with thyroxin which contains iodine are used internally in medicine.

2.5.3 Iodine Deficiency

Iodine is not stored in the body but has several sources, so deficiency is not common. However, deficiency of iodine in pregnancy results in birth of a baby with retarded physical and mental development, a condition known as cretinism (McDonald, 1997). This is as a result of diminished production of vital growth and development hormones (UNICEF, 2005). In children, cretinism is associated with stunting apathy (dwarfisms), lassitude, diminished mental capacities and coarseness of face and skin (Taylor and Sinkiss, 1984), as well as impaired movement capacity, speech and hearing impairments (UNICEF, 2005). Iodine requirement in pregnancy is 250 - 300 µg per day and 225 - 350 µg per day during lactation. During the neonatal period the requirement of the infant is 90 µg per day.
Pregnant women and young infants, but especially the second group, are more sensitive to the effects of an iodine deficiency than the general population because their serum thyroid-stimulating hormone (TSH) and thyroxin are increased and decreased, respectively, for degrees of iodine deficiency that do not seem to affect thyroid function in the general population. A clinical trial study of oral iodized oil conducted in Subang, West Java, Indonesia to evaluate the effect of iodine supplementation on infant mortality involved 617 infants receiving placebo or oral iodized oil (100 mg) at about 6 weeks of age. Follow up was done up to 6 months of age. Infant survival was apparently improved, as indicated by a 72% reduction in the risk of death during the first two months of follow up. Hence the study suggested that infant survival is improved by oral iodized oil supplementation of infants in populations at risk for iodine deficiency. In areas where there is little iodine in the diet, typically remote inland areas and semi-arid equatorial climates where no marine foods are eaten, iodine deficiency gives rise to hypothyroidism, symptoms of which are extreme fatigue, goiter, mental slowing, depression, weight gain, and low basal body temperatures. According to recent studies, iodine deficiency is further associated with gestosis, premature birth, miscarriage, or birth of mentally retarded or borderline intellect babies, and low-weight babies at birth.

Other deficiency symptoms include physical sluggishness, slowed heart rate, weight gain, increased sleeping time of up to 14 to 16 hours a day and
constipation (McDonald, 1997). Thus iodine deficiency is the single most known cause of preventable mental retardation and neurological damage (UNICEF, 2005), which is primarily as a result of babies or small children being rendered hypothyroidic by lack of iodine. The addition of iodine to table salt has largely eliminated this problem in the wealthier nations, but as of March 2006, iodine deficiency remained a serious public health problem in the developing world and some areas of Europe (UNICEF, 2005). However a recent study on Kenyan school going children has shown that introduction of iodinated salt whose iodate level was increased from 33.5 to 168.5 mg/kg by the WHO has controlled the iodine deficiency disorders prevalence at 3.5% below the WHO reference value of 5.0% (Kishoyian, 2011).

On the other hand, like most autoimmune diseases of humans, Hashimoto's thyroiditis results from the combination of a genetic predisposition and an environmental trigger such as excessive ingestion of iodine. It is a progressive inflammatory disease of the thyroid, after exposure to radioactive iodine therapy in childhood. There is also increased long-term risk of developing a tumor in the thyroid gland.

2.5.4 Sources and Studies on Iodine

Iodine is naturally and abundantly found in sea water, sea foods, sea vegetables as well as plants grown on iodine-rich soils (McDonald, 1997). Rich sources include
vegetables and fruits. Other sources include milk and eggs (McDonald, 1997; Paraphona, 2004). The amount of iodine in foods like vegetables and grains depend on the amount of iodine present in soils in which they were grown. At the coastal regions soils are rich in iodine accumulated from the sea hence ocean and gulf sea food is a very rich source of iodine (Paraphona, 2004). Salt water fish together with sea weeds are the best sources of iodine. Kelp, the general name for brown seaweeds, tends to be particularly high in iodine (Dissanayake et al., 1999), and is used as extracts or tablets in health diets (Storbark, 1980). Although the element is quite rare, kelp and certain plants and other algae have some ability to concentrate iodine, which helps introduce iodine into the food chain (Bell et al., 2002). A 100 g of sea water fish provides from 150 to 350 mg of iodine, between twice and three times the RDA for an adult, while fresh water fish contains only 0.2 to 0.4 mg of iodine per 100 g (Paraphona, 2004). Iodized salt is fortified with iodine. It has been used since 1924 and provides a rich source, one teaspoon providing 260 µg of iodine, nearly twice the RDA, which stands at 150 µg per day for adults (McDonald, 1997). A tolerable upper intake level (UL) of 1100 µg per day has been placed (NRC, 2000), the limit of which was assessed by analyzing the effect of supplementation on thyroid-stimulating hormone.
2.6 Selenium

2.6.1 Introduction

Selenium used to be treated as a very toxic substance but modern science now regards it as essential, but in small amounts. It is an essential trace element for both plants and animals. Most selenium compounds are water soluble and are efficiently absorbed from the intestines (WHO, 1998). It is found in all body tissues with the highest concentrations in the kidneys, liver, spleen, pancreas and testicles (McDonald, 1997). The maximum acceptable concentration (MAC) of selenium in portable water is 0.01 ppm. Higher concentrations than this are caused by contamination by industrial waste or dissolution of selenium-containing soils. Excess selenium is poisonous because it can substitute sulphur in proteins of some important enzymes thus altering their functions (McDonald, 1997). Hence it is important to use natural food supplements where there is no risk of exceeding the dietary intake requirements which may happen with the use of the conventional supplement pills. Selenium occurs naturally in a number of inorganic forms, including selenide, selenate and selenite. In soils, selenium most often occurs in soluble forms such as selenate which are leached into rivers very easily by runoff.

2.6.2 Benefits and Uses of Selenium

Selenium has a biological role, and it is found in organic compounds such as dimethyl selenide, selenomethionin, selenocysteine and methylselenocysteine.
Here it plays a role analogous to that of sulfur. Selenium is a catalyst in many chemical reactions and is widely used in the various industrial and laboratory synthesis, especially organoselenium chemistry. It is used in structure determination of proteins and nucleic acids by X-ray crystallography. Selenium (IV) sulfide, SeS₂, is the active ingredient in some dandruff shampoos where it kills the scalp fungus, *Malassezia*, which causes shedding of dry skin fragments. It is used in body lotions to treat *Tinea versicolor* due to infection by a different species of *Malassezia* fungus.

Some plants may accumulate selenium as a defense against being eaten by animals. Other plants such as locoweed require selenium, and their growth indicates the presence of selenium in soil (Ruyle, 2009). It is a component of the unusual amino acids selenocysteine and selenomethionine.

Although it is toxic in large doses, selenium is an essential micronutrient for animals. In man, selenium functions as a strong antioxidant, being a part of the enzyme glutathione peroxidase that helps prevent cell damage that may occur from the breakdown products of fats and other compounds that have been altered chemically due to oxygen (Weisell, 1999; McDonald, 1997). It functions as a cofactor for reduction of glutathione peroxidases and certain forms of thioredoxin reductase found in animals and some plants. Glutathione peroxidase (GSH-Px) catalyses certain reactions that remove reactive oxygen species such as peroxide.
Dietary selenium prevents chemically induced carcinogenesis in many rodent studies. It has been proposed that selenium may help prevent cancer by acting as an antioxidant or by enhancing immune activity. The SU.VI.MAX study (Hercberg et al., 1998) concluded that low-dose supplementation (with 120 mg of ascorbic acid, 30 mg of vitamin E, 6 mg of beta carotene, 100 µg of selenium, and 20 mg of zinc) resulted in a 30% reduction in the incidence of cancer and a 37% reduction in all-cause mortality in males (Hercberg et al., 2004). There is evidence that selenium can help chemotherapy treatment by enhancing the efficacy of the treatment, reducing the toxicity of chemotherapeutic drugs, and preventing the body’s resistance to the drugs. It has been reported that Vitamin E (400 IU) and selenium (200 µg) supplements affect gene expression and can act as a tumor suppressor (Tsavachidou et al., 2009). This seems to support previous evidence that selenium and Vitamin E might be active as cancer preventatives (Klein, 2009). Together with vitamin E, selenium protects the cells from damage by helping neutralize free radicals (McDonald, 1997; O’Shea, 2002; Paraphona, 2004) which are rampant in the presence of cancer. Thus selenium is an anticarcinogen that protects against cancer of the breasts and skin. Upon administration, selenium has also shown 63% and 46% of reduction in prostate and lung cancer respectively (O’Shea, 2002). When taken in foods like vegetables, selenium has recently been found to provide a relatively simple and harmless means of countering the excess risk of rectal cancer in habitual and
persistent beer drinkers (Kune and Watson, 2011). Cancer rates are found to be higher in parts of the world whose soils contain little selenium (McDonald, 1997).

Selenium also plays a role in the functioning of the thyroid gland by participating as a cofactor for the thyroid hormone deiodinase. It is known to protect the body against the toxic effects of mercury, lead, cadmium and silver by creating an antagonistic effect (Paraphona, 2004). It possesses anti-aging properties since it protects against arteriosclerosis and degenerative diseases that cause premature ageing. It enhances and stimulates the immune system which fights infections by contributing to the formation of antibodies that attack infectious agents, thus promoting more energy in the body (Paraphona, 2004).

Selenium alleviates menopausal symptoms in women and assists males in producing healthy sperms. Men need more selenium than women as it is lost in the seminal fluid. Selenium is involved in the systematic utilization of iodine, being a component of the enzyme responsible for converting thyroxine into triiodothyroxine (T\textsubscript{3}) (Weisell, 1999; Arthur and Beckett, 1989; Arthur et al., 1990). It helps fight cold sores and shingles, both caused by the herpes virus (Arthur et al., 1990). Researchers have shown that in selenium deficient animals, a harmless virus can mutate into a virulent form capable of causing damage or death, thus the presence of selenium helps keep the spread and multiplying of viruses in check (Arthur et al., 1990).
Tissue elasticity and pancreatic function is dependant on selenium, which is also used against arthritis and multiple sclerosis. Selenium also makes the blood less “sticky” (thinning of blood) thus preventing the incidence of heart disease and stroke (McDonald, 1997). In nutrition, selenium is used widely in vitamin preparation and other dietary supplements in small doses (typically 50 to 200 µg per day for adult humans) (McDonald, 1997). Some livestock feeds are fortified with selenium as well.

Some research has suggested that selenium supplementation, along with other nutrients, can help prevent the recurrence of tuberculosis (Villamor et al., 2008). A well controlled study showed that selenium intake is positively correlated with the risk of developing type II diabetes. Since high serum selenium levels are positively associated with the prevalence of diabetes, and because selenium deficiency is rare, supplementation is not recommended in well-nourished populations such as the US (Bleys et al., 2007). Experiment findings have demonstrated a protective effect of selenium on methylmercury toxicity (Watanabe, 2002).

2.6.3 Selenium Deficiency

Selenium deficiencies are very common in areas with low selenium concentration in the soil and have been historically linked to a variety of clinical effects (Ramesh, 2011). However these deficiencies are hard to detect because vitamin E
can substitute for selenium in its function (McDonald, 1997). Deficiency in animals affects fertility, produces muscular dystrophy, leukocyte inefficiency and liver necrosis. Endemic cardiomyopathy among the population of Keshan in China where selenium is deficient has been cured by supplementing the diet with 0.065 to 0.13 mg Se⁴⁺ per day (Taylor and Siskiss, 1984).

Several studies have suggested a possible link between cancer and selenium deficiency (Burguera et al., 1990; Clark et al., 1996; Young and Lee, 1999; Lippman et al., 2009). A study was conducted to test the effect of selenium supplementation on the recurrence of skin cancer of selenium-deficient men. It did show a reduced occurrence of total cancers. Some research has indicated a geographical link between regions of selenium-deficient soils and peak incidences of HIV/AIDS infection (Patrick, 1999). AIDS appears to involve a low and progressive decline in levels of selenium in the body, which results in the replication of HIV (Patrick, 1999). Low selenium levels in AIDS patients have been directly correlated with decreased immune cell count and increased disease progression and risk of death. Selenium normally acts as an anti-oxidant; hence low levels of it may increase oxidative stress on the immune system leading to more rapid decline of the immune system. Depleted selenium levels in turn lead to a decline in CD4 helper T-cells, further weakening the immune system (Taylor, 1995). Regardless of the cause of depleted selenium levels in AIDS patients, studies have shown that selenium deficiency does strongly correlate with the
progression of the disease and the risk of death (Baum and Shor-Posner, 1998; Campa et al., 1999). The normal daily intake in man is 0.006 to 0.02 mg per day; with deficiency occurring below 0.006 mg per day (Paraphona, 2004; Taylor and Sinkiss, 1984).

2.6.4 Sources and Studies on Selenium

Natural sources of selenium include certain selenium-rich soils, and selenium that has been bio-concentrated by certain plants. Anthropogenic sources of selenium include coal burning and the mining and smelting of sulfide ores. Dietary selenium comes from vegetables, fruits and grains as well as seafood, nuts, cereals, meat, fish and eggs (McDonald, 1997; Kune and Watson, 2011). The amount of it in the former depends upon the level of the mineral found in the soils in which they grow (McDonald, 1997). Brazil nuts are the richest ordinary dietary source. In descending order of concentration, high levels are also found in kidney, tuna, crab and lobster (Barclay et al., 1995). Muchemi (2006) found varying levels of selenium in different samples of seeds ranging from 16.54 to 182.70 µg/kg; spices: 30.00 to 153.80 µg/kg and grains: 29.58 to 140.00 µg/kg.

2.7 Vanadium

2.7.1 Introduction

Metallic vanadium is not found in nature, but is known to exist in about 65 different minerals (Magyar, 2008). Vanadium is also present in bauxite and in
fossil fuel deposits such as crude oil, coal, oil, shale and tar sands. In crude oil, concentrations up to 1200 ppm have been reported (Pearson and Green, 1993). Like other trace minerals vanadium is considered essential in very tiny amounts to maintain health and ensure proper function of the body.

2.7.2 Benefits and Uses of Vanadium

It acts as a co-enzyme, working as a team with proteins to facilitate important clinical reactions. Even without taking vanadium supplements, there is about 20 - 25 µg of vanadium in the human body which is derived from an average balanced diet (Annussek, 2005). It is present in the heart and blood vessels, kidneys, spleen, liver, bone and testes (Harisson and Mora, 1996). Vanadium uptake appears to be regulated and it appears to have a role in the regulation of sodium and in the metabolism of glucose and lipids. There is speculation that sodium and potassium adenosine triphosphatase (ATPase) activity might be controlled by vanadate ions (Bowen, 1984). There may be an interaction between vanadium and chromium but it is recommended that supplemental chromium and vanadium be taken at different times. High quantities chromium of become very toxic and are linked to manic depression. Signs of overdose or vanadium toxicity include abdominal cramping, diarrhea and a green tongue (Medeiros, 2011).

Vanadium is a relatively controversial dietary supplement primarily for increasing insulin sensitivity and body building (Yeh et al., 2003). It aids in the production
of red blood cells and encourages normal tissue growth and fat metabolism. Like chromium, it has become the focus of study as a possible aid in lowering blood sugar levels in people with diabetes (Annessek, 2005). It is said to improve insulin action by mimicking its function, (Harrison and Mora, 1996) and vanadyl sulfate has been seen to improve glucose control in people with non-insulin dependent diabetes (type II diabetes) (Goldfine, 2000; Boden, 1996). In studies of mice, vanadium has been shown to lower blood sugar and levels of low-density lipoproteins (LDL), cholesterol and triglyceride (Annessek, 2005). In mammals, vanadium inhibits cholesterol biosynthesis and its formation in blood vessels thus preventing heart attack, hypertension and arterioclerosis (Harisson and Mora, 1996).

Studies in animals suggest that vanadium may be necessary for the formation of bones, teeth and cartilage. In one study, goat kids whose mothers received a diet deficient in vanadium showed skeletal damage and died within days of their birth. It thus has the beneficial effects of preventing tooth decay or dental caries, and is considered a potential treatment for osteoporosis. Some athletes and weight lifters take it to build muscle or improve performance (Annessek, 2005) due to the anabolic effect of vanadium similar to that of insulin which leads to high glycogen stores in the muscle tissues. There is some evidence that athletes who take it are merely experiencing placebo effect (Talbott and Hughes, 2007). It also has a role in normal iodine metabolism and thyroid function, as well as
anticarcinogenic properties (in synergy with molybdenum) towards breast cancer (O’Shea, 2002).

Vanadium is essential to ascidians like the sea squids and sea cucumber as vanadium chromagen proteins (Harrison and Mora, 1996). 10 % of the blood cell pigment of the sea cucumber is vanadium, and the concentration of vanadium in their blood is more than 100 times higher than its level in the seawater around them (Harrison and Mora, 1996). Just as the horseshoe crab has blue blood due to copper in hemocyanin, and land animals have red blood from the iron in haemoglobin, the blood of the sea cucumber is yellow because of the vanadium in the vanabin pigment. Several species of macrofungi, namely Amanita muscaria and related species accumulate vanadium up to 500 mg per kg in dry weight. Vanadium is present in the coordination complex, amavadin (Rehder, 1992) in fungal fruit-bodies.

Vanadium-containing nitrogenase is used by some nitrogen-fixing microorganisms. Rats and chickens are also known to require vanadium in very small amounts and deficiencies result in reduced growth and impaired reproduction (Schwarz and Milne, 1971).
2.7.3 Vanadium Deficiency

Vanadium plays a very important biological role in man. Its deficiency leads to symptoms such as hypoglycemia, diabetes, spinal degeneration, bone deformation and arthritis, aching bones and increased dental cavities. Vanadium deficiency may alter the activity of the thyroid gland and its ability to properly use iodine (Medeiros, 2011). Elevated cholesterol, reduced growth and reproductive ability in animals have been observed. A weakening in the immune system is characterized by chest pain, wheezing, coughing, chronic colds, tonsils, runny nose and sore throat. Tobacco use decreases the uptake of vanadium while excess vitamin C can cause deficiency in some individuals. The DRI is not well established but is taken as 1-4 µg for adults (Taylor and Sinkiss, 1984). This quantity is supplied in our daily normal diet.

2.7.4 Sources and Studies on Vanadium

Vanadium together with chromium is abundantly found in vegetables, unrefined vegetable oils and unrefined salt seaweed like Kombu, Arame, Wakame, Nori and Irish moss as well as other sea food like fish (Schauss, 1995). Black pepper, olives, meat, cereals, corn, gelatin, meat, mushrooms, radishes and whole grains are other common sources. Herb sources of vanadium include dill and parsley. Vanadyl sulfate is used as the oral supplementation for vanadium. Anthropogenic sources that are toxic include alloy steels, manufacture of rubber, plastics and
ceramics, and contaminated air, food and water sources. The threshold value for vanadium is 0.05 mg / m³ (Plunkett, 1987).

Muchemi (2006) reported vanadium levels in pumpkin, watermelon and sunflower seeds to range between 1.54 µg/g to 10.53 µg/g, while in selected spices from not detected, ND, to 14.4 µg/g; and in selected grains from 6.28 µg/g to 11.48 µg/g.

2.8 Zinc
2.8.1 Introduction
Zinc is an essential mineral of exceptional biological and public health importance. It is needed as trace element by plants, animals and microorganisms (Prasad, 2008). It is found in nearly 100 specific enzymes (NRC, 2000). Typically it is the second most abundant transition metal in organisms, after iron, and is the only metal which appears in all enzyme classes (Broadley et al., 2007). In protein, zinc ions are often coordinated to the amino acid side chains of aspartic acid, glutamic acid, cystein and histidine (Erik et al., 2009). Cobalt and zinc can replace one another metabolically in different eukaryotic species (Teresa et al., 2004). The concentration of zinc in plants varies based on levels of the element in the soil.
Two examples of zinc-containing enzymes are carbonic anhydrase and carboxypeptidase, which are vital to the processes of carbon dioxide (CO₂) regulation and digestion of proteins, respectively. The non-related β-carbonic anhydrase is required in plants for leaf formation, the synthesis of indole acetic acid (auxin) and anaerobic respiration (alcoholic fermentation) (Gaddallah, 2000).

2.8.2 Benefits and Uses of Zinc

Zinc is an essential element in man. It is required for a robust immune system (McDonald, 1997). It is part of more than seventy different enzyme systems that function in the metabolism of carbohydrates, fats and proteins (O’Shea, 2002; McDonald, 1997). One of these enzymes, superoxide dismutase (SOD) serves as an antioxidant in cells, thus preventing aging and cancer (O’Shea, 2002). Zinc is part of insulin, a hormone that helps regulate blood sugar levels. It plays an important role in the transport of vitamin A from its storage in the liver so that it can be used in the body (McDonald, 1997). It is required for sexual development and gaining height (Horrobin, 1981) and is important for preserving the function of two of the organs in the immune system, the thymic gland and the spleen (McDonald, 1997).

There is 2 to 4 g of zinc distributed throughout the human body (Rink and Gabriel, 2000). Most of it is found in the brain, muscle, kidney and liver, with the highest concentration in the bones, prostate and part of the eye (Wapnir, 1990;
McDonald, 1997; Milan et al., 1998). The rest is found mostly in the skin, hair and nails (Bowen, 1984). Semen is particularly rich in zinc which is a key factor in prostate gland function and reproductive organ growth (Berdanier et al., 2007). It has been estimated that the prostate gland of the male contains more Zn than any other organ in their body (McDonald, 1997). In fact zinc therapy has been used in the treatment or management of certain prostate disorders (McDonald, 1997). It fights infections and inflammations of the prostate gland in older men. Zinc is needed to manufacture testosterone hence shortage leads to low sperm count, loss of libido and other emotional problems (McDonald, 1997). It is lost in ejaculation, since sperms need this mineral to swim towards the egg (O’Shea, 2002).

Zinc is also indicated for women taking birth control pills, or on hormone replacement therapy, pregnant and lactating mothers. Zinc is highly needed particularly in pregnancy and nursing, and in excess fiber consumption (Paraphona, 2004). It is associated with “toxemia” a condition that sometimes occurs in pregnancy (McDonald, 1997). In children, it is responsible for normal growth and sexual development. It is evident then that zinc serves the major function of maintaining the good condition and development of various body parts and particularly the functioning of the reproductive organs (Paraphona, 2004).
Zinc functions in association with phosphorus in the brain (Hershfinkel et al., 2007). It is stored in specific synaptic vesicles by glutamatergic neurons and hence can “modulate brain excitability” (Hambidge and Krebs, 2007). It plays a key role in synaptic plasticity and so in learning (Nakashima and Dyck, 2009). It has been called the “brain dark horse” since it also can be a neurotoxin, suggesting zinc homeostasis plays a critical role in normal functioning of the brain and central nervous system (Bitanihirwe and Cunningham, 2009). It interacts with a wide range of organic ligands (Hambidge and Krebs, 2007), and has roles in the metabolism of ribonucleic acid (RNA) and dioxyribonucleic acid (DNA), signal transduction and gene expression. It also regulates apoptosis. A 2006 study estimated that about 10 % of human proteins (2800) potentially bind zinc, in addition to hundreds which transport and traffic zinc (Broadley et al., 2007). A similar in silico study in the plant Arabidopsis thaliana found 2367 zinc-related proteins (Broadley et al., 2007).

Zinc is also associated with the action of vitamins which it seems to be able to control in the animal organism. Cells in the salivary glands, prostate, immune system and intestine, use zinc- signaling as one way of communicating with other cells (Hershfinkel et al., 2007). Studies have shown that zinc chloride inhibits the proliferation of colon cancer cells which carry the mutant wild–type Adenomatous polyposis coli (APC) gene by stabilizing the APC protein and
disrupting cellular attachment. It is essential to the nutrition and growth of plants and has been found in milk (Jalswal and Narayan, 2004).

Zinc helps in fighting skin problems such as perspiration, odor, acne and boils, and also controls the oil glands (McDonald, 1997). It is necessary for cell division, growth and maintenance of muscles and synthesis of proteins and collagens required for wound healing and a healthy skin. It helps speed up the healing process after an injury and on bedsores (McDonald, 1997; Ananda et al., 2000). Zinc has successfully been used to treat “Wilson’s disease”, a rare inherited disorder that causes an abnormally large copper accumulation. People suffering from sickle cell anemia require high intake of zinc since they lose a lot of it in urine. Zinc supplement have been used to restore a sense of smell and taste lost due to aging and in treatment of cancer or serious infection (McDonald, 1997) which can lead to loss of appetite and hence other deficiencies. Zinc is included in most single tablet over-the-counter daily vitamin and mineral supplements (DiSilvestro, 2004). It is believed to possess antioxidant properties, which protect against premature aging of the skin and muscles of the body, although studies differ as to its effectiveness.

Zinc gluconate, zinc glycine and zinc acetate are used in throat lozenges or tablets to reduce the duration and the severity of cold symptoms (Ananda et al., 2000). Zinc gluconate may shorten the duration and severity of cold symptoms possibly
due to reduction in inflammatory cytokines, when administered within 24 hours of the onset of common cold symptoms (Prasand et al., 2008). The U.S. food and drug administration (FDA) considered zinc gluconate to be generally recognized as safe (GRAS) and a useful zinc dietary supplements. Its preparations can protect against sunburn in the summer and windburn in the winter, and also protects against diaper rash. The Aged–Related Eye Disease study determined that zinc can be part of an effective treatment for age-related muscular degeneration. Zinc supplementation is an effective treatment for acrodermatitis enteropathica, a genetic disorder affecting zinc absorption that was previously fatal to babies born with it. Zinc lactate is used in toothpaste to prevent halitosis (Roldan et al., 2003), while zinc pyrithione is widely applied in shampoos because of its anti-dandruff function (Marks et al., 1985). Zinc ions are known to be an effective antimicrobial agent even at low concentration (McCarthy et al., 1992). Gastroenteritis is strongly attenuated by ingestion of zinc (Aydemir et al., 2006; Valko et al., 2005).

2.8.3 Zinc Deficiency

Zinc deficiency is usually due to insufficient dietary intake, but can be associated with malabsorption, acrodermatitis, enteropathica, chronic liver and renal disease, sickle cell disease, diabetes, malignancy and other chronic illnesses (Prasad, 2008). Most people with pyroluria are zinc deficient (Holford, 2011). Clinical symptoms of mild zinc deficiency include depressed growth, diarrhea, impotence and delayed sexual maturation, alopecia, eye and skin lesions, impaired appetite,
altered cognition, impaired host defense properties, defects in carbohydrate utilization and teratogenesis (National Research Council (NRC) 2000). Depressed immunity has also been reported to result from zinc deficiency (Ibs and Rink, 2003), although excessive zinc can cause the same (Rink and Gabriel, 2000). In women, zinc deficiency is said to cause irregular periods and problems associated with fertility. However, the above conditions that are now recognized as classic signs of zinc deficiency are rarely tested for or corrected with zinc supplements (Holford, 2011). Animals with a diet deficient in zinc require twice as much food in order to attain the same weight gain as animals given sufficient zinc (NRC, 2000).

Zinc deficiency at less than 5 mg lead to symptoms such as retarded growth (dwarfism), delayed wound healing, immature gonads (testicles and ovaries), dermatitis, loss of taste and probably sickle back disease (Bowen, 1984; Paraphona, 2004). Zinc is also associated with a form of blindness that does not respond to Vitamin A, being a constituent of retinene reductase in the retina (Horrobin, 1981). Reduced zinc intake lead to sleep disturbances and being prone to allergies. Deficiency contributes to decreased birth weight of the baby which amounts to greater risk of health problems than in normal weight babies (McDonald, 1997). Infections, injuries and other physical sources of stress cause excess loss of Zn in the urine. “Pica”, the eating of non-food substances such as clay, chalk or ashes can reduce the amount of zinc absorbed (McDonald, 1997).
The zinc chelator phytate which is found in seeds and cereal bran can contribute to zinc mal-absorption in those with heavily vegetarian diets (Prasad, 2008). The blood zinc levels decline with age in some people, this being accompanied by loss of immune functions, leading to frequent infection-related diseases. In the elderly above the age of sixty five, zinc intake need accompaniments of Vitamin B₁₂ in order to improve absorption and hence be of benefit to the immune system.

Groups at risk for zinc deficiency include the elderly, vegetarians, and those with renal insufficiency. Diagnosing zinc deficiency is a persistent challenge. Nearly two billion people in the developing world are deficient in zinc (Hambidge and Krebs, 2007). Zinc deficiency in children causes an increase in infection and diarrhea, contributing to death of about 800,000 children worldwide per year. The World Health Organization (WHO) advocates zinc supplementation for severe malnutrition and diarrhea. Zinc supplement help prevent disease and reduce mortality, especially among children with low birth weight or stunted growth. Since zinc is lost in sweat, deficiency is likely in hot countries (Stobark, 1985).

Zinc deficiency is crop plants’ most common micronutrient deficiency, and is particularly common in high pH soils. Zinc, together with other trace elements like manganese, iron, and copper is vital to plant metabolism as it plays an essential function in such process as respiration and photosynthesis hence a deficiency in even one element will adversely affect the health growth of the
plant. This may be caused by conditions that render the plant element unavailable to the plant. These elements are required in miniscule quantities. Increasing salinity in the soils is associated with rising concentration of trace elements (Ya’akobi, 1984).

2.8.4 Sources and Studies on Zinc

Although zinc is found in whole grain along with selenium and vitamin E, it is not well absorbed since it is tightly bound to phytates, substances in the grains that prevent its absorption (McDonald, 1997). On the contrary, zinc in vegetables is readily bio-available. Zinc is highly found in beans, nuts, almonds, whole grains, pumpkin seeds, sunflower seeds, blackcurrant, meat (muscle), poultry, fish and sea foods. Red meats, especially beef, lamb and liver have some of the highest concentration of zinc in food. Other sources include fortified food and dietary supplements, which come in various forms. A 1998 review concluded that zinc oxide, one of the most common supplements in the United States, and zinc carbonate are nearly insoluble and poorly absorbed in the body (Allen, 1998). However harmful excessive supplementation is a problem among the relatively affluent and should probably not exceed 20 mg per day in healthy people (Maret and Sandstead, 2006), although the United States National Research Council (NRC) set a tolerable upper intake (TUI) of 40 mg per day (NRC, 2000).
Zinc human intake is via food stuffs and water. The daily requirement for man is 15-20 mg per day (WHO, 1998). In the US the RDA for zinc is 8 mg per day for women and 11 mg per day in men (NRC, 2000). Normal diet has zinc ranging from 4 to 25 mg zinc per day (Bowen, 1984). Absorption is only 30 to 50% but urine excretion is only 4% of the intake (Bowen, 1984). Absorption is depressed by phytates and high calcium or phosphate diets but is improved by casein extract or liver hydrolysate.

Labile zinc may be as a result of natural processes occurring in the catchments and estuaries if there are no known significant anthropogenic inputs. When grown on soil with adequate zinc content, the food plants that contain the highest zinc levels are wheat (germ and bran) and various seeds such as sesame, mustard and alfalfa (Ensminger and Konlande, 1993).

The zinc concentration in the United States drinking waters varies between 0.06 to 7.00 mg/L with a mean of 1.33 mg/L (APHA et al., 1995). Concentration above 5 mg/L can cause a bitter astringent taste and an opalescent in alkaline water (APHA et al., 1995). Mitei (1990) found zinc in Kenyan soils to range from 36 to 290 mg/g. Elsewhere zinc in Kenyan rivers was reported to be between 9 and 89 mg/L (Mathuthu et al., 1996), with Migori river recording a mean of 32.52 mg/L (Mbovu, 2002).
Refined honey samples from Kenya, Australia and U. K. were reported to have mean zinc levels of 4.0 to 12.0 µg/g (Wamwangi, 1999). Pumpkin, watermelon and sunflower seeds were found to contain 55.6, 41.0 and 39.3 µg/g of zinc respectively (Muchemi, 2006). Othman and Mbogo (2005) found average zinc content in some Tanzanian fruits to range from 0.12 to 0.32 mg/100g fw, while some Nigerian fruits had zinc ranging from 0.89 to 5.46 mg/100g fw (Aremu and Udoessien, 1990). Some raw edible leafy vegetables determined on AAS were reported to have zinc ranging from 4.6 to 15 mg/100g fw (Omollo, 1994), while forage for cattle grazing in Uasin Gishu contained a mean of 19.50±8.26 mg/kg dry matter (Kuboka, 2011). Vardanyan and Ingole (2004) found stems and leaves of *Sesuvium portulacastrum* growing at the polluted Carambolim Lake in India to contain 76.31 and 29.80 µg/g Zn respectively. Sediments from Mombasa island were found to have a mean of 813.67 µg/g, the high levels being associated with contamination from the Kibarani waste dump site (Hashim, 2001).

Marginal and severe essential trace elements imbalances can be considered risk factors for several diseases of public health importance. There is therefore need to analyze for essential trace elements in various types of food.
2.9 Sesuvium portulacastrum (L.)L. (“Mboga ya Pwani”)

2.9.1 Description of S. portulacastrum (L.)L.

S. portulacastrum is commonly known as shoreline purslane or just sea purslane. It is a sprawling perennial herbaceous halophytic plant that grows in coastal areas throughout the world. It is found in damp, sandy locations such as among corals and mangroves, beaches, dunes, salt ponds and marsh edges up to the high tidal mark of the coastal shores. Thus the plant grows in waters and salinity that is lethal to most trees and herbs and hence enjoys no competition from weeds (Gilman, 1999). It also thrives in loamy and clay soils, and coastal limestone and sandstone, regardless of whether acidic, neutral or basic. It can grow in semi shade (higher woodland) or no shade but requires moist soils (Cardin and Tindale, 1993). It also grows in nutrient poor soils, tolerates salt, wind and even floods. It is often the first plant to show up on the beach after a hurricane thus stabilizing the sand, and then spreads quickly to form broad patches (Cardin and Tindale, 1993). Sea purslane is a member of the carpetered family and has a creeping form that spreads out as a ground cover in moderate density but aggressively by rooting from its joints to form mats or branches. It grows tight to the ground where there is little rain but can rise to its full height of 30 cm with water (Gilman, 1999). Plate 2.1 shows S. portulacastrum stems, leaves and flowers.
The scientific classification of *S. portulacastrum* (L.) L. is as follows:

- **Kingdom**: Plantae
- **Division**: Magnoliophyta
- **Class**: Magnoliopsida
- **Order**: Caryophyllales
- **Family**: Aizoaceae
- **Genus**: Sesuvium
- **Species**: Sesuvium portulacastrum
- **Binomial name**: Sesuvium portulacastrum (L.) L.

*Plate 2.1: S. portulacastrum* (L.) L. (Mboga ya Pwani) (Source: Tau’olunga, 2007).
This halophyte is a common inhabitant of the mangroves in South Florida and grows naturally in Africa, Asia, Australia, North America and South America (Upholf, 1968). It has also naturalized in many places where it is not indigenous, which suggests that *S. portulacastrum* could be relocated for sustainable utilization as an edible vegetable (O’Shea, 2002). In Kenya, the plant grows at the Coastal region and goes by the local name “Mboga ya Pwani” (Kwale Community, Personal Communication).

Sea purslane has thick fleshy edible leaves sprouting from thick smooth succulent reddish green stems up to 1 m long that branch sparingly but regularly to form dense stands on the ground (Gilman, 1999). Both the stems and leaves of the fleshy herbs are edible with a salty flavor. The smooth, glossy green leaves are linear or foliated from 10 to 70 mm long and 2 to 15 mm wide (Gilman, 1999). Flowers are pink or purple. The herb flowers all year round and the flowers are hermaphrodite with both male and female organs (Cardin and Tindale, 1993). The plant requires no human intervention to thrive, regenerating itself faster the more it is harvested. It needs virtually no irrigation or fertilizer since it grows on mineral-rich waters (Gilman, 1999), as can be seen in plates 2.2 and 2.3. It is therefore suspected to contain substantial mineral content absorbed from its habitat. Plants grown on mineralized soils take up and contain minerals. When we eat such plants in form of vegetables or fruits, our bodies take in the minerals as trace elements since they are bio-available (O’Shea, 2002).
Plate 2.2: A sampling station in Vanga region with *S. portulacastrum* growing at the beach

Plate 2.3: A sampling station in Wasini region with *S. portulacastrum* growing amidst corals and submerged in seawater at high tide
S. portulacastrum is used for sand-dune fixation, desalination and phytoremediation along coastal regions. The plant tolerates abiotic constraints such as salinity, drought and toxic metals and as an ornamental plant (Lokhande et al., 2012). This perennial herb or vine is known as an edible wild plant in some tropical coastal areas of the US and Caribbean, and is cultivated and consumed as a vegetable in India, Indonesia and Southern China (Upholf, 1968). In South Asia, it is grown and sold at markets as a vegetable and fodder plant for domestic animals (Schimidt and Koyro, 2004; Lokhande et al., 2012). Currently it is consumed as vegetable to a minute scale at the Kenyan coastal region and is said to have some medicinal properties (Personal Communication, Kwale community).

Sea purslane has been widely cultivated as food and used traditionally for the last 2000 years, being highly utilized during famine. It has the crisp, fresh taste of a succulent and is used to make omelet, while its mucilage is used as thickener for soups. It is used like spinach although it is a better nutrient source than spinach (Gilman, 1999). Both the stems and leaves are edible. The seeds are edible raw or cooked and used in bread making. Wild purslane is tastier than the cultivated varieties. It is also tasty food for turtles, birds, rabbits, deer, goats and sheep. Medicinal uses include treatment of fever, scurvy and kidney disorders (Magwa et al., 2006). It is a great ground cover and can also be grown as a hanging plant at the balcony. It grows back thicker and faster the more it is pruned (Gilman, 1999).
2.9.2 Previous Research on *S. portulacastrum*

Stem and leaves of this plant analyzed in India and Armenia were found to contain an average of 22.44 µg and 0.48 µg of Cr respectively and 76.31 µg and 29.80 µg of Zn respectively per gram of dry weight (Vardanyan and Ingole, 2006). Another study is reported to have isolated an insect moulting hormone, 20-hydroxyecdysone (20E, 2), from *S. portulacastrum* (Rele et al., 2003; Lokhande et al., 2012; Gangan*a and Hussaina, 2011) for use in sericulture industry. Essential oil has also been extracted from its fresh leaves and was found to exhibit antibacterial properties on species like *Escherichia coli*, *Salmonella typhii*, *Staphylococcus aureus* and *Barcillus subtillis* among others (Magwa et al., 2006). It also exhibited antifungal activity against *Candida albicans*, *Penicillium notatum*, *Aspergillus flavus* and *Aspergillus niger* (Magwa et al., 2006). Other studies have reported *S. portulacastrum* to be the more promising species for saline soil desalination in arid and semi-arid regions, when compared to other halophytes *Arthrocnum indicum* and *Suaeda fruticosa*, since it had the higher capacity to absorb soluble salts thus decreasing the soil electric conductivity (Rabhi et al., 2008). This suggests that vegetative bioremediation or bioreclamation of salt-affected soils may become an economic solution mainly for developing countries since chemical additions are becoming increasingly expensive (Rabhi et al., 2008).
Recent studies have shown significant (70%) decolorization of a toxic textile dye, Green HE4B (GHE4B) (50 mg l⁻¹) using in vitro grown Sesuvium plantlets in the presence of 200 mM sodium chloride (NaCl) within 5 days of incubation. The enzymatic analysis performed on the root and shoot tissues of the in vitro plantlets subjected to GHE4B decolorization showed a noteworthy induction of tyrosinase, lignin peroxidase and NADH-DCIP reductase activities, indicating the involvement of these enzymes in the metabolism of the dye GHE4B. This demonstrates the potential of S. portulacastrum for the efficient degradation of textile dyes and its efficacy on saline soils contaminated with toxic compounds (Patil et al. 2012).

2.9.3 S. portulacastrum as a Halophyte

S. portulacastrum is a typical coastal plant that has been noted to thrive along the Kenyan coast and fits the description of a true halophyte. Halophytes grow under conditions that are partly terrestrial and partly aquatic. They have been defined as “salt loving plants” with low water potential in their roots, or as “salt tolerant plants” that will thrive in sea water salinity of 540 mM (Mabberly, 1997). They are plants that naturally grow where they are affected by salinity in the root areas or by salt spray, such as in saline semi deserts, mangrove swamps, marshes and sloughs and seashores. The sheltered areas deposit fine particles of soil causing mud-flats that offer increased satiability to sediments. This allows seaweeds and salt-tolerant flowering plants to become established, while their presence helps to
stabilize the mud surface (Oyugi, 2000). *S. portulacastrum* is a pioneer plant species that grows luxuriantly at 100–400 mM NaCl concentrations. It further grows at severe salinity of 1000 mM NaCl without any toxic symptoms on the leaves (Lokhande *et al.*, 2012).

Relatively few plants species are halophytes, perhaps only 2% of all plant species. Among these, majority of them are glycophytes and are damaged fairly easily by salinity (Glen *et al.*, 1999). Facultative halophyte are able to settle on salty soils where the salt is tolerated but can also grow in salt free or at least low-salt milieu such as the dicotyledons (Bergfield *et al.*, 2003). Other halophytes are obligates that grows only in salty habitats. Halophytes are often succulent, and many species have salt glands or salt bladders on the leaf surface. The active concentration of salt in the vacuole and the storage of large volumes of water help to keep the salt concentration of the plasma low. Hydro-halophytes grow in aquatic conditions or on wet soils. These include most mangroves and salt mash species that grow along coastlines. In Pakistan, the halophyte *Aster tripolium* is normally irrigated with saline water in the summer when there is no rain (Bergfield *et al.*, 2003).

True halophytes thrive on water having more than 0.5% NaCl, and exercise salt resistance either by salt tolerance or salt avoidance (Bergfield *et al.*, 2003). Salt tolerance involves physiological and biochemical adaptations for maintaining
protoplasmic viability as cells accumulate electrolytes, while salt avoidance involves structural and physiological adaptations to minimize salt concentrations of the cells or physiological exclusions by root membranes. Succulents use the increase in water contents within large vacuoles to minimize salt toxicity. The excretion halophytes have glandular cells capable of secreting excess salts from plant organ, for example the leaves.

One qualitative measure of salt tolerance is the total dissolved solids in irrigation water that a plant can tolerate. Sea water typically contains 40 gL$^{-1}$ of dissolved salts mostly sodium chloride (Glen et al., 1999). Beans and rice can tolerate about 1 to 3 gL$^{-1}$ and are considered to be glycophytes. The dwarf glasswort, Salicornia bigelovii is a promising halophyte for use as a crop (Glen et al., 1999). Plants such as barley (Hordeum vulgare) and the date palm (Phonix elactylifera) can tolerate up to about 5gL$^{-1}$ and can be considered as marginal halophytes (Glen et al., 1999).

Many aquatic plants and halophytes have been found to have important health, and economic effects (McHugh, 1988). Some halophytes are being studied for use as “third generation” biofuel precursors. Halophytes such as Salicornia bigelovii can be grown in harsh environments where they would not compete with food crops for resources thus making them promising sources of biodiesel or bioalcohol (Glen et al., 1999). Salvadora persica is an evergreen perennial halophyte capable
of growing under extreme conditions, from very dry environments to highly saline soils. It has therefore generated some interest as a plant of high economic potential as a source of oil and medicinal compounds (Albino et al., 2000).

2.9.4 Health Importance of Halophytes to Man

Halophytes, like some aquatic plants have been used as food by man, providing the necessary dietary requirements such as vitamins and trace elements for general health, and therapeutically as herbs for remedy of certain clinical conditions. The edible aquatic algae Wakame (*Undaria purnatifida*) is thought to prevent breast cancer, while *Alghardhiella subluate* also an algae, is potentially useful in the management of HIV and AIDS (Gilman, 1999). Sea weeds have also been harvested for food and historically have been a source of iodine, potash and other minerals used in industry and medicine, since they concentrate trace elements from their environment (White and Keleshian, 1994). A number have been used for drug preparations including anticoagulants, antibiotics, antihelmenthes, antihypertensive agents, reducers of blood cholesterol, dilatory agents and insecticides (White and Keleshian, 1994).

Halophytic plants have been reported to have both antioxidant and microbial activities simultaneously. Chloroformic and methanolic extracts of the halophytes *Eryngium maritimum* L., *Crithmum maritimum* L. and *Cakile maritima* tested positive for antimicrobial activities against twelve bacterial and yeast strains, and
also exhibited radical scavenging and antioxidant activities (Meot-Duros, 2008). *Tamarix gallica*, another halophytic species, has hepatotonic and stimulant properties, and has been used traditionally in the treatment of various liver disorders. Studies have shown that leaf and flower infusion have anti-inflammatory and anti-diarrheic properties while leaf and flower extracts have exhibited antioxidant activity and appreciable antibacterial properties against human pathogen strains such as *Micrococcus luteus, Escherichia coli* and *Candida*. These findings suggest that *Tamarix* may be considered as an interesting source of antioxidants for therapeutic or pharmaceutical industries and for food manufactures (Ksouri et al., 2009).

### 2.9.5 Economic Importance of Halophytes

Halophytes may be used for a variety of purposes like food, fiber, fuel wood, medicines, source of chemicals, landscaping, ornamental, carbon sequestration (Khan and Ansari, 2008). One of the very important utilities lies in their use as fodder. An animal feeding trial showed that traditional green fodder (maize) and a halophytic grass (*Panicum*) were equally good for growth and development of 1-year-old cow calves. Meat from animals fed 100% *Panicum* was leaner and hence better for human consumption from a health point of view (Khan and Ansari, 2008).
Some aquatic plants and halophytes have been cultured and grown in large scale for income generation, both as food and as raw materials for processing commercial goods (McHugh, 1988). The sea algae carrageenan, for example, is grown in Zanzibar to produce agar-agar which is used in the manufacture of ice-cream and toothpaste due to its gel-like properties (McHugh, 1988). Along with marine algae, sea weed also contains carbohydrates, the main ones being mannitol, polysaccharides, alganic acid and laminarin; others include agars, carragens and funcalleran, all of which are of great economic importance. The polysaccharides are induced to form gels which find wide applications in textile printing, food industry, pharmaceuticals, film production, and as stabilizers and binders in fish foods, confectionary and release tablets (McHugh, 1988).

Saline agriculture has been practiced where conventional foods crops are cultured and grown in mildly saline water, and their yields processed to produce salt-free proteins (White and Keleshian, 1994). It is speculated that this concept could be extended to modern foods such as maize, rice, wheat, and potatoes in order to diversify and expand the worlds food supply (White and Keleshian, 1994). Some halophytes are being investigated for value as forage or fodder crops, most of which have high digestibility. The greatest promise for sea-water irrigated halophytes will probably be as seed crops, since seeds of halophytes do not accumulate salt any more than those of glycophytes. The seeds of many halophytes have high proteins and oil contents and compare favorably with
traditional oilseed crops. Sustained high yields of seed and biomass already have been obtained from some halophytes irrigated with seawater (Leary et al., 1985). The potential utilization of halophytes grown under saline water irrigation will serve to conserve freshwater and will enable crop production in marginal areas. Thus halophytes can be utilized as cash crops, particularly in dry and saline ecosystems, and as animal fodder in arid and semi-arid regions (ElShaer, 2006).

There is great need to continue carrying out studies on rare and unfamiliar food sources such as *S. portulacastrum* in order to help discover their full potential and become useful to man.

### 2.10 Methods of Analysis

#### 2.10.1 Introduction

Some methods used in trace metal analysis include atomic absorption spectroscopy (AAS) (Oyugi, 2000; Kuboka, 2011), energy dispersive x-ray fluorescence (EDXRF) (Perez *et al.*, 2002; Wamwangi, 1999; Hashim, 2001), total reflection x-ray fluorescence (TXRF) (Wamwangi, 1999), and inductively coupled argon plasma (ICAP) (Vardanyan and Ingole, 2004). In this study the trace metals in the plant, soil and water samples will be determined by AAS due to its availability. It also meets the prerequisite of speed, simplicity, sensitivity and selectivity (Katz and Salem, 1992). Selenium was determined by the hydride generation technique (HG-AAS).
Iodine has been determined using colorimetry and by iodometric titration method (APHA et al., 1995; Kishoyian, 2011). In this study the iodometric titration method was chosen because it is fast and quantitative. The method gives free available iodine since combined iodine is rarely encountered (APHA et al., 1995). The methods used in this study are briefly explained in the following subsection.

2.10.2 Principle of Flame Atomic Absorption Spectroscopy

The flame atomic absorption spectroscopy (FAAS) is the most widely used of all atomic spectral methods because of its simplicity, effectiveness and relatively low cost. It is highly specific because AAS lines are remarkably narrow (0.002 – 0.005 nm) and electric transition energies are unique for each element (Skoog and Leary, 1992). The use of hollow cathode lamps as line sources with band widths even narrower than their absorption peaks has eliminated devices of non-linear calibration that lower the sensitivity. Doppler broadening of the emitted lines is minimized by good choice of the operating conditions for the source, such that the emitted line broadening is less than the broadening of the absorption peak that occurs in the flame. The main disadvantage is that a separate lamp source is needed for each element analyzed (Skoog and Leary, 1992).

The principle of AAS involves a physical process of absorption of light by free atoms of an element at a wavelength specific to that element. Absorption of light is associated with the process of transition of atoms from one energy level to
another. A flame is used to break down the sample into atomic vapor and convert it into free atoms of the analytical element (Skoog and Leary, 1992). A beam of monochromatic radiation of characteristic wavelength for the analytical element is passed through the atoms, which absorb the radiation in proportion to their number in the flame, depending on their concentration in the sample. Thus absorption of radiation by the atoms is directly proportional to the concentration of the absorbing species (Loon, 1980). A calibration curve plotted using absorbance from known metal standards within the concentration range of the samples help determine the sample concentration traced form its recorded absorbance (Loon, 1980). Conditions and optimum settings for the analysis of each element in this study by AAS are summarized in Table 2.1.
Table 2.1: The AAS Working Conditions

<table>
<thead>
<tr>
<th>PARAMETER</th>
<th>CHROMIUM</th>
<th>SELENIUM</th>
<th>VANADIUM</th>
<th>ZINC</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wavelength, nm</td>
<td>357.9</td>
<td>197.0</td>
<td>318.5</td>
<td>213.9</td>
</tr>
<tr>
<td>Slit Width, nm</td>
<td>0.2</td>
<td>1.0</td>
<td>0.2</td>
<td>1.0</td>
</tr>
<tr>
<td>Oxidant</td>
<td>Air</td>
<td>Air</td>
<td>NO₂</td>
<td>Air</td>
</tr>
<tr>
<td>Fuel</td>
<td>Acetylene</td>
<td>Acetylene</td>
<td>Acetylene</td>
<td>Acetylene</td>
</tr>
<tr>
<td>Flame</td>
<td>A / A</td>
<td>A / A</td>
<td>NO₂ / A</td>
<td>A / A</td>
</tr>
<tr>
<td>Oxidant Flow Rate, L/min</td>
<td>1.5</td>
<td>1.5</td>
<td>4.5</td>
<td>1.5</td>
</tr>
<tr>
<td>Detection Limit, µg/kg</td>
<td>0.02</td>
<td>0.03</td>
<td>0.11</td>
<td>0.01</td>
</tr>
<tr>
<td>Sensitivity, mg/L</td>
<td>0.015</td>
<td>0.02</td>
<td>0.4</td>
<td>0.01</td>
</tr>
</tbody>
</table>

2.10.3 Hydride Generation Atomic Absorption Spectroscopy

The hydride generation atomic absorption spectroscopy (HG-AAS) method applies to elements that are easily atomized by the flame such as selenium, arsenic and mercury. The metal is first converted into volatile hydride by addition of an acidified aqueous solution of the sample into a small volume of 1% aqueous solution of sodium borohydride, NaBH₄ contained in a glass cell. After mixing for a short time the formed hydride is entrained into the atomization chamber in inert
argon gas which is aligned on the lights path. The chamber is usually a silica tube furnace or a flame. The sample maybe introduced either by direct injection into a “cool” hydrogen flame or in a long path (15 cm) silica cell with an external heating in a flame or electrothermal (Fifield and Kealey, 1990; Harisson and Mora, 1996). The radiation from the hollow cathode lamp passes through the tube to the monochromator and on to the detector from where the absorbance is measured (Harrison and Mora, 1996).

2.10.4 Principle of Energy Dispersive X-ray Fluorescence

The principle of energy dispersive x-ray fluorescence (EDXRF) involves use of a beam of accelerated electrons or x-rays to bombard the metals present in a sample. Upon interaction, a portion of the incident beam will be absorbed. This excites the atoms causing the inner K and L shell electrons to be ejected from the atom. This in turn prompts other electrons from the outer shells to jump to fill in the left “holes”. In so doing the excited atoms emit fluorescent secondary x-rays. The energy or wavelength of the emitted x-ray is characteristic of the emitting element, and hence provides a finger print of the elemental composition of a sample. The intensity of these rays is directly proportional to the concentration of the emitting atoms (Fifield and Kealey, 1990; Harrison and Mora, 1996). Measurements on EDXRF are generally limited to the elements of atomic number eleven (11) and above.
2.10.5 Principle of Iodimetric Titration Analysis

In this method, iodine is quantitatively titrated with standard sodium thiosulfate solution using starch as indicator. The iodine concentration is worked out from the reaction stoichiometry. The iodine determination is carried out at pH 4 with help of a phosphate buffer added to the sample. This is because below pH 3.5, substances such as oxidized forms of manganese interfere and above pH 4.5 the reaction is not quantitative (APHA et al., 1995).
CHAPTER THREE

3.0 METHODOLOGY

3.1 Research Overview

This study was a combination of purposive, quantitative and descriptive research design (Kombo and Tromp, 2006). The level of utilization of S. portulacastrum by the Kwale community was assessed through a questionnaire while quantitative analysis was used to determine the level of elements in the samples. The mean levels per element were compared across the plant, soil and water matrices and between the dry and wet seasons.

3.2 Study Area

In this study three sampling regions were included, namely Funzi, Vanga, and Wasini Island all in Kwale County on the Kenyan coastline, as shown on Plate 4. The sampling areas were easily accessible and S. portulacastrum was found to grow wildly and in abundant amounts.
3.3 Sample Size

In each study region four sampling stations were identified within 50 m to 120 m apart, from where simple random sampling was done to give a good representation of the whole population. From each of these stations three types of samples were collected including stems and leaves of S. portulacastrum and the soil on which the plant was growing. From the waters of the Indian Ocean surrounding the study area three water samples were collected from different stations: at a stagnated pond on the plant garden, at the beach to the garden and
about 200 m into the sea. All plant, soil and water samples were composite samples, being a combination of grab samples picked at four scattered points in the sampling station. Sampling was done in five alternating dry and wet seasons in January, April, July and October, 2007 and January 2008 to establish if there is any significant seasonal effect on levels of trace elements in the plant, water and soil ecosystems. A total of 45 samples were collected during each of the five sampling sessions. Hence a total of 225 samples were collected in this study, each being analyzed in duplicate to determine the levels of vanadium, zinc, chromium, selenium and iodine.

A questionnaire was distributed at each of the three study regions to assess the level of awareness and utilization of *S. portulacastrum* among the local community. Quota sampling was applied when distributing the questionnaire in order to include various respondents by gender, age and social status (Kombo and Tromp, 2006). A total of 90 respondents were involved in this study, 30 from each region. The sample size was determined using the following equation:

\[ n_o = \left(\frac{z}{e}\right)^2 pq \]

where, \( n_o \) = the sample size

\( z = \) the abscissa of the normal curve that cuts off an area at the tail at a given confidence level

\( e = \) the desired level of precision

\( q = 1 - p \)
\[
p = \text{the estimated proportion of an attribute that is present in the population}
\]

In this study, a maximum variability of \( p = 0.5 \) at 95\% confidence level and ±5\% precision was used. The sample size was thus determined as follows:

\[
n_0 = \left(\frac{0.954}{0.05}\right)^2 (0.5) (0.5) = 90
\]

Hence a total of 90 respondents were involved in the study.

3.4 Sampling

3.4.1 Water Sample Collection

Three sampling stations were identified at each sampling region: on ground depressions where the plant is growing, at the shoreline and further into the sea. These were collected directly into clean plastic bottles by submerging and opening the bottle under water to avoid contamination. Four grab samples were mixed to give the representative composite sample of each sampling station. The samples were filtered and then acidified immediately after sampling with enough concentrated HNO\(_3\) to a pH less than 2.0 (APHA et al., 1995). This was to reduce possible loss of elements by adsorption on the container walls, to inhibit microorganism and bacterial action on the elements and to retain volatile material (Bowen, 1984). Samples were then preserved at a temperature of 4 °C before further treatment and analysis.
3.4.2 Soil Sample Collection

A plastic polyvinylchloride (PVC) corer or sediment sampler was used to collect soil sample at the designated stations to a depth of 10 cm. These were placed into clean plastic bags and sealed to avoid contamination. Preservation was done at 4 °C before further treatment and analysis. The choice of plastic material for the corer was to eliminate chances of metal contamination as would be caused by a metallic one.

3.4.3 Leaves and Stem Sample Collection

The leaves and stem of ‘Mboga ya Pwani’ were collected manually by uprooting the plant and pulling up the running stems along with the leaves by hand. This was possible because the roots on the stems do not run deep in the sandy soil. Each sample was packed and sealed into clean well labeled plastic bags. The samples were then flushed in deionized water to remove any adhering soil and seawater. Leaves were then detached from the stems and each preserved separately at 4 °C pending further treatment and analysis.

3.5 Chemicals, Reagents and Solvents

The reagents used in this study were all of analytical grade (AR). Nitric acid (HNO₃), hydrochloric acid (HCl), sodium hydroxide (NaOH) and perchloric acid (HClO₄) were supplied by Sigma-Aldrich company of Germany while methyl isobutyl ketone was sourced from Fisher Scientific company from UK. The water
used was distilled and deionized. The metal standards were sourced from commercially prepared stock solutions of 1000 ppm in 1% of HNO₃. Working standards were prepared within the concentration ranges of each element in the sample by serial dilution from the stock solution. These together with the blank were used to develop the calibration curves from which elemental concentration in the samples was derived.

### 3.6 Cleaning of Glassware and Sample Containers

Soil and plant samples were collected in hard plastic bags of appropriate sizes that had been washed in 1:1 HNO₃ and rinsed in distilled water. Some 500 mL high density polyethylene (HDPE) sample bottles were used for collection of sea water samples. The HDPE bottles were preferred because they are fairly cheap compared to glass, and do not leach out or exchange metal ions with the sample (APHA et al., 1995). The bottles and all glassware to be used were first washed in detergent and rinsed to remove superficial dirt. They were then soaked in 1:1 HNO₃ solution for 24 hours in order to leach out any adsorbed metal ions that may contaminate the samples (APHA et al., 1995). They were then thoroughly rinsed in deionized water before drying in a dust free area. Bottles were then packed and sealed in separate bags for storage, thus protecting them from contamination from the air.
3.7 Sample Treatment

3.7.1 Leaf and Stem Sample Digestion

The leaf and stem samples were dried in a thermostated oven at 60 °C and 80 °C respectively for four days. The samples were then allowed to cool, placed in separate bags and sealed awaiting further preparation. These moderate temperatures were to ensure that any volatile components were not lost from the samples. The prolonged drying time was to ensure gradual drying with complete removal of all moisture. Air drying was avoided to prevent contamination from the environment such as dust from landing on the samples. The samples were then ground in a Wiley mill into fine powder. The ground samples were again sealed into their respective containers. The mill was properly cleaned in between different samples to avoid contamination.

A 5.00 g portion of finely ground stem or leaf sample was placed in a 250 mL beaker. A 20 mL volume of HNO₃ was added and the mixture covered with a watch glass. It was then heated on a medium heat hot plate to just below boiling for 30 minutes. The solution was then topped up to 15 mL with concentrated HNO₃, and 8 mL HClO₄ added (APHA et al., 1995). This was evaporated to near dryness on medium heat and warmed, after which 20 mL of deionized water was added, and the solution filtered into a 100 mL volumetric flask with rinsings. It was then cooled and diluted to volume (Loon, 1980). This was now the sample stock solution ready for analysis. A reagent blank was prepared in a similar
manner as the sample, but without the sample. The digested sample was put in a well labeled plastic bottle and stored ready for analysis.

3.7.2 Soil Sample Digestion

Soil samples were treated in the same way as the leaf and stem samples up to grinding and storage. A 2.50 g portion of the finely ground soil samples was weighed in duplicate and placed in Teflon beakers. 40 mL HF and 4 mL HNO₃ were added and the mixture evaporated to near dryness until fumes appeared. After cooling, 10 mL HNO₃ and 30 mL HCl (40.0 mL aqua regia) was added and evaporated on low heat to near dryness. Some 2 mL HNO₃ was added until brown fumes stopped. The beaker was flashed with deionized water over the sides. These contents were filtered into 50 mL volumetric flask with rinsings. This was cooled, made to volume and stored ready for analysis. A reagent blank was prepared in similar manner as the samples (Loon, 1985).

3.7.3 Water Sample Digestion and Pre-concentration

Sea water samples were digested in concentrated HCl and HNO₃ in the ratio of 1:3. In each case a 200 mL portion of the sample was placed in a beaker and 1 mL HNO₃ added, covered with a watch glass and evaporated to dryness on a medium heat hot plate. A 2 mL volume of HCl and 1 mL HNO₃ were added to the residue and again evaporated to dryness. A drop of HCl was added followed by 100 mL
deionized water. The solution was then filtered and diluted to 200 mL, and stored awaiting concentration before analysis.

Pre-concentration was done using the solvent extraction AAS method (Loon, 1980; Loon, 1985). Some 20 mL portions of digested water samples was acidified to pH 1.0 with HNO₃ and placed in a 250 mL separatory funnel fitted with a Teflon stop cork. A 4 mL portion of the mixed borate, citrate and phosphate buffer was added and shaken well. The pH of the solution was adjusted to 4.0 ± 0.1 using 20% w/v NaOH. A 5 mL portion of 1% mixed chelating agent, ammonium pyrrilodine dithiocarbamate (APDC) was added and shaken briefly. About 10 minutes was allowed for the metal - APDC chelate to form before 15 mL of methyl isobutyl ketone (MIBK) was added and the solution shaken vigorously for two minutes, after which the two layers were left to separate. The lower aqueous layer was then removed into a beaker and the MIBK layer transferred to a tightly capped glass bottle. The aqueous layer was returned into the separatory funnel and extracted again in fresh 15 mL MIBK solvent. The organic layer from this second extraction was added to the first extract in the glass bottle. This constituted the sea water sample solution ready for analysis. Standards were carried through the same digestion procedure as the samples. The blank consisted of a water saturated MIBK solution. This was prepared by mixing one part of the MIBK with one part of water in a separatory funnel and shaking for 30 seconds. The two layers were then allowed to separate. The aqueous layer
was discarded while the MIBK layer formed the blank which was used to calibrate the AAS before sample analysis.

### 3.7.4 Sample Preparation for Iodine Analysis

Samples for iodine analysis were subjected to microwave digestion to minimize evaporation of iodine as a result of rapid boiling. Adequate portions of each were placed in the sample pot and an HCl and HNO\textsubscript{3} acid mixture added. The pot was placed into the jacket and the mixture digested for half an hour. The solution was then allowed to cool for another half hour, filtered into a 50 mL volumetric flask and topped up to the mark, then properly labeled and stored ready for analysis.

### 3.8 Sample Analyses

#### 3.8.1 Sample Analysis by Flame Atomic Absorption Spectroscopy

During the analysis of each individual metal, the particular hollow cathode lamp was inserted into the instrument, and the characteristic analytical wavelength set. The gas flow rate and the burner flame adjusted to provide the required temperature. The burner height was adjusted to ensure the hot analytical part of the flame was in alignment with the optical path of measurement of the instrument. The blank was used to set the zero reading. The standards were then aspirated and their absorbance recorded. A calibration curve of concentration against absorbance was drawn for each elements analysis. The stems, leaves, soil and water samples were then aspirated in their duplicates and the absorbance
recorded. The concentrations of the samples were calculated by extrapolation of absorbance of the individual samples on the graphs of the elements. The mean values for each sample were then evaluated.

3.8.2 Sample Analysis by Hydride Generation Atomic Absorption Spectroscopy

This method was applied for the analysis of selenium. The 25 cm$^3$ of acidified aqueous solution of the sample was added to a small volume of 1% aqueous solution of sodium borohydride (NaBH$_4$) contained in a silica cell and mixed for a short time. The analyte was converted into a volatile hydride which was then entrained into the atomization zone on the flame using inert argon gas which is aligned on the analytical radiation source from a selenium hollow cathode lamp and the detector. The absorbance of the sample was then recorded and concentrations worked out from the calibration curves generated from the blank and standards, where absorbance is directly proportional to the concentration.

3.8.3 Iodimetric Titration for Iodine

The 0.01 M sodium thiosulphate solution titrant was first standardized against potassium iodide primary standard solution. For each of the digested samples, 10 mL portions of solution was pipetted into a 250 mL conical flask and titrated to a pale brown colour. Two drops of starch solution were then added to enhance the endpoint detection and titration completed from a blue-black to colourless
endpoint. The titration was repeated more accurately three times and the average titre calculated and recorded, and used to calculate the level of iodine in the sample.

3.9 Validation of Method for Metal Analysis

In this study the stem, leaf, soil and water samples from Vanga in the wet season were analyzed for zinc by both the AAS and the result compared to those of same samples analyzed by the EDXRF method (Skoog and Learly, 1992; Harison and Mora, 1996). The results are presented in Table 3.1.

Table 3.1 Comparison of Zinc Levels in the Samples by AAS and EDXRF

<table>
<thead>
<tr>
<th>SAMPLE</th>
<th>AAS mean±SE µg/g</th>
<th>EDXRF mean±SE µg/g</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>STEM</td>
<td>17.87±0.64</td>
<td>18.51±0.54</td>
<td>0.38</td>
</tr>
<tr>
<td>LEAVES</td>
<td>17.54±0.59</td>
<td>17.28±0.59</td>
<td>0.121</td>
</tr>
<tr>
<td>SOIL</td>
<td>19.28±0.54</td>
<td>20.19±0.69</td>
<td>0.287</td>
</tr>
<tr>
<td>WATER</td>
<td>0.74±0.64</td>
<td>0.76±0.64</td>
<td>0.104</td>
</tr>
</tbody>
</table>

(t-test: p<0.05 at 95% confidence level)

From Table 3.1, the results obtained for zinc using EDXRF and AAS do not differ significantly since p values are greater than 0.05 at the 95% confidence level. Regression coefficient values for all the metals ranged from 0.996 to 1 as
presented in Table 3.2, meaning linear calibration curves were obtained in which absorbance was directly proportional to the concentration of the metals. Thus the results given in this study were considered to be reliable.

Table 3.2: Regression Coefficient of the Essential Trace Elements by AAS

<table>
<thead>
<tr>
<th>Element</th>
<th>Regression coefficient, $r^2$</th>
<th>Regression line</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chromium</td>
<td>1</td>
<td>$Y = 0.046x - 0.000$</td>
</tr>
<tr>
<td>Selenium</td>
<td>0.998</td>
<td>$Y = 0.003x - 0.004$</td>
</tr>
<tr>
<td>Vanadium</td>
<td>0.996</td>
<td>$y = 0.021x + 0.021$</td>
</tr>
<tr>
<td>Zinc</td>
<td>0.999</td>
<td>$y = 0.361x + 0.004$</td>
</tr>
</tbody>
</table>

3.10 Statistical Data Analyses

The Statistical Package for Social Sciences (SPSS) (Miller and Miller, 1990) was used for data analysis. The t-test was used to compare the means between dry and wet seasons. The means of element levels across the four matrices and between the three regions were compared using analysis of variance (ANOVA) followed by SNK test for multiple comparison of the means.
CHAPTER FOUR

4.0 RESULTS AND DISCUSSION

4.1 Introduction

This chapter presents and discusses the results obtained from the study. The level of utilization of the locally growing vegetable, *S. portulacastrum* (L.) L. (Mbogya Pwani) among the Kwale community was obtained from the questionnaire data.

Experimental results for the analysis of chromium, iodine, selenium, vanadium and zinc in stem, leaf, soil and water samples from the selected regions are also presented. The regional and seasonal variation of levels of the elements in the samples is reported in respective tables below and the general trends observed and discussed.

4.2 Local Community Utilization of *Sesuvium portulacastrum*

The data collected by questionnaire from respondents in the three regions of Funzi, Vanga and Wasini on the level of utilization of *S. portulacastrum* is presented in Table 4.1. Two major uses of the plant were reported at all the study areas, namely as food and medicine, and in one region scenery for tourist attraction. The extent of each specific use is indicated and contributory factors suggested.
Table 4.1: Percent Level of Community Awareness and Utilization of *S. portulacastrum* and its Specific Uses at the Regions

<table>
<thead>
<tr>
<th>Sampling Regions</th>
<th>% Population Awareness</th>
<th>% Utilization</th>
<th>% Specific Use</th>
<th>Other Use</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>Food only</td>
<td>Medicine only</td>
</tr>
<tr>
<td>Funzi</td>
<td>40.0</td>
<td>26.7</td>
<td>75.0</td>
<td>-</td>
</tr>
<tr>
<td>Vanga</td>
<td>83.3</td>
<td>13.3</td>
<td>83.3</td>
<td>-</td>
</tr>
<tr>
<td>Wasini</td>
<td>93.3</td>
<td>83.3</td>
<td>87.5</td>
<td>-</td>
</tr>
</tbody>
</table>

From table 4.1 the highest level of awareness of *S. portulacastrum* was observed at Wasini at 93.3% of the population followed closely by Vanga at 83.3%, and Funzi at a bare 40.0%. Thus the plant is known in the three regions and used mainly as food and medicinal herb to different extents, except at Wasini where there is additional utilization as scenery attraction. There is no member of the local community who utilizes the plant for medicinal purposes alone, this being applied as the need arises.

Only 26.7% of the population at Funzi utilized *S. portulacastrum*, a level much lower than that reported for Wasini (83.3%). This could probably be due to the fact that human settlement at Funzi is further inland and the plant is less obvious at the coastline and relatively fewer people know the plant (40.0% awareness). However, it is observed that over a quarter of them (26.7%) actually utilized the
plant. Utilization as food was much higher at 75.0%, compared to combined food and medicinal use at only 25.0%, the latter use only recognized by older members of the community for the treatment of stomach ailments and diarrhea (Funzi community, personal communication). Normally the plant is utilized as food only during famine when their subsistence crops have failed.

At Vanga the plant was observed to be greatly underutilized represented by only 13.3% of the population that has knowledge of it. However, 83.3% of them utilize it as food only while the remaining 16.7% comprising of old men use it both as food and as a medicinal herb, whose benefits were claimed to include its ability to increase male vigor, lower body fever, treat skin rashes and stomach ailments (Vanga community, personal communication). Vanga has a much more conservative community compared to the other regions, culturally relying almost wholly on fish for their daily meal and almost no use of vegetables both at home as well as at the local hotels. The human settlements literally touch the sea and a high dyke wall has been built to prevent flooding of their residential settlements. Though they may encounter the plant at the beaches and on small islands towards the deep sea as they go fishing, many local residents are not aware that it is an edible vegetable. Fish is the major component in every diet; hence the midday meal will only be prepared after the men bring home fish from the sea. Utilization of the plant as food is said to be essentially during famine.
Wasini region reported the highest level of utilization of *S. portulacastrum* at 83.3% of the total population compared to the much lower levels of 26.7% and 13.3% observed at Funzi and Vanga respectively. From Table 4.1, all regions showed higher utilization as food compared to medicine. The high level of utilization at Wasini is directly related to high level of awareness of the vegetable by the local community. This could have been contributed to by the fact that Wasini is a small island on which the *S. portulacastrum* vegetable grows wildly on the beach amidst corals and mangroves, just next to the people’s residence on the beach creating very attractive scenery.

The local women have organized themselves into the popular Wasini Women Group and taken advantage of this natural ecosystem by building a boardwalk around the mangrove and coral garden where this plant grows, providing a very attractive scenery. They protect the garden and charge a fee to tourists coming to view the scenery. They also harvest and sell the vegetable to the local Wasini Mpunguti Lodge where it is served as a special delicacy to the tourists. This occupation has greatly improved their economic status. Being sensitized to the use of the plant as food, they routinely cook the same at home. Their exposure at the groups’ activities may have led to the high level of utilization of the plant as food, reported at 87.5%. Only a few old people here at 12.5% of the community use the plant both as food and for medicinal purposes.
This questionnaire study contributed an insight into the social-economic implications related to the levels of awareness and utilization of the halophytic vegetable. In Western Kenya, indigenous knowledge regarding the health benefits of African leafy vegetables has been found to promote their consumption patterns. Age was found to be positively correlated to the consumption levels but no significant difference in consumption levels was observed with respect of gender, religion, education, family size and occupation (Nyakaboke, 2011).

4.3 Levels of Essential Trace Elements in Stem, Leaves, Soil and Water Samples

4.3.1 Introduction

Tables 4.2 to 4.6 show the levels of vanadium, zinc, chromium, selenium and iodine respectively, in the stems and leaves of *S. portulacastrum* and soil and water samples, showing regional and seasonal variations. The same is graphically illustrated in Appendix VII to XI. The results are discussed first as per individual element, followed by a summary of the observed general trends in the matrices, regions and seasons.

4.3.2 Levels of Chromium in the Stem and Leaves of *S. portulacastrum*, Soil and Water Samples

Table 4.2 shows the seasonal and regional distribution of chromium in the samples.
Table 4.2: Concentration of Chromium in the Stem, Leaves, Soil and Water Samples at the Regions in Dry and Wet Seasons

<table>
<thead>
<tr>
<th>REGION</th>
<th>SEASON</th>
<th>STEM (n=24)</th>
<th>LEAVES (n=24)</th>
<th>SOIL (n=24)</th>
<th>WATER (n=18)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>mean±SE µg/g</td>
<td>mean±SE µg/g</td>
<td>mean±SE µg/g</td>
<td>mean±SE µg/g</td>
</tr>
<tr>
<td>FUNZI</td>
<td>DRY</td>
<td>3.00 ±0.48&lt;sup&gt;Ac&lt;/sup&gt;</td>
<td>1.49 ±0.19&lt;sup&gt;Ab&lt;/sup&gt;</td>
<td>5.14 ±0.35&lt;sup&gt;Ad&lt;/sup&gt;</td>
<td>0.27 ±0.01&lt;sup&gt;Aa&lt;/sup&gt;</td>
</tr>
<tr>
<td></td>
<td>WET</td>
<td>1.53 ±0.13&lt;sup&gt;Xb&lt;/sup&gt;</td>
<td>1.04 ±0.11&lt;sup&gt;Xb&lt;/sup&gt;</td>
<td>5.18 ±0.33&lt;sup&gt;Xc&lt;/sup&gt;</td>
<td>0.29 ±0.01&lt;sup&gt;Xa&lt;/sup&gt;</td>
</tr>
<tr>
<td></td>
<td>&lt;sup&gt;t&lt;sub&gt;cal&lt;/sub&gt;&lt;/sup&gt; 2.441</td>
<td>1.779</td>
<td>0.066</td>
<td>1.720</td>
<td></td>
</tr>
<tr>
<td>VANGA</td>
<td>DRY</td>
<td>2.91 ±0.24&lt;sup&gt;Ac&lt;/sup&gt;</td>
<td>1.58 ±0.17&lt;sup&gt;Ab&lt;/sup&gt;</td>
<td>7.09 ±0.28&lt;sup&gt;Bd&lt;/sup&gt;</td>
<td>0.30 ±0.01&lt;sup&gt;Ba&lt;/sup&gt;</td>
</tr>
<tr>
<td></td>
<td>WET</td>
<td>3.68 ±0.14&lt;sup&gt;Yc&lt;/sup&gt;</td>
<td>2.26 ±0.22&lt;sup&gt;Yb&lt;/sup&gt;</td>
<td>6.58 ±0.23&lt;sup&gt;Yc&lt;/sup&gt;</td>
<td>0.28 ±0.01&lt;sup&gt;Ya&lt;/sup&gt;</td>
</tr>
<tr>
<td></td>
<td>&lt;sup&gt;t&lt;sub&gt;cal&lt;/sub&gt;&lt;/sup&gt; 2.340</td>
<td>2.481</td>
<td>1.341</td>
<td>1.880</td>
<td></td>
</tr>
<tr>
<td>WASINI</td>
<td>DRY</td>
<td>4.23 ±0.22&lt;sup&gt;Bc&lt;/sup&gt;</td>
<td>2.99 ±0.17&lt;sup&gt;Bb&lt;/sup&gt;</td>
<td>9.65 ±0.37&lt;sup&gt;Cd&lt;/sup&gt;</td>
<td>0.31 ±0.01&lt;sup&gt;Ba&lt;/sup&gt;</td>
</tr>
<tr>
<td></td>
<td>WET</td>
<td>4.71 ±0.22&lt;sup&gt;Zc&lt;/sup&gt;</td>
<td>2.90 ±0.20&lt;sup&gt;Zb&lt;/sup&gt;</td>
<td>8.60 ±0.22&lt;sup&gt;Zd&lt;/sup&gt;</td>
<td>0.28 ±0.01&lt;sup&gt;Xa&lt;/sup&gt;</td>
</tr>
<tr>
<td></td>
<td>&lt;sup&gt;t&lt;sub&gt;cal&lt;/sub&gt;&lt;/sup&gt; 1.482</td>
<td>0.342</td>
<td>2.149</td>
<td>2.502</td>
<td></td>
</tr>
</tbody>
</table>

Mean values within the same row followed by the same small letters are not significantly different. Mean values within the same column followed by the same capital letters in the same season are not significantly different at α=0.05 (SNK test).

Mean values within the same column for a given region are not significantly different if <span style='font-size:12pt;'><sup>t<sub>cal</sub></sup> &lt; <sup>t<sub>crit</sub></sup></span> (t<sub>crit</sub> = 2.024).

From Table 4.2 chromium levels in the stem during the dry season ranged from 2.91±0.24 µg/g at Vanga to 4.23±0.22 µg/g at Wasini, and from 1.53±0.13 µg/g at Funzi to 4.71±0.2 µg/g at Wasini during the wet season respectively. Values at Funzi and Vanga varied significantly during the wet and dry seasons (<span style='font-size:12pt;'><sup>t<sub>cal</sub></sup> &gt; <sup>t<sub>crit</sub></sup></span) while those at Wasini did not. A cross the regions the dry season saw the level of...
chromium being significantly higher at Wasini (4.23 ±0.22 µg/g) than in Funzi and Vanga whose values did not show a significant difference. In the wet season the levels varied significantly across the three regions. However, stems from Wasini appeared to have higher levels of chromium than the other regions.

Chromium levels in the leaves during the dry season ranged from 1.49±0.19 µg/g at Funzi to 2.99 ±0.17 µg/g at Wasini, and from 1.04±0.11 µg/g at Funzi to 2.90 ±0.20 µg/g at Wasini in the wet season respectively. Levels in the leaves from Funzi and Wasini did not show a significant difference between the wet and dry seasons, an observation that was made only at Vanga. Across the regions, chromium in leaves was significantly higher at Wasini in both dry and wet seasons (2.99 ±0.17 µg/g and 2.90 ±0.20 µg/g) respectively than at both Funzi and Vanga. Levels of this essential trace element were observed to significantly lower in the leaves than in the stems in both seasons and at all regions, except at Funzi during the wet season when the levels did not vary significantly.

Chromium levels in the soil during the dry season ranged from 5.14±0.35 µg/g at Funzi to 9.65 ±0.37 µg/g at Wasini, and from 5.18±0.33 µg/g at Funzi to 8.60±0.22 µg/g at Wasini in the wet season respectively. No significant variation was observed between dry and wet season levels obtained from Funzi and Vanga, but only at Wasini. However the three regions showed significantly different levels of chromium in both seasons. Wasini had the highest levels followed by Vanga and
Funzi respectively. Soil levels were significantly higher than in the stems and leaves respectively.

In water chromium levels during the dry season ranged from 0.27±0.01 µg/g at Funzi to 0.31±0.01 µg/g at Wasini, and from 0.28±0.01 µg/g at Wasini and Vanga to 0.29±0.01 µg/g at Funzi during the wet season. Seasonal variation within the regions was only significantly evident at Wasini. Across the regions no significant variation was observed during the wet season, while during the dry season Funzi gave a significantly lower level of chromium (0.27±0.0 µg/g) than Vanga (0.30±0.01 µg/g) and Wasini (0.31±0.01 µg/g) respectively whose values did not differ significantly. Levels of chromium in the water were quite low and differed significantly from those of the soil which were highest and stems and leaves respectively.

In summary, chromium levels were highest in the soil implying a good rate of retention in this matrix compared to the lower levels in the water. Stems had higher levels than the leaves and suggest ability to concentrate or store the element before relocation to the leaves.

Chromium in different selected samples was reported to be within the following ranges: seeds 5.00 to 6.2 µg/g; spices 1.76 to 12.8 µg/g; grains 2.24 to 5.86 µg/g (Muchemi, 2006). *S. portulacastrum* in this report has a mean of 3.35 µg/g
chromium in the stems and 2.04 µg/g in the leaves. These values from this study are comparable to those of the spices and grain samples that ranged from 1.76 µg/g to 12.8 µg/g. *S. portulacastrum* samples from India reported a mean chromium level of 0.48 µg/g in the stems and 7.44 µg/g in the leaves (Vardanyan and Ingole, 2004). The levels in the Indian stem are much lower than the Kenyan plant value of 3.35, while the Kenyan leaves levels of 2.04 are much lower than that of the Indian plant. This shows that while the Kenya plant accumulate more chromium in the stem, the Indian one accumulates more in the leaves, implying that the two could probably be different species of the plant.
4.3.3 Levels of Iodine in the Stem and Leaves of *S. portulacastrum*, Soil and Water Samples

Table 4.3 shows the seasonal and regional distribution of selenium in the samples.

**Table 4.3: Concentration of Iodine in the Stem, Leaves, Soil and Water Samples at the Regions in Dry and Wet Seasons**

<table>
<thead>
<tr>
<th>REGION</th>
<th>SEASON</th>
<th>STEM (n=24) mean±SE µg/g</th>
<th>LEAVES (n=24) mean±SE µg/g</th>
<th>SOIL (n=24) mean±SE µg/g</th>
<th>WATER (n=18) mean±SE µg/g</th>
</tr>
</thead>
<tbody>
<tr>
<td>FUNZI</td>
<td>DRY</td>
<td>15.42±0.91&lt;sup&gt;Ac&lt;/sup&gt;</td>
<td>9.93 ±0.98&lt;sup&gt;Bb&lt;/sup&gt;</td>
<td>10.45±0.66&lt;sup&gt;Ab&lt;/sup&gt;</td>
<td>10.43±1.18&lt;sup&gt;Ab&lt;/sup&gt;</td>
</tr>
<tr>
<td></td>
<td>WET</td>
<td>15.44 ±1.41&lt;sup&gt;Xc&lt;/sup&gt;</td>
<td>9.59 ±1.64&lt;sup&gt;Ya&lt;/sup&gt;</td>
<td>9.59 ±1.64&lt;sup&gt;Xa&lt;/sup&gt;</td>
<td>10.60 ±0.83&lt;sup&gt;Xa&lt;/sup&gt;</td>
</tr>
<tr>
<td></td>
<td>t&lt;sub&gt;cal&lt;/sub&gt;</td>
<td>0.014</td>
<td>0.134</td>
<td>0.553</td>
<td>0.108</td>
</tr>
<tr>
<td>VANGA</td>
<td>DRY</td>
<td>12.93±0.64&lt;sup&gt;Ab&lt;/sup&gt;</td>
<td>8.96 ±0.75&lt;sup&gt;Aa&lt;/sup&gt;</td>
<td>8.19 ±0.98&lt;sup&gt;Aa&lt;/sup&gt;</td>
<td>16.56 ±1.13&lt;sup&gt;Bc&lt;/sup&gt;</td>
</tr>
<tr>
<td></td>
<td>WET</td>
<td>12.87 ±0.88&lt;sup&gt;Xb&lt;/sup&gt;</td>
<td>8.45 ±0.61&lt;sup&gt;Xa&lt;/sup&gt;</td>
<td>6.01 ±0.91&lt;sup&gt;Xa&lt;/sup&gt;</td>
<td>14.56 ±1.44&lt;sup&gt;Yb&lt;/sup&gt;</td>
</tr>
<tr>
<td></td>
<td>t&lt;sub&gt;cal&lt;/sub&gt;</td>
<td>0.058</td>
<td>0.482</td>
<td>1.538</td>
<td>1.103</td>
</tr>
<tr>
<td>WASINI</td>
<td>DRY</td>
<td>15.07 ±0.80&lt;sup&gt;Ab&lt;/sup&gt;</td>
<td>9.60±0.54&lt;sup&gt;Ba&lt;/sup&gt;</td>
<td>14.22 ±0.88&lt;sup&gt;Bb&lt;/sup&gt;</td>
<td>10.63±0.99&lt;sup&gt;Aa&lt;/sup&gt;</td>
</tr>
<tr>
<td></td>
<td>WET</td>
<td>15.96 ±1.78&lt;sup&gt;Xb&lt;/sup&gt;</td>
<td>10.70±1.40&lt;sup&gt;Ya&lt;/sup&gt;</td>
<td>15.33±1.07&lt;sup&gt;Yb&lt;/sup&gt;</td>
<td>7.74±0.88&lt;sup&gt;Za&lt;/sup&gt;</td>
</tr>
<tr>
<td></td>
<td>t&lt;sub&gt;cal&lt;/sub&gt;</td>
<td>0.505</td>
<td>0.835</td>
<td>0.799</td>
<td>2.047</td>
</tr>
</tbody>
</table>

Mean values within the same row followed by same small letters are not significantly different. Mean values within the same column followed by the same capital letters in the same season are not significantly different at α=0.05 (SNK test).

Mean values within the same column for a given region are not significantly different if t<sub>cal</sub> < t<sub>crit</sub> (t<sub>crit</sub> = 2.024).

From Table 4.3 levels of iodine in stem samples of *S. portulacastrum* during the dry season ranged from 12.93±0.64 µg/g at Vanga to 15.42±0.91 µg/g at Funzi
and in wet season from 12.87±0.88 µg/g at Vanga to 15.96±1.78 µg/g at Wasini respectively, indicating Vanga to have the lowest levels among the regions. There was no significant seasonal difference in iodine levels in the stems at individual regions (t_{cd} < t_{crit}).

The levels of iodine in the leaves of *S. portulacastrum* ranged from 8.96±0.75 µg/g at Vanga to 9.93±0.98 µg/g at Funzi in the dry season and from 8.45±0.61 µg/g at Vanga and 10.70±1.40 µg/g at Wasini in the wet season respectively. There was no significant seasonal variation reported from the individual regions. Apparently Vanga had the lowest levels of iodine in the leaves which were different from other regions in both seasons. The leaves had lower levels of iodine than the stems but the difference was only significant at Funzi and Vanga.

Iodine levels in the soil during the dry season ranged from 8.19±0.98 µg/g at Vanga to 14.22±0.88 µg/g at Wasini and from 6.01±0.91 µg/g at Vanga to 15.33±1.07 µg/g at Wasini in the wet season respectively. There was no significant seasonal difference at individual regions, but Wasini was observed to have higher values than in Funzi and Vanga in both the wet and dry seasons. The same two regions showed similar iodine levels in the soil and leaves in both seasons but these levels were significantly lower than the stems. At Wasini levels in the soil and stems were not significantly different but were significantly higher than in the leaves.
Levels of iodine in water during the dry season ranged from 10.43±1.18 µg/g at Funzi to 16.56±1.13 µg/g at Vanga while the wet season gave a range of 7.74±0.88 µg/g at Wasini to 14.56±1.44 µg/g at Vanga respectively. Slight significant seasonal variation was only observed at Wasini. Across the regions Vanga reported higher iodine levels in water than both Funzi and Wasini, but whose values did not vary significantly. Among the matrices iodine levels were highest in water only at Vanga and differed significantly from soil, leaves and stems. At Funzi iodine levels were significantly higher in stem followed by water, soil and leaves. At Wasini levels were significantly highest in stems, followed by soil, leaves and water respectively. Thus no specific trend was observed for iodine distribution except in the plant samples where stems have higher levels than the leaves.
4.3.4 Levels of Selenium in the Stem and Leaves of *S. portulacastrum*, Soil and Water Samples

Table 4.4 shows the seasonal and regional distribution of selenium in the samples.

**Table 4.4: Concentration of Selenium in the Stem, Leaves, Soil and Water Samples at the Regions in Dry and Wet Seasons**

<table>
<thead>
<tr>
<th>REGION</th>
<th>SEASON</th>
<th>STEM (n=24) mean±SE µg/g</th>
<th>LEAVES (n=24) mean±SE µg/g</th>
<th>SOIL (n=24) mean±SE µg/g</th>
<th>WATER (n=18) mean±SE µg/g</th>
</tr>
</thead>
<tbody>
<tr>
<td>FUNZI</td>
<td>DRY</td>
<td>1.07±0.11&lt;sup&gt;Ac&lt;/sup&gt; 0.65±0.08&lt;sup&gt;Ab&lt;/sup&gt; 1.44±0.14&lt;sup&gt;Ad&lt;/sup&gt; 0.19±0.01&lt;sup&gt;Aa&lt;/sup&gt;</td>
<td>0.84±0.08&lt;sup&gt;Ybc&lt;/sup&gt; 0.73±0.09&lt;sup&gt;Yb&lt;/sup&gt; 1.04±0.06&lt;sup&gt;Yc&lt;/sup&gt; 0.34±0.09&lt;sup&gt;Ya&lt;/sup&gt;</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>WET</td>
<td>0.92±0.06&lt;sup&gt;Ab&lt;/sup&gt; 0.70±0.04&lt;sup&gt;Ab&lt;/sup&gt; 1.33±0.12&lt;sup&gt;Ac&lt;/sup&gt; 0.21±0.01&lt;sup&gt;Aa&lt;/sup&gt;</td>
<td>1.04±0.12&lt;sup&gt;Yc&lt;/sup&gt; 0.58±0.11&lt;sup&gt;Yb&lt;/sup&gt; 1.20±0.12&lt;sup&gt;Yc&lt;/sup&gt; 0.24±0.01&lt;sup&gt;Ya&lt;/sup&gt;</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>&lt;i&gt;t&lt;/i&gt;&lt;sub&gt;cal&lt;/sub&gt;</td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>VANGA</td>
<td>DRY</td>
<td>1.05±0.06&lt;sup&gt;Ac&lt;/sup&gt; 0.67±0.05&lt;sup&gt;Ab&lt;/sup&gt; 1.38±0.17&lt;sup&gt;Ad&lt;/sup&gt; 0.22±0.01&lt;sup&gt;Aa&lt;/sup&gt;</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>WET</td>
<td>1.01±0.08&lt;sup&gt;Yb&lt;/sup&gt; 0.40±0.09&lt;sup&gt;Ya&lt;/sup&gt; 1.31±0.13&lt;sup&gt;Yc&lt;/sup&gt; 0.21±0.01&lt;sup&gt;Ya&lt;/sup&gt;</td>
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<td></td>
</tr>
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</table>

Mean values within the same row followed by same small letters are not significantly different. Mean values within the same column followed by the same capital letters in the same season are not significantly different at α=0.05 (SNK test).

Mean values within the same column for a given region are not significantly different if <i>t</i><sub>cal</sub> < <i>t</i><sub>crit</sub> (<i>t</i><sub>crit</sub> = 2.024).

From Table 4.4 selenium levels in the stems during the dry season ranged from 0.92±0.06 µg/g at Vanga to 1.07±0.11 µg/g at Funzi and from 0.84±0.08 µg/g at
Funzi to 1.01±0.08 µg/g at Wasini in the wet season respectively. There was no significant seasonal difference in the concentration values of selenium within and across the regions.

Selenium levels in the leaves during the dry season ranged from 0.65±0.08 µg/g at Funzi to 0.70±0.04 µg/g at Vanga, and from 0.40±0.09 µg/g at Wasini to 0.73±0.09 µg/g at Funzi during the wet season respectively. Selenium was significantly higher at Wasini in the dry season than in the wet season. Across the regions the lowest significant value of 0.40±0.09 µg/g was reported at Wasini in the wet season. The level of selenium was observed to be higher in the stems than in the leaves in the three regions.

Soil selenium levels ranged from 1.33±0.12 µg/g at Vanga to 1.44±0.14 µg/g at Funzi during the dry season and from 1.04±0.06 µg/g at Funzi to 1.31±0.13 µg/g at Wasini in the wet season respectively. Soils at Wasini seemed to have accumulated higher levels of selenium than other regions though not significantly. The soil matrix apparently contained the highest levels of selenium among all the samples, followed progressively by stems, leaves and water, the difference being significant.

The water samples gave significantly lower levels of selenium than other matrices in both seasons. During the dry spell levels increased from a low of 0.19±0.01
μg/g at Funzi, to a high of 0.22±0.01 μg/g at Wasini, while in the wet season the levels ranged from 0.21±0.01 μg/g at Wasini to 0.34±0.09 μg/g at Funzi, suggesting no particular regional trend. However levels of 0.19±001 μg/g and 0.34±0.09 μg/g reported at Funzi in the dry and wet seasons varied significantly at the 95% confidence level.

In summary, seasonal selenium levels were highest during the dry season, but varied significantly across the regions. Levels were highest in the soil followed by stems, leaves and finally water. The level of selenium in the samples was observed to be lower than that of vanadium, zinc and chromium as reported above.

Muchemi (2006) found varying levels of selenium in different samples of seeds ranging from 16.54 to 182.7 μg/kg; spices: 30 to 153.8 μg/kg and grains: 29.58 to 140 μg/kg. These values are lower than the selenium levels obtained from this study in stems (0.99 μg/g) and leaves (0.63 μg/g Se), (990 and 630 μg/kg respectively).
4.3.5 Levels of Vanadium, µg/g, in the Stem and Leaves of *S. portulacastrum*, Soil and Water Samples

Table 4.5 summarizes the seasonal and regional distribution of vanadium in the samples.

**Table 4.5: Concentration of Vanadium in the Stem, Leaves, Soil and Water Samples Showing Regional and Seasonal Variation**

<table>
<thead>
<tr>
<th>REGION</th>
<th>SEASON</th>
<th>STEM (n=24) mean±SE µg/g</th>
<th>LEAVES(n=24) mean±SE µg/g</th>
<th>SOIL (n=24) mean±SE µg/g</th>
<th>WATER(n=18) mean±SE µg/g</th>
</tr>
</thead>
<tbody>
<tr>
<td>FUNZI</td>
<td>DRY</td>
<td>9.08 ±0.43&lt;sup&gt;Ba&lt;/sup&gt;</td>
<td>8.62±0.41&lt;sup&gt;Bc&lt;/sup&gt;</td>
<td>10.61±0.46&lt;sup&gt;Ad&lt;/sup&gt;</td>
<td>1.92±0.07&lt;sup&gt;Aa&lt;/sup&gt;</td>
</tr>
<tr>
<td></td>
<td>WET</td>
<td>7.15±0.49&lt;sup&gt;XC&lt;/sup&gt;</td>
<td>4.68±0.43&lt;sup&gt;XB&lt;/sup&gt;</td>
<td>9.03 ±0.43&lt;sup&gt;XD&lt;/sup&gt;</td>
<td>2.60 ±0.10&lt;sup&gt;Xa&lt;/sup&gt;</td>
</tr>
<tr>
<td></td>
<td>&lt;i&gt;t&lt;/i&gt;&lt;sub&gt;cal&lt;/sub&gt;</td>
<td>2.896</td>
<td>3.665</td>
<td>2.382</td>
<td>5.730</td>
</tr>
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<td>VANGA</td>
<td>DRY</td>
<td>7.76±0.35&lt;sup&gt;AC&lt;/sup&gt;</td>
<td>5.61 ±0.38&lt;sup&gt;AB&lt;/sup&gt;</td>
<td>10.75±0.25&lt;sup&gt;AD&lt;/sup&gt;</td>
<td>2.23 ±0.08&lt;sup&gt;BA&lt;/sup&gt;</td>
</tr>
<tr>
<td></td>
<td>WET</td>
<td>6.41 ±0.26&lt;sup&gt;XC&lt;/sup&gt;</td>
<td>4.39 ±0.31&lt;sup&gt;XB&lt;/sup&gt;</td>
<td>9.16 ±0.42&lt;sup&gt;XD&lt;/sup&gt;</td>
<td>2.56 ±0.10&lt;sup&gt;XA&lt;/sup&gt;</td>
</tr>
<tr>
<td></td>
<td>&lt;i&gt;t&lt;/i&gt;&lt;sub&gt;cal&lt;/sub&gt;</td>
<td>2.782</td>
<td>2.287</td>
<td>3.440</td>
<td>2.695</td>
</tr>
<tr>
<td>WASINI</td>
<td>DRY</td>
<td>9.76 ±0.47&lt;sup&gt;BC&lt;/sup&gt;</td>
<td>6.54 ±0.26&lt;sup&gt;BB&lt;/sup&gt;</td>
<td>12.99 ±0.49&lt;sup&gt;BD&lt;/sup&gt;</td>
<td>2.71 ±0.08&lt;sup&gt;BA&lt;/sup&gt;</td>
</tr>
<tr>
<td></td>
<td>WET</td>
<td>8.28 ±0.38&lt;sup&gt;YC&lt;/sup&gt;</td>
<td>5.94 ±0.25&lt;sup&gt;YB&lt;/sup&gt;</td>
<td>11.30 ±0.41&lt;sup&gt;YD&lt;/sup&gt;</td>
<td>2.83 ±0.16&lt;sup&gt;XA&lt;/sup&gt;</td>
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<tr>
<td></td>
<td>&lt;i&gt;t&lt;/i&gt;&lt;sub&gt;cal&lt;/sub&gt;</td>
<td>2.251</td>
<td>1.618</td>
<td>2.458</td>
<td>0.736</td>
</tr>
</tbody>
</table>

Mean values within the same row followed by same small letters are not significantly different. Mean values within the same column followed by the same capital letters in the same season are not significantly different at α=0.05 (SNK test).

Mean values within the same column for a given region are not significantly different if <i>t</i><sub>cal</sub> < <i>t</i><sub>crit</sub> (<i>t</i><sub>crit</sub> = 2.024).
From Table 4.5 the vanadium levels in stems of *S. portulacastrum* ranged from 7.76±0.35 µg/g at Vanga to 9.76±0.47 µg/g at Funzi during the dry season and from 6.41±0.26 µg/g at Vanga to 8.28±0.38 µg/g at Wasini in the wet season. All seasonal data for individual regions varied significantly (t_{cal} > t_{crit}). Across the regions however, the level of vanadium at Vanga was significantly low (7.76±0.35 µg/g) compared to those reported from Funzi and Wasini (9.08 ±0.43 µg/g and 9.76 ±0.47 µg/g) respectively, which among themselves did not differ significantly.

Vanadium levels in the leaves ranged from 5.61±0.38 µg/g at Vanga to 6.82±0.41 µg/g at Funzi during the dry season and from 4.39±0.31 µg/g at Vanga to 5.94±0.25 µg/g at Wasini during the wet season respectively. Significant seasonal variation was observed both at Funzi and Vanga. Across the regions during the dry season levels from Funzi and Wasini compared well but were significantly higher than that at Vanga (5.61 ±0.38 µg/g). In the wet season the level at Wasini (5.94 ±0.25) was higher than the levels at Vanga and Funzi which among themselves did not differ significantly.

Vanadium levels in the soil during the wet season ranged from 10.61±0.46 µg/g at Funzi to 12.99±0.49 µg/g at Wasini, and from 9.03±0.43 µg/g at Funzi to 11.30±0.41 µg/g at Wasini in the dry season respectively. There was significant seasonal variation within the individual regions (t_{cal} > t_{crit}). Across the regions
there was no significant difference between the values from Funzi and Vanga in both seasons, but these differed from those reported from Wasini which were significantly higher (12.99 ±0.49 µg/g). Generally vanadium levels in the soil are significantly higher than in both the leaves and stems of *S. portulacastrum* both regionally and seasonally. This could probably mean the soil is able to accumulate the element at a higher rate than it is being depleted by the plant.

Vanadium levels in sea water samples were significantly very low compared to other matrices both seasonally and regionally. Levels in the dry season ranged from 1.91±0.07 µg/g at Funzi to 2.71±0.08 µg/g at Wasini, and from 2.56±0.10 µg/g at Vanga to 2.83±0.16 µg/g at Wasini in the wet season respectively. Seasonal variation in the level of vanadium in the water was only significant at Funzi and Vanga. Across the regions, the value reported at Funzi during the dry season was significantly different from values reported from Vanga and Wasini which themselves did not vary significantly. Similar comparison during the wet season did not show any significant difference. Water around Wasini showed the highest levels of vanadium in both seasons though not significantly.

Muchemi (2006) reported vanadium levels in pumpkin, watermelon and sunflower seeds to range between 1.54 µg/g to 10.53 µg/g, while in selected spices from ND to 14.4 µg/g and in selected grains 6.28 µg/g to 11.48 µg/g. These values are within the same range as those obtained in this study of between 4.68
µg/g in the leaves and 9.76 µg/g in the stems of *S. portulacastrum*. These quantities meet the DRI of 1 to 4 µg V for adults, if one gram of the vegetable is taken into the body per day.

### 4.3.6 Levels of Zinc in the Stem and Leaves of *S. portulacastrum*, Soil and Water Samples

The mean values of zinc in the samples from the three regions in both seasons are presented in Table 4.6.

**Table 4.6: Concentration of Zinc in the Stem, Leaves, Soil and Water Sample at the Regions in Dry and Wet Seasons**

<table>
<thead>
<tr>
<th>REGION</th>
<th>SEASON</th>
<th>STEM (n=24) mean±SE µg/g</th>
<th>LEAVES (n=24) mean±SE µg/g</th>
<th>SOIL (n=24) mean±SE µg/g</th>
<th>WATER (n=18) mean±SE µg/g</th>
</tr>
</thead>
<tbody>
<tr>
<td>FUNZI</td>
<td>DRY</td>
<td>17.12±0.96&lt;sup&gt;Ac&lt;/sup&gt;</td>
<td>14.58 ±0.42&lt;sup&gt;Ab&lt;/sup&gt;</td>
<td>16.75±0.55&lt;sup&gt;Ac&lt;/sup&gt;</td>
<td>0.76 ±0.03&lt;sup&gt;Ba&lt;/sup&gt;</td>
</tr>
<tr>
<td></td>
<td>WET</td>
<td>13.80 ±1.14&lt;sup&gt;Xb&lt;/sup&gt;</td>
<td>12.24 ±0.68&lt;sup&gt;Xb&lt;/sup&gt;</td>
<td>17.26 ±1.88&lt;sup&gt;Xc&lt;/sup&gt;</td>
<td>0.78 ±0.03&lt;sup&gt;xa&lt;/sup&gt;</td>
</tr>
<tr>
<td></td>
<td>t&lt;sub&gt;cal&lt;/sub&gt;</td>
<td>2.213</td>
<td>3.117</td>
<td>0.307</td>
<td>0.662</td>
</tr>
<tr>
<td>VANGA</td>
<td>DRY</td>
<td>18.02 ±0.77&lt;sup&gt;Ac&lt;/sup&gt;</td>
<td>15.54 ±0.62&lt;sup&gt;Ac&lt;/sup&gt;</td>
<td>18.97±1.22&lt;sup&gt;Ac&lt;/sup&gt;</td>
<td>0.71 ±0.03&lt;sup&gt;Ba&lt;/sup&gt;</td>
</tr>
<tr>
<td></td>
<td>WET</td>
<td>13.76 ±0.94&lt;sup&gt;Xb&lt;/sup&gt;</td>
<td>13.00 ±0.92&lt;sup&gt;Xb&lt;/sup&gt;</td>
<td>20.70±2.04&lt;sup&gt;Yc&lt;/sup&gt;</td>
<td>0.74±0.03&lt;sup&gt;xa&lt;/sup&gt;</td>
</tr>
<tr>
<td></td>
<td>t&lt;sub&gt;cal&lt;/sub&gt;</td>
<td>3.490</td>
<td>2.383</td>
<td>0.776</td>
<td>0.684</td>
</tr>
<tr>
<td>WASINI</td>
<td>DRY</td>
<td>22.19±0.86&lt;sup&gt;Bc&lt;/sup&gt;</td>
<td>18.00 ±1.08&lt;sup&gt;Bb&lt;/sup&gt;</td>
<td>28.66±1.77&lt;sup&gt;Bd&lt;/sup&gt;</td>
<td>0.65 ±0.03&lt;sup&gt;Ba&lt;/sup&gt;</td>
</tr>
<tr>
<td></td>
<td>WET</td>
<td>25.05 ±0.43&lt;sup&gt;Yc&lt;/sup&gt;</td>
<td>14.29 ±0.46&lt;sup&gt;Xb&lt;/sup&gt;</td>
<td>25.28 ±1.16&lt;sup&gt;Zc&lt;/sup&gt;</td>
<td>0.69±0.04&lt;sup&gt;xa&lt;/sup&gt;</td>
</tr>
<tr>
<td></td>
<td>t&lt;sub&gt;cal&lt;/sub&gt;</td>
<td>2.567</td>
<td>2.697</td>
<td>1.425</td>
<td>0.951</td>
</tr>
</tbody>
</table>

Mean values within the same row followed by same small letters are not significantly different. Mean values within the same column followed by the same capital letters in the same season are not significantly different at α=0.05 (SNK test). Mean values within the same column for a given region are not significantly different if t<sub>cal</sub> < t<sub>crit</sub> (t<sub>crit</sub> = 2.024).
From Table 4.6, zinc levels in the stems of *S. portulacastrum* during the dry season ranged from 17.12±0.96 µg/g at Funzi to 22.19±0.86 µg/g at Wasini and from 13.76±0.94 µg/g to 25.05±0.43 µg/g to in the wet season respectively. In all regions there was significant difference between levels from the wet season and the dry season as shown by the calculated and tabulated *t* values (Table 4.6). Across the regions Wasini had significantly much higher zinc levels in the dry season (22.19±0.86 µg/g) than at Funzi and Vanga (17.12±0.96 µg/g and 18.02 ±0.77) respectively. A similar trend was observed in the wet season. The levels at Funzi and Vanga did not vary significantly.

Zinc levels in the leaves during the dry season ranged from 14.58±0.42 µg/g at Funzi to 18.00±1.08 µg/g at Wasini, and from 12.24±0.68 µg/g at Funzi to 14.29±0.46 µg/g at Wasini in the wet season respectively. At each region there was significant seasonal variation as shown by the calculated and tabulated *t* values (Table 4.6). However data from the three regions during the wet season did not vary significantly, but in the dry season Wasini had significantly higher mean level of zinc (18.00±1.08 µg/g) than Funzi and Vanga (14.58±0.42 µg/g and 15.54 ±0.62 µg/g) respectively. The lowest levels were observed at Funzi. Zinc levels in the leaves from Funzi and Wasini were significantly lower than in the stems in both seasons, but at Vanga there was no significant difference.

Zinc levels in the soil during the dry season gave a range of 16.75±0.55 µg/g at Funzi to 28.66±1.77 µg/g at Wasini, while the wet spell values ranged from
17.26±1.88 μg/g at Funzi to 25.28±1.16 μg/g at Wasini respectively. There was no significant difference at any region between levels reported from the dry and wet seasons according to the t-test at the 95% confidence level. Across the regions however, while there was no significant difference between the zinc levels from Funzi and Vanga in the dry and wet seasons, Wasini reported higher levels than these two regions in both seasons. Zinc levels in the soil were significantly higher in the soil samples than in the leaves and stems, both regionally and seasonally.

During the dry spell zinc levels in the water ranged from 0.65±0.03 μg/g at Wasini to 0.76±0.03 μg/g at Funzi, and from 0.69±0.04 μg/g at Wasini to 0.78±0.03 μg/g at Funzi in the wet season respectively. There was no significant seasonal variation at individual regions (t_{cal} < t_{crit}). Across the regions values increased progressively from Wasini through Funzi to Vanga in both seasons. Zinc levels were significantly lower in the water than in the soil, leaves and stem.

In summary, sea water samples showed very low zinc levels compared to other matrices. A progressively decreasing regional trend of zinc levels in the soil, stem and leaves was observed from Wasini through Vanga to Funzi in both seasons but water presented the opposite trend. Comparatively, stems had higher levels of zinc than the leaves and the values were higher in the dry season than in the wet season.
The zinc concentration in the United States drinking waters varies between 0.06 to 7.00 mg/L with a mean of 1.33 mg/L (APHA et al., 1995). Concentration above 5 mg/L can cause a bitter astringent taste and an opalescent in alkaline water (APHA et al., 1995). Mitei (1990) found zinc in Kenyan soils to range from 36 to 290 mg/g. Elsewhere zinc in Kenyan rivers was reported to be between 9 and 89 mg/L (Mathuthu et al., 1996).

Pumpkin, watermelon and sunflower seeds were found to contain 55.6, 41.0 and 39.3 µg/g of zinc respectively (Muchemi, 2006). Othman and Mbogo (2005) found average zinc content in some Tanzanian fruits to range from 0.12 to 0.32 mg/100g fw, while some Nigerian fruits had zinc ranging from 0.89 to 5.46 mg/100g fw (Aremu and Udoessien, 1990). Some raw edible leafy vegetables determined on AAS were reported to have zinc ranging from 4.6 to 15 mg/100g fw (Omollo, 1994). Vardanyan and Ingole (2004) found stem and leaves of S. portulacastrum growing at the polluted Carambolim Lake in India to contain 76.31 and 29.80 µg/g of zinc in the leaves and stems respectively. S. portulacastrum reported in this study has zinc ranging from 14.9 µg/g in the leaves to 18.48 µg/g in the stems. These values are less than the above vegetables and seeds, but higher than those in fruits. The levels do not exceed the permissible level of zinc in foods as provided by FAO and WHO of 6 mg/100g fw (Aremu and Udoessien, 1990) and are within the normal zinc levels commonly occurring
in plants of 0.5 - 3.0 mg/100mg dry weight (Isaac, 1980). This shows that this plant can be used as a food source for zinc or to supplement other food sources.

4.4 Summary of Essential Trace Element Levels in the Stem, Leaves, Soil and Water Samples

4.4.1 Mean distribution of Elements in S. portulacastrum

This section gives a comparison of the mean levels of the elements in different parts of the plant namely the stems and leaves as represented in Table 4.7. The mean values given are an average of each element from all the regions regardless of season.
Table 4.7: Mean Distribution of Elements in the Leaves and Stems of *S. portulacastrum*

<table>
<thead>
<tr>
<th>Element</th>
<th>STEM</th>
<th>LEAVES</th>
<th>t_cal</th>
<th>t_crit</th>
<th>p-values</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean±SE (µg/g)</td>
<td>Min-Max (µg/g)</td>
<td>Mean±SE (µg/g)</td>
<td>Min-Max (µg/g)</td>
<td></td>
</tr>
<tr>
<td>Chromium</td>
<td>3.35±0.15</td>
<td>ND-8.40</td>
<td>2.04±0.10</td>
<td>ND-4.20</td>
<td>13.39</td>
</tr>
<tr>
<td>Iodine</td>
<td>14.59±0.43</td>
<td>5.08-30.00</td>
<td>9.55±0.38</td>
<td>ND-22.00</td>
<td>16.8</td>
</tr>
<tr>
<td>Selenium</td>
<td>0.99±0.03</td>
<td>0.20-2.40</td>
<td>0.63±0.03</td>
<td>ND-1.60</td>
<td>12.15</td>
</tr>
<tr>
<td>Vanadium</td>
<td>8.23±0.20</td>
<td>4.00-16.00</td>
<td>5.79±0.16</td>
<td>1.20-10.20</td>
<td>20.43</td>
</tr>
<tr>
<td>Zinc</td>
<td>18.48±0.50</td>
<td>7.40-33.20</td>
<td>14.90±0.35</td>
<td>8.80-30.00</td>
<td>7.17</td>
</tr>
</tbody>
</table>

Table 4.7 shows that *S. portulacastrum* contains higher levels of all the studied elements in the stems than in the leaves. The difference was significant, since the $t_{cal}$ values are all greater than $t_{crit}$ of 1.98 at 95% confidence limits. The stems could be acting as temporary storage for the elements before relocation to the leaves, which would regenerate afresh after the older ones wither or are harvested. Zinc and iodine were the most abundant elements in both stems and leaves, followed by vanadium, chromium and selenium respectively. The two elements are also noted to be in high levels in the soil; hence the plants’ uptake of the same is in proportion to their levels in the immediate environment.
4.4.2 Seasonal and Regional Variation of Essential Trace Element Levels in *S. portulacastrum*

Table 4.8 gives the mean seasonal and regional levels of elements in *S. portulacastrum*.

**Table 4.8: Seasonal Variation of Essential Trace Element Levels in Leaf and Stem Samples of *S. portulacastrum* at the Regions**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Season</th>
<th>FUNZI(n=48)</th>
<th>VANGA(n=48)</th>
<th>WASINI(n=48)</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chromium</td>
<td>Dry</td>
<td>3.21±0.27&lt;sup&gt;a&lt;/sup&gt;</td>
<td>3.86±0.31&lt;sup&gt;a&lt;/sup&gt;</td>
<td>5.62±0.38&lt;sup&gt;b&lt;/sup&gt;</td>
<td>0.000</td>
</tr>
<tr>
<td></td>
<td>Wet</td>
<td>2.58±0.30&lt;sup&gt;a&lt;/sup&gt;</td>
<td>4.17±0.29&lt;sup&gt;b&lt;/sup&gt;</td>
<td>5.40±0.37&lt;sup&gt;c&lt;/sup&gt;</td>
<td>0.000</td>
</tr>
<tr>
<td>Iodine</td>
<td>Dry</td>
<td>11.93±0.57&lt;sup&gt;b&lt;/sup&gt;</td>
<td>10.03±0.52&lt;sup&gt;a&lt;/sup&gt;</td>
<td>12.97±0.52&lt;sup&gt;b&lt;/sup&gt;</td>
<td>0.001</td>
</tr>
<tr>
<td></td>
<td>Wet</td>
<td>11.58±0.92&lt;sup&gt;a&lt;/sup&gt;</td>
<td>9.11±0.62&lt;sup&gt;b&lt;/sup&gt;</td>
<td>14.00±0.89&lt;sup&gt;c&lt;/sup&gt;</td>
<td>0.000</td>
</tr>
<tr>
<td>Selenium</td>
<td>Dry</td>
<td>1.05±0.07&lt;sup&gt;a&lt;/sup&gt;</td>
<td>0.98±0.06&lt;sup&gt;a&lt;/sup&gt;</td>
<td>1.03±0.07&lt;sup&gt;a&lt;/sup&gt;</td>
<td>0.732</td>
</tr>
<tr>
<td></td>
<td>Wet</td>
<td>0.87±0.05&lt;sup&gt;b&lt;/sup&gt;</td>
<td>0.94±0.08&lt;sup&gt;a&lt;/sup&gt;</td>
<td>0.91±0.08&lt;sup&gt;a&lt;/sup&gt;</td>
<td>0.768</td>
</tr>
<tr>
<td>Vanadium</td>
<td>Dry</td>
<td>8.83±0.31&lt;sup&gt;ab&lt;/sup&gt;</td>
<td>8.04±0.31&lt;sup&gt;a&lt;/sup&gt;</td>
<td>9.76±0.39&lt;sup&gt;b&lt;/sup&gt;</td>
<td>0.002</td>
</tr>
<tr>
<td></td>
<td>Wet</td>
<td>6.95±0.36&lt;sup&gt;a&lt;/sup&gt;</td>
<td>6.65±0.34&lt;sup&gt;a&lt;/sup&gt;</td>
<td>8.50±0.38&lt;sup&gt;b&lt;/sup&gt;</td>
<td>0.001</td>
</tr>
<tr>
<td>Zinc</td>
<td>Dry</td>
<td>16.15±0.41&lt;sup&gt;a&lt;/sup&gt;</td>
<td>17.51±0.54&lt;sup&gt;a&lt;/sup&gt;</td>
<td>22.95±0.90&lt;sup&gt;b&lt;/sup&gt;</td>
<td>0.000</td>
</tr>
<tr>
<td></td>
<td>Wet</td>
<td>14.43±0.81&lt;sup&gt;a&lt;/sup&gt;</td>
<td>15.82±0.94&lt;sup&gt;a&lt;/sup&gt;</td>
<td>21.54±0.86&lt;sup&gt;b&lt;/sup&gt;</td>
<td>0.000</td>
</tr>
</tbody>
</table>

<sup>*Mean ± SE (µg/g) followed by same small letters for the same parameter are not significantly different at α = 0.05 (SNK test)</sup>
From Table 4.8 levels of the essential trace elements are apparently higher during the dry season than in the wet season, although significant seasonal variation is only reported for vanadium at Funzi, chromium at Vanga and Wasini, Selenium at Funzi and iodine at Wasini. This could probably be attributed to the normally high temperatures at the coastal region that cause a high rate of evaporation in the dry season. The only minor exception is observed for chromium at Vanga and iodine at Wasini. The level of all elements is highest at Wasini region in both seasons while the other regions follow but not in any particular order. This could be due to anthropogenic input from a damping site for the island next to the sampling area. There is less interference at Funzi, while Vanga sampling site is on an uninhabited island off the mainland shore away from human interferences. The availability of the elements in the stems and leaves is seen to decrease in the order zinc, iodine, vanadium, chromium and selenium respectively.

4.4.3 Levels of Essential Trace Elements in the Soil and Water

This section gives a comparison of the mean levels of the essential trace elements in the soil and seawater on which *S. portulacastrum* thrives as represented in Table 4.9. The mean values given are an average from all the regions regardless of season.
Table 4.9: Mean Distribution of Essential Trace Elements in the Soil and Water

<table>
<thead>
<tr>
<th>ELEMENT</th>
<th>SOIL</th>
<th>WATER</th>
<th>t&lt;sub&gt;cal&lt;/sub&gt;</th>
<th>p-values</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean±SE (µg/g)</td>
<td>Min-Max (µg/g)</td>
<td>Mean±SE (µg/g)</td>
<td>Min-Max (µg/g)</td>
</tr>
<tr>
<td>Chromium</td>
<td>7.16±0.22</td>
<td>3.22-19.46</td>
<td>0.29±0.00</td>
<td>0.24-0.34</td>
</tr>
<tr>
<td>Iodine</td>
<td>11.47±0.51</td>
<td>ND-25.40</td>
<td>11.91±0.54</td>
<td>1.99-22.86</td>
</tr>
<tr>
<td>Selenium</td>
<td>1.37±0.07</td>
<td>0.55-4.67</td>
<td>0.23±0.01</td>
<td>0.16-0.33</td>
</tr>
<tr>
<td>Vanadium</td>
<td>11.03±0.24</td>
<td>5.89-17.21</td>
<td>2.44±0.05</td>
<td>1.50-3.57</td>
</tr>
<tr>
<td>Zinc</td>
<td>21.26±0.85</td>
<td>2.70-39.01</td>
<td>0.72±0.01</td>
<td>0.49-0.91</td>
</tr>
</tbody>
</table>

(t<sub>crit</sub> = 1.98)

From Table 4.9 levels of all the elements except iodine were observed to be much higher in the soil than in the water, and the difference was quite significant, as evidenced by their t<sub>cal</sub> values largely exceeding the t<sub>crit</sub> of 1.98 at 95% confidence level. This could be attributed to the ability of the soil to continuously bind and thus accumulate the elements over time from constant exposure to the highly mineralized seawater. Iodine values of 11.47±0.51 µg/g in the soil and 11.91±0.54 µg/g in the water were not significantly different at p=0.05 level of significance. In water iodine had the highest level of all the elements with 11.91±0.54 µg/g, followed from afar by vanadium with 2.44±0.05 µg/g. The rest ranged from
0.23±0.01 µg/g to 0.72±0.01 µg/g. Chromium and selenium had the lowest levels in both matrices at 7.16±0.2 µg/g and 1.37±0.07 µg/g in the soil, and 0.29±0.00 µg/g and 0.23±0.01 µg/g in the water, respectively. It is also observed that their levels are comparatively low in the plant matrix as shown in Table 4.9.

### 4.4.4 Correlation between Levels of Essential Trace Elements in Water, Soil and the Plant

This section gives the relationship between the levels of the analyzed essential trace elements in the water, soil and plant matrices. Table 4.10 gives a correlation between the level of elements in the water with those in the soil and plant respectively, and also between the soil and the plant.

#### Table 4.10 Correlation Coefficient Values (r*) for Essential Trace Elements in Different Sample Matrices

<table>
<thead>
<tr>
<th>ELEMENT</th>
<th>Water vs Soil</th>
<th>Water vs Plant</th>
<th>Soil vs Plant</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chromium</td>
<td>0.068 (0.526)</td>
<td>0.216 (0.041)</td>
<td>0.529 (0.000)</td>
</tr>
<tr>
<td>Iodine</td>
<td>-0.329 (0.001)</td>
<td>0.012 (0.912)</td>
<td>0.187 (0.041)</td>
</tr>
<tr>
<td>Selenium</td>
<td>-0.008 (0.693)</td>
<td>0.013 (0.900)</td>
<td>0.346 (0.000)</td>
</tr>
<tr>
<td>Vanadium</td>
<td>0.162 (0.128)</td>
<td>-0.149 (0.160)</td>
<td>0.570 (0.000)</td>
</tr>
<tr>
<td>Zinc</td>
<td>-0.221 (0.036)</td>
<td>-0.098 (0.360)</td>
<td>0.377 (0.004)</td>
</tr>
</tbody>
</table>

r* - Pearson correlation coefficient

N/B Values in parenthesis are p-values
From Table 4.10 only iodine and zinc showed a significant negative correlation between the levels in the soil and water (p-values < 0.05), while the correlation between the levels of other elements were not significant (p > 0.05). Thus though the levels of iodine and zinc may be high in the water, their level of accumulation in the soil is much lower.

There is significant positive correlation of the element levels in the plant and the soil with p < 0.05. Thus the uptake of the studied elements by *S. portulacastrum* directly depends on their concentration in the soil. Thus the elements’ content in the plant is as good as the soil on which it grows.

Only chromium in the water and plant samples gave a p-value < 0.05, meaning that this was the only element whose level in the plant was significantly and positively correlated with their levels in the water (r = 0.216). Thus as the level of chromium increases in the water its level of accumulation in the plant also increases. The levels of other elements in the water did not show any particular correlation to the levels in the plant. This could imply that the plants’ uptake of these elements is not dependent on their levels in the water but rather acquires them from the soil.
CHAPTER FIVE

5.0 CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusions

Utilization of *S. portulacastrum* (L.) L. in the study areas of Funzi, Vanga and Wasini was found to be mainly as food and to a lesser extent as medicine, with an additional use only at Wasini of creating scenery for tourist attraction.

Questionnaire data showed the highest level of utilization of the plant in Wasini region at 83.33% mainly as food with slight medicinal use, probably due to sensitization from the women group activities. Vanga reported the least utilization at 13.3% despite the plant being in plenty, probably due to the community’s ignorance of its potential nutritional and economic benefits. At Funzi the limited utilization as food is reported to be 26.67% and during famine, while few old men appreciate its medicinal value. The young generation in all the three communities was observed to be generally unaware of the medicinal benefits of plant.

The halophyte *S. portulacastrum* (L.) L. was found to contain essential trace elements Zn, V, Cr, Se and I in both its leaves and stems. Selenium gave the least levels while zinc gave the highest with mean ranges from 0.63±0.03 µg/g Se to 18.48±0.50 µg/g Zn in the leaves and 0.99±0.03 µg/g Se to 18.48±0.50 µg/g Zn in stems respectively.
Stems had higher levels of the elements than the leaves, probably because the leaves soon wither and fall off while the stems persist to accumulate more of the elements over time. This observation may also suggest that the stem might be acting as storage of trace elements after uptake before translocation to the leaves. The high storage is thus advantageous for the plants’ useful biochemical functions in human system.

The level of essential trace elements varied in each matrix, region and season. Zinc and iodine were the most abundant elements in the solid matrices throughout the regions and seasons. These were followed by vanadium, chromium and selenium respectively. The dry season tended to record generally higher levels than the wet season in most samples across the regions, probably due to the plant losing water by evaporation, and the soil also concentrating and accumulating more of the elements under these conditions. Wasini region tended to record higher levels of the elements in all matrices across the seasons. Levels of the metals were observed to be highest in the soil samples, followed by stem, leaves and least in the water.

Levels of iodine were highest in seawater samples and least in the soil, probably because iodine tends to exist abundantly in this matrix mainly in the soluble form. Apart from iodine, other elements exist in relatively low levels in seawater but the soil has consistently over time been able to bind and thus accumulated substantial
amounts of the same due to constant exposure to the highly mineralized seawater when submerged during the high tides. The degree of accumulation of elements by the halophyte *S. portulacastrum* (L) L was observed to be generally in relative proportions to their availability in the soil.

5.2 Recommendations

5.2.1 Recommendations from the study

Since *S. portulacastrum* (L) L. was found to have high levels of essential trace elements, there is need for public health stakeholders to create awareness of the plant as an edible vegetable among the local communities especially at Vanga and Funzi regions and to educate them of its nutritional value hence promote maximum utilization of this locally available food and economic resource. There is need to sensitize the young generation most of who have lost the cultural feeding habits, to the existence of indigenous plant that are of nutritional medicinal and economic value in order to enhanced utilization which will lead to improved health and economic status. Such plants would help better manage the effects of immune compromising conditions such as HIV/AIDS, and enhance the realization of improved maternal health, decreased child mortality, promotion of proper growth and development, and generally improve the living standard of the local residents.
Although most of the Wasini community utilizes of *S. portulacastrum*(L) *L.* as food, they should be made aware of its actual nutritional value and be encouraged to continue consuming the vegetable. The Wasini Women Group could also be educated on proper preservation technology of the vegetable involving hygienic drying and packaging to enable them venture into a wider market for it both locally and abroad, and thus attract higher economic benefit.

The reported levels of Zn, V, Cr, Se and I in the plant suggest that *S. portulacastrum* (*L*) *L.* can be used as a food source or supplement for other food sources in respect of the studied elements.

### 5.2.2 Recommendations for Further Research

The stems of *S. portulacastrum* (*L*) *L.* are succulent and contain higher levels of the studied trace elements than the leaves. If consumed, maximum utilization and nutritional benefit from the vegetable would be achieved. However further study is recommended on the stem including the fiber content to establish its palatability.

The possibility for adaptability of *S. portulacastrum* (*L*) *L.* in regions further inland away from the sea could also be investigated through aquaculture and irrigation so as to maximize exploitation to large scale within the coastal region and beyond. This move will enhance awareness of this indigenous plant, promote
food sufficiency and optimize utilization. There will be economic gain in terms of job creation, health promotion and poverty alleviation leading to improved living standard. Thus sustainable utilization of the plant would help meet several millennium goals simultaneously, as well as contributing to the achievement of Vision 2030.

Analysis of other essential elements on the plant is recommended in order to establish a comprehensive nutritive data base. Essential oils, proteins, vitamins and carbohydrate levels, as well as phytochemicals in the plant could also be investigated.

However, there is also need to investigate the possibility of the plant accumulating toxic elements in levels that may compromise the beneficial use of the plant as a supplement for health purposes. The relevant stakeholders should institute measures to monitor and control anthropogenic pollution on the sea to avoid this. However, if S. portulacastrum (L) L. is found to accumulate excessive levels of such metals from unpolluted sea water, then it could be put to the alternative application as a cleaning agent for these metals along polluted coastlines.

Further studies could be done to investigate the alleged claims of its medicinal value to ascertain the possibility of it being used as herbal remedy for such
conditions as infertility, diarrhea, scurvy, skin rash and possibly other ailments. If proved positive, then it could constitute a potential raw material for therapeutic or pharmaceutical preparations.
REFERENCES


Boden, G., (1996); Effects of Vanadyl Sulfate on Carbohydrate and Lipid Metabolism in Patients with Non-Insulin Dependent Diabetes Mellitus. *Metabolism* 45: 1130-1135.


APPENDIX I: Questionnaire to Assess the Level of Community Utilization of *S. portulacastrum* in the Sampling Regions

Tick in the appropriate box.

1. Respondent’s age, (years): \(<25\)  \(25-45\)  \(45-65\)  \(>65\)

2. Gender: \(\text{Male}\) \(\text{Female}\)

3. Are you a local resident? \(\text{Yes}\) \(\text{No}\)

4. Are you a vegetarian? \(\text{Yes}\) \(\text{No}\)

5. Do you know “Mboga ya Pwani”? \(\text{Yes}\) \(\text{No}\)

6. For how long have you known the plant? \(\text{< 5 years}\)  \(5-20\)  \(>20\) years

7. Do you use “Mboga ya Pwani”? \(\text{Yes}\) \(\text{No}\)

8. If yes, as what? \(\text{Food}\)  \(\text{Medicinal herb}\)  \(\text{Other}\)

9. How frequently do you use it? \(\text{Rarely}\)  \(\text{Quite often}\)  \(\text{Never}\)

10. How long have you used the plant? \(\text{< 5 years}\)  \(5-20\)  \(>20\) years
APPENDIX I: continued

11. What is the level of availability of the plant?

| Scarce | Adequate | Plenty |

Does the community use ‘Mboga ya Pwani’?

| Yes | No |

12. If yes, what does it use the Mboga for?

| Food | Medicinal herb | Both | Other |

13. Do you know of other people interested in the plant?

| Yes | No |

14. If yes, who? ………………………………………………………………………

15. For what purpose? …………………………………………………………………

Thank you for your cooperation.
APPENDIX II: Questionnaire Results for Level of Community Utilization of *S. portulacastrum* in the Sampling Regions

<table>
<thead>
<tr>
<th>PARAMETER</th>
<th>RESPONSE</th>
<th>FUNZI</th>
<th>VANGA</th>
<th>WASINI</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age</td>
<td>&lt; 25 yrs</td>
<td>16.7</td>
<td>13.3</td>
<td>13.3</td>
</tr>
<tr>
<td></td>
<td>25 – 45</td>
<td>30.0</td>
<td>30.0</td>
<td>26.7</td>
</tr>
<tr>
<td></td>
<td>45 – 65</td>
<td>40.0</td>
<td>36.7</td>
<td>40.0</td>
</tr>
<tr>
<td></td>
<td>&gt; 65</td>
<td>13.3</td>
<td>20.0</td>
<td>20.0</td>
</tr>
<tr>
<td></td>
<td>Total</td>
<td>100.0</td>
<td>100.0</td>
<td>100.0</td>
</tr>
<tr>
<td>Gender</td>
<td>Male</td>
<td>53.3</td>
<td>66.7</td>
<td>60.0</td>
</tr>
<tr>
<td></td>
<td>Female</td>
<td>46.7</td>
<td>33.3</td>
<td>40.0</td>
</tr>
<tr>
<td></td>
<td>Total</td>
<td>100.0</td>
<td>100.0</td>
<td>100.0</td>
</tr>
<tr>
<td>Local resident?</td>
<td>Yes</td>
<td>80.0</td>
<td>70.0</td>
<td>96.7</td>
</tr>
<tr>
<td></td>
<td>No</td>
<td>20.0</td>
<td>30.0</td>
<td>3.3</td>
</tr>
<tr>
<td></td>
<td>Total</td>
<td>100.0</td>
<td>100.0</td>
<td>100.0</td>
</tr>
<tr>
<td>Vegetarian?</td>
<td>Yes</td>
<td>0.0</td>
<td>20.0</td>
<td>10.0</td>
</tr>
<tr>
<td></td>
<td>No</td>
<td>100.0</td>
<td>80.0</td>
<td>90.0</td>
</tr>
<tr>
<td></td>
<td>Total</td>
<td>100.0</td>
<td>100.0</td>
<td>100.0</td>
</tr>
<tr>
<td>Do you know <em>mboga ya Pwani</em>?</td>
<td>Yes</td>
<td>40.0</td>
<td>83.3</td>
<td>93.3</td>
</tr>
<tr>
<td></td>
<td>No</td>
<td>60.0</td>
<td>16.7</td>
<td>6.7</td>
</tr>
<tr>
<td></td>
<td>Total</td>
<td>100.0</td>
<td>100.0</td>
<td>100.0</td>
</tr>
<tr>
<td>For how long?</td>
<td>&lt; 5 yrs</td>
<td>0.0</td>
<td>0.0</td>
<td>14.3</td>
</tr>
<tr>
<td></td>
<td>5-20yrs</td>
<td>33.3</td>
<td>56.0</td>
<td>17.8</td>
</tr>
<tr>
<td></td>
<td>&gt; 20</td>
<td>66.7</td>
<td>44.0</td>
<td>67.9</td>
</tr>
<tr>
<td></td>
<td>Total</td>
<td>100.0</td>
<td>100.0</td>
<td>100.0</td>
</tr>
</tbody>
</table>
APPENDIX II: continued

<table>
<thead>
<tr>
<th>Do you use Mboga ya Pwani?</th>
<th>Yes</th>
<th>66.7</th>
<th>28.0</th>
<th>89.3</th>
</tr>
</thead>
<tbody>
<tr>
<td>No</td>
<td>33.3</td>
<td>72.0</td>
<td>10.7</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>100.0</td>
<td>100.0</td>
<td>100.0</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>As what?</th>
<th>Food</th>
<th>88.9</th>
<th>100.0</th>
<th>89.3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Medicinal herb</td>
<td>11.1</td>
<td>0.0</td>
<td>10.7</td>
<td></td>
</tr>
<tr>
<td>Other</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>100.0</td>
<td>100.0</td>
<td>100.0</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>How frequently?</th>
<th>Rarely</th>
<th>100.0</th>
<th>71.4</th>
<th>60.0</th>
</tr>
</thead>
<tbody>
<tr>
<td>Quite often</td>
<td>0.0</td>
<td>28.6</td>
<td>40.0</td>
<td></td>
</tr>
<tr>
<td>Never</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>100.0</td>
<td>100.0</td>
<td>100.0</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>For how long have you Used the plant?</th>
<th>&lt; 5yrs</th>
<th>0.0</th>
<th>14.3</th>
<th>16.0</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>5 -20 yrs</td>
<td>25.0</td>
<td>42.8</td>
<td>28.0</td>
</tr>
<tr>
<td></td>
<td>&gt; 20 yrs</td>
<td>75.0</td>
<td>42.9</td>
<td>56.0</td>
</tr>
<tr>
<td>Total</td>
<td>100.0</td>
<td>100.0</td>
<td>100.0</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>How available is the plant?</th>
<th>Scarce</th>
<th>16.7</th>
<th>36.0</th>
<th>7.1</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Adequate</td>
<td>58.3</td>
<td>28.0</td>
<td>39.3</td>
</tr>
<tr>
<td></td>
<td>Plenty</td>
<td>25.0</td>
<td>36.0</td>
<td>53.6</td>
</tr>
<tr>
<td>Total</td>
<td>100.0</td>
<td>100.0</td>
<td>100.0</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Does community use the plant?</th>
<th>Yes</th>
<th>25.0</th>
<th>20.0</th>
<th>100.0</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>No</td>
<td>75.0</td>
<td>80.0</td>
<td>0.0</td>
</tr>
<tr>
<td>Total</td>
<td>100.0</td>
<td>100.0</td>
<td>100.0</td>
<td></td>
</tr>
</tbody>
</table>
APPENDIX II: continued

<table>
<thead>
<tr>
<th>If yes, what for?</th>
<th>Food only</th>
<th>83.3</th>
<th>87.5</th>
</tr>
</thead>
<tbody>
<tr>
<td>Medicinal herb only</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
</tr>
<tr>
<td>Both</td>
<td>25.0</td>
<td>16.7</td>
<td>12.5</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>100.0</strong></td>
<td><strong>100.0</strong></td>
<td><strong>100.0</strong></td>
</tr>
</tbody>
</table>

| Other people interested in it? | Yes | 0.0 | 0.0 | 83.3 |
| No | 100.0 | 100.0 | 16.7 |
| **Total** | **100.0** | **100.0** | **100.0** |

| If Yes, Who? | N/A | N/A | N/A | Tourists |
| For What Purpose? | N/A | N/A | N/A | Food, Scenery |
APPENDIX III: Calibration Curve for Chromium

\[ y = 0.046x - 0.000 \]
\[ R^2 = 1 \]

APPENDIX IV: Calibration Curve for Selenium

\[ y = 0.003x - 0.004 \]
\[ R^2 = 0.998 \]
APPENDIX V: Calibration Curve for Vanadium

\[ y = 0.021x + 0.021 \]
\[ R^2 = 0.996 \]

APPENDIX VI: Calibration Curve for Zinc

\[ y = 0.361x + 0.004 \]
\[ R^2 = 0.999 \]
APPENDIX VII : Concentration of Chromium in the Stem, Leaves, Soil and Water Samples at the Regions in Dry and Wet Seasons

![Graph showing concentration of chromium in different samples at Funzi, Vanga, and Wasini regions in dry and wet seasons.]

APPENDIX VIII : Concentration of Iodine in the Stem, Leaves, Soil and Water Samples at the Regions in Dry and Wet Seasons

![Graph showing concentration of iodine in different samples at Funzi, Vanga, and Wasini regions in dry and wet seasons.]
APPENDIX IX: Concentration of Selenium in the Stem, Leaves, Soil and Water Samples at the Regions in Dry and Wet Seasons

APPENDIX X: Concentration of Vanadium in the Stem, Leaves, Soil and Water Samples at the Regions in Dry and Wet Seasons
APPENDIX XI: Concentration of Zinc in the Stem, Leaves, Soil and Water Samples at the Regions in Dry and Wet Seasons
APPENDIX XII : Comparison of Elemental Levels in *S. portulacastrum* with other Samples

<table>
<thead>
<tr>
<th>SAMPLE</th>
<th>VANADIUM</th>
<th>ZINC</th>
<th>CHROMIUM</th>
<th>SELENIUM</th>
<th>IODINE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kenyan <em>Sesuvium portulacastrum</em></td>
<td>5.79-8.23</td>
<td>14.9-18.48</td>
<td>2.04-3.35</td>
<td>0.63-0.99</td>
<td>9.55-14.59</td>
</tr>
<tr>
<td>Indian <em>Sesuvium portulacastrum</em></td>
<td>N/A</td>
<td>49.8-76.31</td>
<td>0.48-7.44</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>Tanzanian Fruits</td>
<td>N/A</td>
<td>1.20-3.20</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>Nigerian Fruits</td>
<td>N/A</td>
<td>8.90-54.60</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>Leafy Vegetables</td>
<td>N/A</td>
<td>45.0-150.0</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>Spices</td>
<td>ND-14.40</td>
<td>N/A</td>
<td>1.76-12.30</td>
<td>0.03-0.154</td>
<td>N/A</td>
</tr>
<tr>
<td>Grain</td>
<td>6.28-11.48</td>
<td>N/A</td>
<td>2.24-5.86</td>
<td>0.030-0.140</td>
<td>N/A</td>
</tr>
<tr>
<td>Seed</td>
<td>1.54-10.53</td>
<td>9.30-55.60</td>
<td>5.00-6.20</td>
<td>0.016-0.183</td>
<td>N/A</td>
</tr>
<tr>
<td>RDI values</td>
<td>1-4 µg</td>
<td>12-15 mg</td>
<td>50-200 µg</td>
<td>55-70 µg</td>
<td>150 µg</td>
</tr>
</tbody>
</table>
### APPENDIX XIII: Concentration of Elements in Natural Sea Water

<table>
<thead>
<tr>
<th>ELEMENT</th>
<th>CONCENTRATION, UNITS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vanadium</td>
<td>1.8 µg/L</td>
</tr>
<tr>
<td>Chromium</td>
<td>260.0 ng/L</td>
</tr>
<tr>
<td>Zinc</td>
<td>590.0 ng/L</td>
</tr>
<tr>
<td>Selenium</td>
<td>180.0 ng/L</td>
</tr>
<tr>
<td>Iodine</td>
<td>64.0 µg/L</td>
</tr>
<tr>
<td>Sodium</td>
<td>10.8 g/L</td>
</tr>
<tr>
<td>Chloride</td>
<td>19.4 g/L</td>
</tr>
<tr>
<td>Bromide</td>
<td>67.0 mg/L</td>
</tr>
<tr>
<td>Potassium</td>
<td>398.0 mg/L</td>
</tr>
<tr>
<td>Iron</td>
<td>140.0 ng/L</td>
</tr>
<tr>
<td>Cobalt</td>
<td>6.0 ng/L</td>
</tr>
<tr>
<td>Copper</td>
<td>350.0 ng/L</td>
</tr>
<tr>
<td>Mercury</td>
<td>2.0 ng/L</td>
</tr>
<tr>
<td>Lead</td>
<td>36.0 ng/L</td>
</tr>
</tbody>
</table>

Source: Farley, 2009