CHAPTER (I)

Introduction and Basic Concepts

There are some endemic diseases in the different parts of Sudan which are in many cases attributed to malnutrition caused by food culture imposed by the environment. Therefore, there seem to be a relationship between environment and health situations of the human community in each area. There are some indications which can be obtained by waste excreted by the human body, represented in the necessary elements composing its food in any of these areas .Thus from this we can know the shortage in the elements of food necessary for good nutrition.

This thesis represents an attempt to solve some problems concerning health relating to an environment and food culture that are likely to be in connection with endemic diseases. It practice a study applied to Kassala State in eastern Sudan, where samples from human hair and nails are collected from localities(schools and hospitals).The collected numbers are 350 samples for both of hair and nails, people volunteered each with one sample, for hair or for nail. Variables of the study included samples location, kind of sample (male, female), and age.The aim of this study is to establish a health map in a new way by using physical techniques by examining and determine elements in the sample, and then comparing the obtained results with the standard constituents' of both water and food existing in the study area .The technique used in this study is X-Ray Fluorescence(XRF) to examine hair and nails samples, since human waste components from these samples show indication of significance to human food components. We hope this study would pronde to health proplems explanations in Kassala State by regarding the results in connection with the diseases spread in this State.

In this study physicial technique are used to acquire useful data to address certain health and development problems. The study is expected to provide data explaining the correlation between the chemical elements composing the human body and variables such as: (environmental-concenterations of elements in nails and hair with respect to age and gender). Hence comparing these data for all rural areas in Kassala State would assist in drawing a nutrition map to be utilized in solving the afore noted problems.

In this study we will discuss the above mentioned of the elemental composions of human hair and nails. Physical analysis of human hair and nails has been performed to determine the chemical elements through spectroscopic analysis techniques.

Samples were collected to represent a model for the community Afterwards these samples have been analyzed by employing the available techniques through spectroscopy.

In this research we will be mainly concerned about the area of Kassala State, in Eastern Sudan, as a project which can be further extended to other areas in Sudan.

This research project is expected to provide information for the benefit of the both people and authorities in Kassala State, for the promotion of health performanc.

The human body contains chemical compounds such as water, carbohydrates, and amino acids, these compounds is turn consist of elements such as carbon, hydrogen, oxygen,nitrogen ,phosphrous,calcium iron, magnesium, manganese and so on. All of these chemical compounds and elements occur in various forms and combinations both in the human body and in the plants and animal organism that humans eat. The human body consists of elements and compounds, ingested, digested, absorbed and circulated through the blood stream to feed the cell of the body. The human body contains a greater number of minerals which are necessary to our survival; the deficiency of this mineral can cause death, the access of this mineral concentration may lead to some troubles. Decreasing the body supplies from essential may lead to the syndrome of lack of iron which causes anemia. In contrast the increased concentrations of lead or mercury cause poisoning.

The absorption or depletion metals in human tissue mainly occur due to environmental and/or occupational exposure,poor diet,illness and digestion drug.

The human nails and hair are interfacing between the body and the environment and they play an important role in the defense of organism. The nail plate also contains minerals such as Fe,Cu,Zn which are the main minerals in it.The content of Zn is higher in males than females. Hair analysis might soon become a powerful diagnostic tool in monitoring of environmental exposure and studying the nutritional status of individuals.

The thesis is composed of seven chapters, Chapter one includes an introduction and basic concepts in which there is an overview of the study area and some other basic concepts of relevance to it, Chapter two which gives a theoretical background includes the Maxwell equation ,electromagnetic waves photon and energy ,atomic spectra and the energy level and line spectra of hydrogen , Chapter three includes spectroscopy analysis techniques in which there is a brief reviewing to a number of spectroscopy techniques that are available, Chapter four is devoted to X-Ray Fluorescence (XRF) technique.In Chapter five materials and methods are presented in which there is a description for equipments and apparatus setup and sample preparations are given.

In Chapter six results are displayed and discussed them. Chapter seven comprises conclusion and future work in a form of recommendations to be taken in consideration.

The thesis ends with lengthy list of references relevant to this study.

In addition a number of appendices with analytical readings of samples elements is included.

1-1 Definition of Nutrition:

Nutrition is the sum total of the processes involved in the taking in and utilization of food substances by which growth, repair and maintenance of the body are accomplished.

Studies of nutrition status must take into account the state of the body before and after experiments, as well as the chemical composition of the whole diet and of all material excreted, comparing the food to the waste can help determine the specific compounds and elements absorbed and metabolized in the body.[1]

1-2 Malnutrition:

Malnutrition refers to insufficient excessive or imbalanced consumption of nutrients by an organism. In developed countries the diseases of the malnutrition are most often associated with nutritional imbalance or excessive consumption.[2]

1-3 Essential Trace Elements:

The simplest definition of the essential element is that it is an element required for life, its absence results in death or a severe malfunction of the organism.[3]-[4]

1-4 Structure of the Human Nail plate:

The human nail plate is much more complex structure than it looks at the first sight. It protects the nail bed, the part directly under the nail plate filled with blood vessels, and the nail matrix poroximal vental surface of the nail responsible for the cells profile ration and nail growth.

Although thin, the nail has 80-90 layers of dead cells.**Figure (1-1)** showed the scanning electron microscope image of human nail[5]-[6]

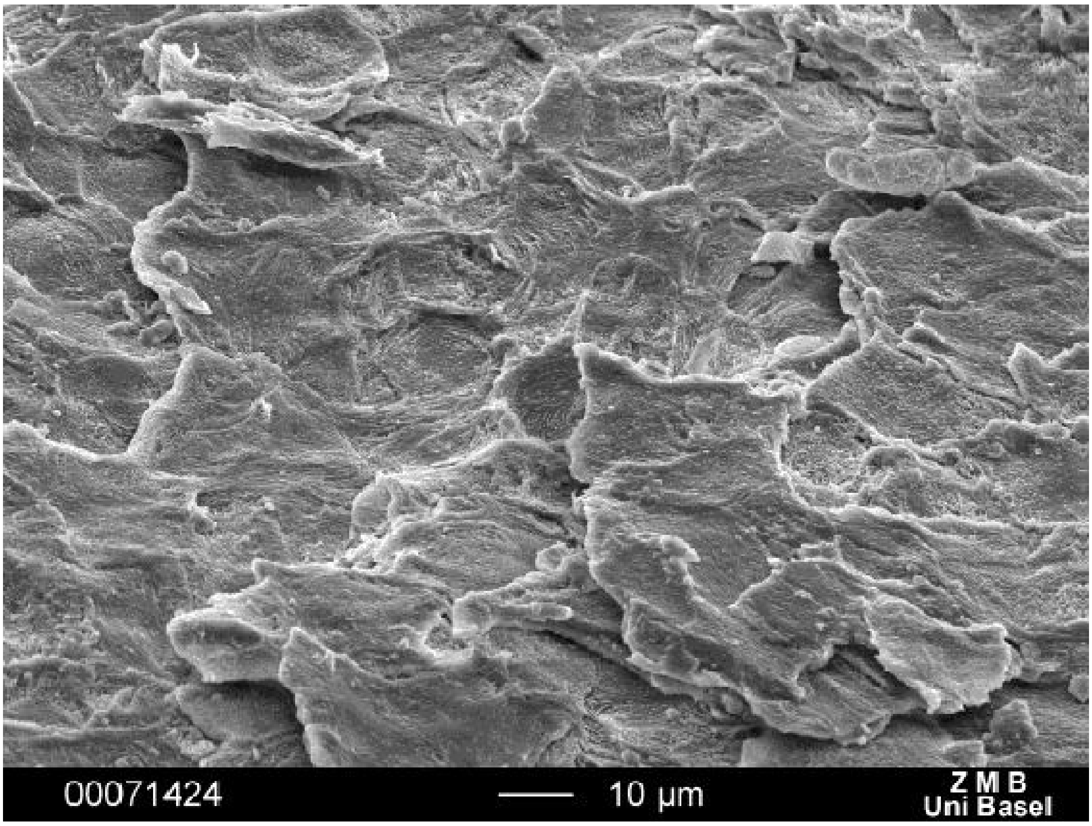


Figure (1-1): Image of the nail plate surface(scanning electron microscope (SEM) picture).

1-5 Structure of Human Hair:

The hair can be defined as a slender thread like out growth from a follicle in the skin of the mammals, composed mainly of keratin; It has three morphological regions, the cuticle, medulla and cortex.

Hair grows from the papilla it consists of a shaft that project above the skin, and a root that is imbedded in the skin. Its basic components are keratin, melanin and trace quantitative of metallic elements. These elements are deposited in the hair during its growth and /or absorbed by the hair from an external environmental factor after period of growth, the hair remains in the follicle in a resting stage to eventually be sloughed from the body **Figure (1-2)** showed the scanning electron microscope image of human hair[.[7]

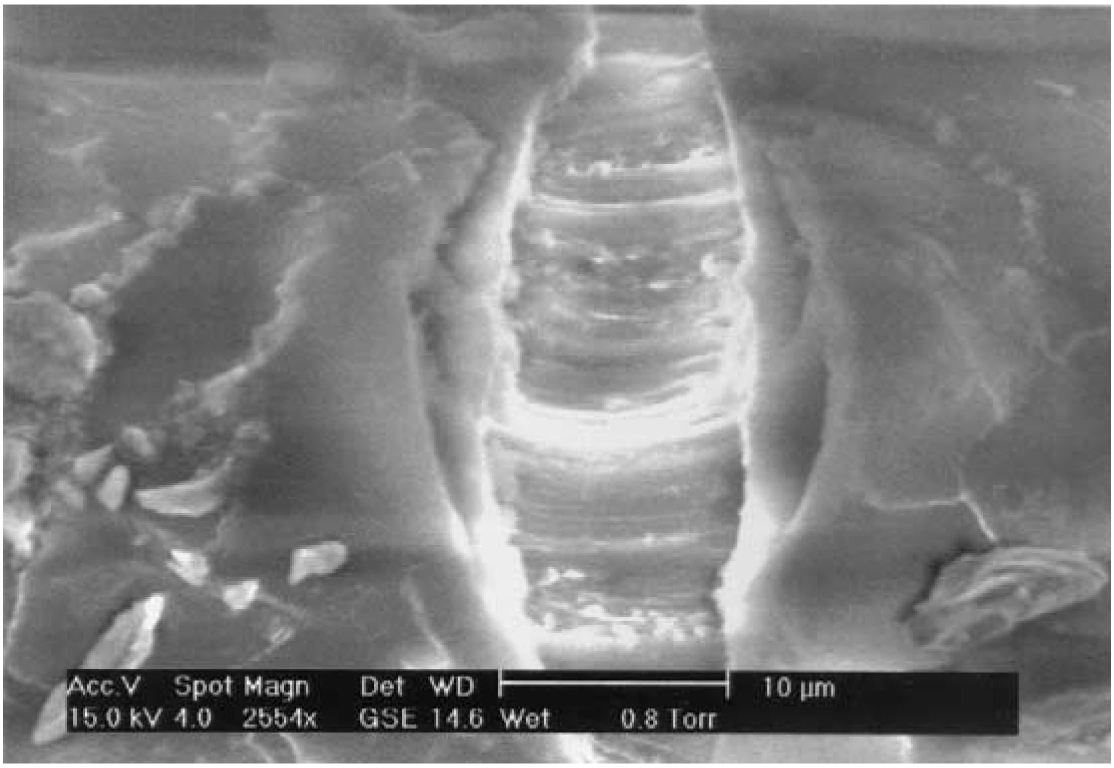


Fig (1-2) : Image of hair (scanning electron microscope (SEM) picture).

1-6 Study Area:

The state of Kaasala is located in the eastern part of Sudan, between latitudes $14^\circ\ 45^-$ and $17^\circ\ 15^-$ N, and longitudes of $34^\circ\ 40^-$ and 37° E, in an area of $42330Km^2$ in the state they are eleven localities', the study has covered the most populated localities named below in**Table (1-1).**

Table (1-1): The study area (localities)

NO	Locality	Distance from Kassala
1	Kassala town	-----
2	Refi Kassala	25 Km
3	Refi Aroma	49 Km
4	Refi Shamal Eldelta	70 Km
5	Refi Wad Elhelaw	140 Km
6	Telkok	115 Km
7	Refi Hameshkoreb	190 Km

Kassala town is the capital of the State located at latitude $15° 27^{-}$ N and longitude $36° 24^{-} E$ and at distance of $625\ Km$ from Khartoum.

Eritrean hills in east and River Nile and Red sea states in the north and Khartoum and Gedaref states in the west and south.

The Gash seasonal river which flows from June to October, divides the town into eastern and western residential areas. The area has mainly two climatic seasons, rather prolonged and generally hot (April- September) with rain fall (May- September) and a relatively short winter generally cool and dry with low humidity (November-March).

The average temperature $33℃ - 47℃$, account of population $(2{,}636{,}3000)$ (2010) [8]

Aroma town is located to the north-west to Kassala at latitude $15°\ 27^{-} N$ and longitude $36°\ 24^{-}E$ and at distance of about $70Km$ from Kassala town, climatalogical properties are the same as Kassala but it varies with a dusty climate most of the year. The others localities climate typically like Kassala.

1-7 Water Resources in Kassala State:

1-7-1 Surface water:

1. **AtbaraRiver:** flows into the main Nile at about 320 km north west wards. Its catchments lie in Ethiopia with an area of 112,460 $Km^2$and at altitude ranging from 2,500 to 3,500 meters above sea level. The tributary of the Atbara is the Setit which flows from June to December but dry for the rest of the year.
2. **Gash River**: is the main intermittent river in the state. Its catchments area is 465 km long before reaching Kassala town. The average annual flow is 483 million cubic meters. Its runoff is important for the recharging of the alluvial aquifers in the Gash Delta.

(3) **Surface runoff**: this includes sheet flow, gullies, and streams mainly along border areas. Water courses are many but small in size and carry small amount of water towards the Gash Delta. Watercourses in the district of Butana and Setit flow towards the Atbara River. The state although rich in drainage systems still loses some of runoff water to depressions and rivers. It has been therefore, planned by soil department to develop earth embankment and small dams across the seasonal streams to secure water for cultivation for forestry and range purposes.

(4) **Water ponds (Hafirs):** the hafirs represent the only appropriate water points in the areas where geologic formation and structure do not favor the presence of ground water. Most of these large Hafirs retain water for the entire dry season. The water holding capacities of all hafirs in the State is about 350 million cubic meters.

(5) **Ground water**: the ground water sources are mainly confined to Atbara River bank and Gash basin in Kassala.

1-7-2 Irrigation:

The major formations of irrigation in the State are gravity irrigation which is used in New Halfa Scheme and flush irrigation by natural flow of surface water courses (wadis) at the Gash delta. The area irrigated annually varies according to the variation in the river flow; the mean irrigated area annually is 300,000 feddans. Irrigation from ground water sources is exclusively confined to the basin of the River Gash around Kassala town.[8]

Table (1-2): Sources of Drinking Water in some Localities of Kassala

NO	Locality	Sources of Drinking Water
1	Kassala town	Artesian wells + ground water station
2	Refi Kassala	Ground water station +normal wells
3	Refi Aroma	Normal wells
4	Refi Shamal Eldelta	Hafirs +artificial recharge basin
5	Refi Wad Elhelaw	Ground water station+ sand filter
6	Telkok	Normal wells
7	Refi Hameshkoreb	Ground water station +Normal wells+ Hafirs

1-8 The Socio Profile of Kassala state:

Kassala State is a vast plain that roughly is considered the homeland of the Beja tribes, dominant group, it includes Hadundowa, BeniAmer, Bishareyen, Halanga, and the stock of arab origin and these include Shukriya, Kawahla, Lahawaien, and Rashaida as nomads, semi-nomads or settled. There are also other pastoral groups such as Kenana, Rufaa and Ambararo who move into the state from southern Gedaref during the rainy season.

Table (1-3): Food Components in some Localities of Kassala state

NO	Locality	Food Components
1	Kassala town	Sorgham,wheat,vegetables,milk,fruits,meat
2	Refi Kassala	Dura, milk, meat some times
3	Refi Aroma	Dura, milk, meat some times
4	Refi Shamal Eldelta	Dura, milk, meat some times
5	Refi Wad Elhelaw	Dura, milk, meat some times
6	Telkok	Dura, milk, meat some times
7	Refi Hameshkoreb	Dura, milk, meat some times

Figure (1-3): Sudan Map:

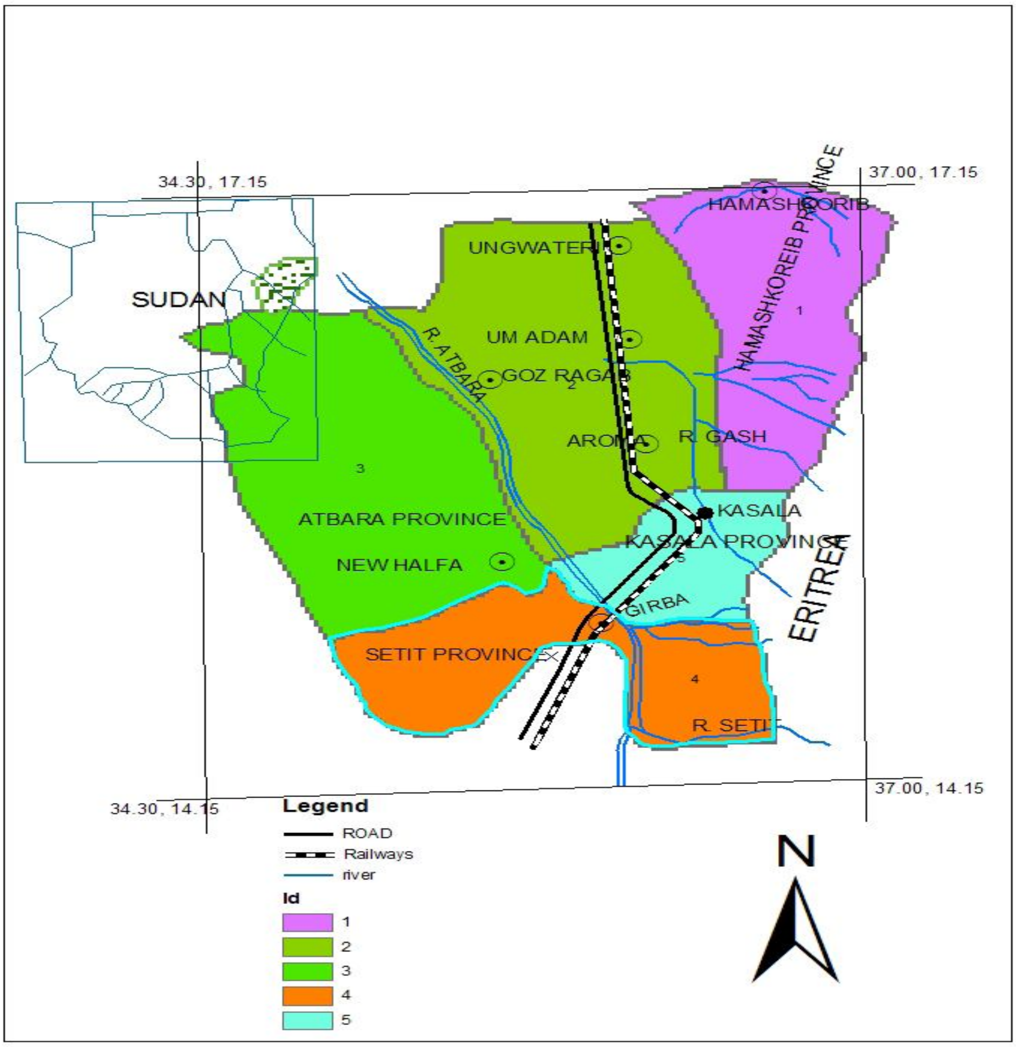


Figure (1.4): Kassala State Map

Table (1-4): Nutritional Diseases in some Localities of Kassala state

NO	Locality	Types of Nutritional Diseases
1	Kassala town	Anemia due to chronic disease(HIV-Cancer)
2	Refi Kassala	Anemia for chronic disease(HIV-Cancer)
3	Refi Aroma	Iron deficiency anemia+TB
4	Refi Shamal Eldelta	Iron deficiency anemia+TB
5	Refi Wad Elhelaw	Anemia due to chronic disease(HIV-Cancer)
6	Telkok	Iron deficiency anemia+TB
7	Refi Hameshkoreb	Nutritional anemia+TB+Sickle cell anemia

1-9 Electromagnetic spectrums:

The electromagnetic spectrum is the range of all possible frequencies of electromagnetic radiation. The "electromagnetic spectrum" of an object has a different meaning, and is instead the characteristic distribution of electromagnetic radiation emitted or absorbed by that particular object.

The electromagnetic spectrum extends from high to low frequencies used for modern radio communication to gamma radiation at the short-wavelength (high-frequency) end, thereby covering wavelengths from thousands of kilometers down to a fraction of the size of an atom. The limit for long wavelengths is the size of the universe itself, while it is thought that the short wavelength limit is in the vicinity of the Planck length, although in principle the spectrum is infinite and continuous.

Most parts of the electromagnetic spectrum are used in science for spectroscopic and other probing interactions, as ways to study and characterize matter. In addition, radiation from various parts of the spectrum has found many other uses for communications and manufacturing.[9]

The types of electromagnetic radiation are broadly classified into the following classes:

1. Gamma radiation.
2. X-ray radiation.
3. Ultraviolet radiation.
4. Visible radiation.
5. Infrared radiation.
6. Microwave radiation.
7. Radio waves.

1-10 Origin of Electromagnetic Radiation:

Visible, ultraviolet and infrared light originates from electronic transitions in atoms. Gamma rays originate from similar events in the nuclei of atoms rays may form in any of severalways but most commonly from rapid acceleration of atoms. At the other end of spectrum radio waves result from the oscillations of large numbers of charged particles.

The visible region of electromagnetic radiation extends from 0.38 to 0.78 µm. The infrared region extends from the end of the visible region at 0.78 µm to the microwave region with a wavelength of ~1mm. The infrared region is usually divided into three sections. The section used mostly by material scientist is the mid infrared region extending from 2.5 µm or 4000 cm-1 (wave number) to ~ 50 µm or 200cm^{-1}. The region between the visible and mid infrared regions is called near infrared region. This region of the infrared has been used for many applications, especially for quantitative analysis. The region beyond ~50 µm (200cm^{-1}) is called the far infrared region. This region is used for studying the low frequency vibrations and some molecular rotations.[10]

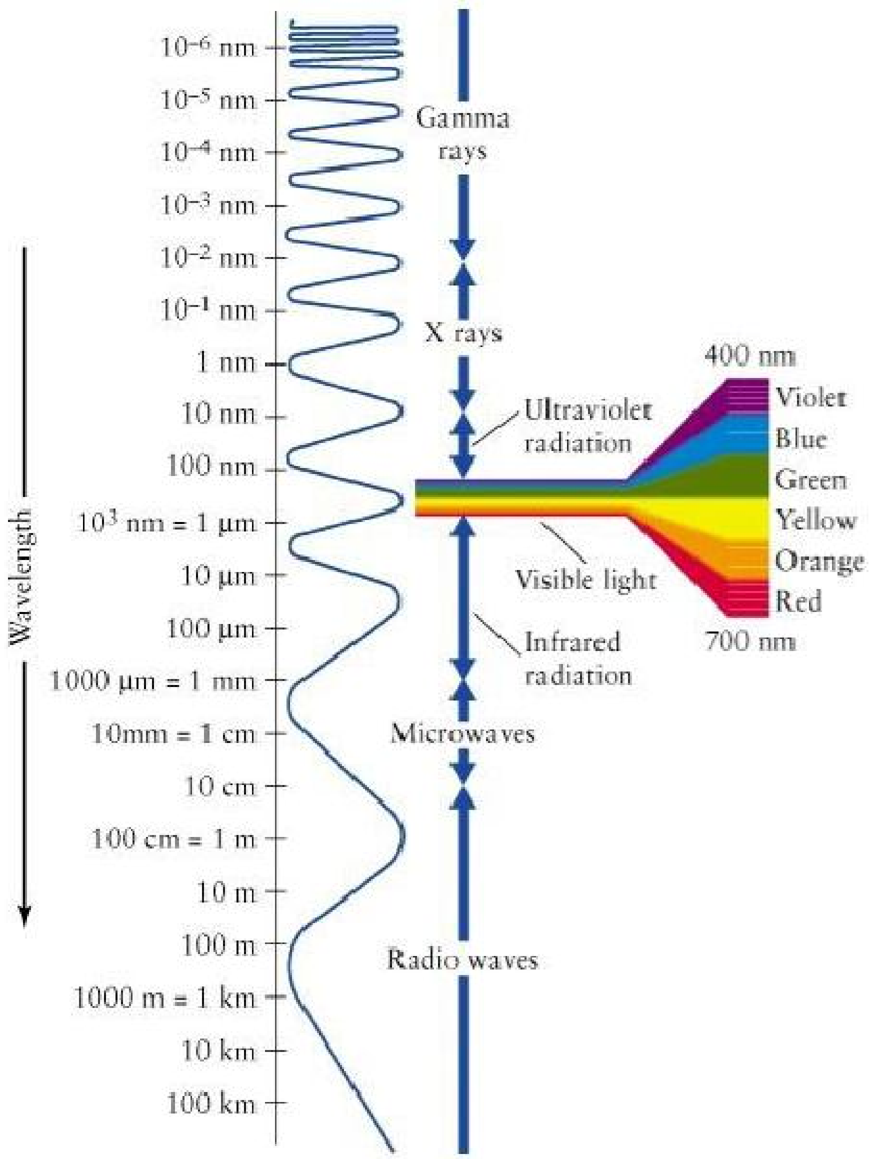


Figure (1-5): Wavelengths of the Electromagnetic Spectrum

1-11Spectrum Management:

Because spectrum is an international commodity it is controlled by international agreement. The ITU (International Telecommunications Union) is the United Nations organization which coordinates the allocation of frequencies to the activities which use them (e.g satellite communications, and radar systems).

ITU organizes and World Radio communication Conferences (WRC) every two to three years modify the frequency allotments as required (or requested).The low end of spectrum is very congested and so to get more bandwidth is necessary to use higher frequencies

1-12 Basic Theory:

When light interacts with matter, the photons which make up the light may be absorbed or scattered, or may not interacts with the materials and may be pass straight through it. If the energy of an incident photon corresponds to the energy gap between the ground state of molecule and an excited state, the photon may be absorbed and the molecule promoted to the higher energy excited state. It is this change which is measured in absorption spectroscopy by the detection of the loss of that energy of radiation from light.

However it also possible from the photon to interact with the molecule and scatter from it. In this case there is no need for the photon to have an energy which matches the difference between two energy levels of the molecule. The scattered photons can be observed by collecting light at an angle to the incident light beam provided there is no absorption from any electronic transitions which have similar energies to that of incident light.[11]-[12]

1-13 Definition of Spectroscopy:

Spectroscopy and spectrograph are terms used to refer to the measurement of radiation intensity as a function of wave length and are used to describe experimental spectroscopic methods. Spectral measurements devices are referred to as spectrometers spectrophoton meters, spectrograph or spectral analyzers.

Spectroscopy is a sufficiently broad field that many sub disciplines exist, each with numerous implementations of specific spectroscopic techniques. The various implementations and techniques can be classified in several ways, other types of spectroscopy are distinguished by specific application.[13]

1-14 Objectives of Study:

This study aims to:

(1) Contribute to human nutrition study through spectroscopic analysis of hair and nails in the population of Kassala State.

(2) Determine the elements composition of human nails substance and to provide data for long term losses of the nutrient.

(3) Determine the elements composition of human hair substance and to provide data for long term losses of the nutrient.

(4) The analysis of finger nail and hair has been useful in the study of trace metals accumulation in the body.

(5) Assess information on the relationship between exposure to an environmental pollutant and human body health .

(6) Consider a part of human nutrition as base line in information in Kassala.

(7) Provide information for the benefit for people and authorities in Kassala State, for the promotion of health performance

(8) Assess the relation between the decrease of elements in nutrition and diseases in the area.

CHAPTER (II)

Theoretical Background

2-1 Introduction:

In this chapter a brief theoretical background about some physics concepts like photons and energy, interaction of electromagnetic wave with matter, Maxwell's questions , electromagnetic waves in free space and conductors ,vibrating atoms and electrons in the presence of electric and magnetic fields, atomic structure and spectroscopy.

2-2 Photons and Energy:

In the 16th and 17th centuries, early in the modern study of light there was a great controversy about light nature. Some thought that light is made up of waves while others thought that is a collection of particles. Both concepts explained some of the behavior of light, but not all. It was finally determined that light is made up of particles called "photons" which exhibit both particle like and wave-like properties. Each photon has as intrinsic energy determined by the equation.[14]

$$\boldsymbol{E = h\upsilon ------(2-1)}$$

Where (υ) is the frequency of the light and (h) is called Planck's constant. Since for a wave, the frequency and wave length are related by the equation

$$\boldsymbol{\lambda\upsilon = c} \text{ ----------------- } \mathbf{(2\text{-}2)}$$

Where λ is the wave length of the light and c is the speed of light in a vacuum .This can be written as

$$\boldsymbol{E = h\, c\backslash\lambda} \text{ -------------- } \mathbf{(2\text{-}3)}$$

It is evident from this equation that the longer the wave length of light, the lower the energy of the photon, consequently ultra violet is much more "energetic" than infrared light.

For the light energy to cause an electron to move a higher energy state E_m the energy of a single photon must equal, almost exactly the energy difference between the two states (the Bohr atom model).Consequently the wave length of that photon must be:

$$\boldsymbol{\lambda} = (\boldsymbol{h}\,\boldsymbol{c})/\Delta\boldsymbol{E} \text{----------------------- } \textbf{(2-4)}$$

Where $\Delta E = E_m - E_N$ .Likewise, when electron decays to a lower energy level in a radioactive transition, the photon of light given off, emitted by the atom must also have energy equal to the energy difference between the two states.[15]

2-3 Interaction of Electromagnetic Waves with matter:

In electromagnetic wave, Maxwell's equations constitute of four equations, compiled by James Clerk Maxwell, that describe the behavior of the electric and magnetic fields, as well as their interactions with matter.

Maxwell's four equations express respectively how electric charges produced electric fields (Gauss's law), how currents and changing electric fields produce magnetic fields (Amperes' law) and how changing magnetic fields produce electric field (Faradays law of induction).

2-4 Maxwell's equations:

The modern mathematical formulation of Maxwell equation is due to Heaviside and Willard Gibbs who in 1884 reformulated Maxwell's original system of equations to a far simpler representation using vector calculus.

$$\boldsymbol{\nabla} \times \boldsymbol{B} = \varepsilon_\circ \frac{\partial \boldsymbol{E}}{\partial t}$$

$$\boldsymbol{\nabla} \times \boldsymbol{E} = -\mu_\circ \frac{\partial \boldsymbol{B}}{\partial t}$$

$$\boldsymbol{\nabla}.\boldsymbol{E} = 0$$

$$\boldsymbol{\nabla}.\boldsymbol{B} = 0$$

$$\boldsymbol{\nabla}.\boldsymbol{D} = \rho$$

$$\boldsymbol{J} = \sigma\boldsymbol{E}$$

$$\boldsymbol{D} = \varepsilon\mathbf{E} \qquad ,\boldsymbol{B} = \mu\boldsymbol{H} \qquad \text{-------- } \textbf{(2-5)}$$

Where $\boldsymbol{B}, \boldsymbol{D}, \boldsymbol{H}, \boldsymbol{E}, \varepsilon, \mu$ and ρ

Stands for the magnetic flux density, electric flux density , magnetic field intensity, electric field intensity , electric permittivity,magnetic permeability and electric charge density respectively.

2-5 Polarization and susceptibility:

The electromagnetic wave in any medium can be described by

$$\boldsymbol{E = E_\circ e^{i(kz-\omega t)} - - - - - (2-6)}$$

Where k is the wave number and z the direction,ω the frequency and t the time.

In any polarization material the polarization vector P takes the form

$\boldsymbol{P = \varepsilon_\circ \chi E}$--------------- **(2-7)**

And the electric flux density assumes the following relation

$\boldsymbol{D = \varepsilon E = \varepsilon_\circ(1 + \chi)E = \varepsilon_\circ E + P}$ ---------------- **(2-8)**

Where χ is the susceptibility.

Hence the electric permittivity **ε** is given by

$\boldsymbol{\varepsilon = \varepsilon_\circ(1 + \chi)}$ ---------------- **(2-9)**

If it happens that the electric dipole subtends an angle ⍰ w.r.t the external field E, the electric susceptibility can thus be written as a complex quantity, i.e $p = \boldsymbol{\chi E = (\chi_1 + i\chi_2)E}$ -------------------------- **(2-10)**

Thus ε can also be written as:

$\boldsymbol{\varepsilon_1 + i\varepsilon_2 = \varepsilon_\circ + \varepsilon_\circ(\chi_1 + \chi_2)}$ ---------------------- **(2-11)**

The refractive index n can in turn become a complex quantity.

$$\boldsymbol{n = n_1 + in_2 = \frac{c}{v} = c\sqrt{\mu\varepsilon}}$$

$\boldsymbol{n_1{}^2 - n_2{}^2 + 2n_1n_2i = c^2\varepsilon}\mu$ ------------------------ **(2-12)**

As a result $\boldsymbol{n_1{}^2 - n_2{}^2 + 2n_1n_2i = c^2}\mu\boldsymbol{(\varepsilon_1 + i\varepsilon_2)}$

$$\boldsymbol{n_1{}^2 - n_2{}^2 = c^2}\mu\boldsymbol{\varepsilon_1 = c^2}\mu\boldsymbol{\varepsilon_0\,(1 + \chi_1)}$$

$\boldsymbol{2n_1n_2 = c^2}\mu\boldsymbol{\varepsilon_2 = c^2}\mu\boldsymbol{\varepsilon_0\chi_2}$ ---------------------------- **(2-13)**

Bearing in mind that the wave number k is giving by

$$k = \frac{2\Pi}{\lambda} = \frac{2\Pi f}{v} = n\frac{\omega}{c} \quad \text{------------------------------ (2-14)}$$

$$K_1 + iK_2 = \frac{\omega}{c}\,(n_1 + in_2) \quad \text{-------------------------- (2-15)}$$

Utilizing **(2-11) ,(2-13)** and **(2-15)** one gets

$$K_1 = \frac{\omega}{c}n_1\,,\ K_2 = \frac{\omega}{c}n_2\,, K_2 = \frac{2\Pi\mu\omega}{n_1}\,\chi_2 ------(2-16)$$

2-6 Electromagnetic Wave in Free Space:

In side matter but in regions where there is no free charge or free current

Maxwell's equations become.

$$(i)\nabla.D = 0 \qquad (ii)\nabla \times E = -\frac{\partial B}{\partial t}$$

$$(iii)\nabla.B = 0 \qquad (iv)\ \nabla \times H = \frac{\partial D}{\partial t} \quad \text{------------------------- (2-17)}$$

If the medium is linear

$$D = \varepsilon_0 E\ ,\ H = \frac{1}{\mu_0}\,B \quad \text{--------------------------------- (2-18)}$$

In homogeneous case ε and μ not vary from point to point then Maxwell's equations reduce to

$$(i)\nabla.E = 0 \qquad (ii)\ \nabla\ \times B = \mu\varepsilon\frac{\partial E}{\partial t} \text{----------------------- (2-19)}$$

When replacing μ_0 , ε_0 by μ , ε this equation describes matter instead of homogeneous medium at a speed

$$V = \frac{1}{\sqrt{\mu\varepsilon}} = \frac{c}{n} \quad \text{--------------------------- (2-20)}$$

Where n is the index of refraction of the material. Therefore the index of refraction obtained by

$$n \equiv \sqrt{\frac{\varepsilon\mu}{\varepsilon_0\mu_0}} \quad \text{------------------------- (2-21)}$$

For most materials μ is very close to μ_0 so

$$\boldsymbol{n \cong \sqrt{\varepsilon_r}} \text{ ---------------------------- } \textbf{(2-22)}$$

Where ε_r is the relative dielectric constant

$$\boldsymbol{(\varepsilon_r = 1 + \chi_0 = \frac{\varepsilon}{\varepsilon_0})} \text{ ------------------ } \textbf{(2-23)}$$

Since ε_r is almost always greater than 1, as a result light more slowly through the matter, a fact that is well known from optics.

Equation **(2-19)** constitute a set of coupled first order, partial deferential equations for $E \ and \ B$ they can be decoupled by a applying the curl to (iii) and (iv) to get

$$\boldsymbol{\nabla \times (\nabla \times E) = \nabla(\nabla . E) - \nabla^2 E = \nabla \times \left(-\frac{\partial B}{\partial t}\right) = -\frac{\partial}{\partial t}(\nabla \times B) = -\mu_0 \varepsilon_0 \frac{\partial^2 E}{\partial t^2}}$$

$$\boldsymbol{\nabla \times (\nabla \times B) = \nabla(\nabla . B) - \nabla^2 B = \nabla \times \left[\varepsilon_0 \mu_0 \frac{\partial E}{\partial t}\right] = \mu_0 \varepsilon_0 \frac{\partial y}{\partial x}(\nabla \times E) = -\mu_0 \varepsilon_0 \frac{\partial^2 B}{\partial t^2}}$$

$$\boldsymbol{\nabla^2 E = \mu_0 \varepsilon_0 \frac{\partial^2 E}{\partial t^2} \quad , \quad \nabla^2 B = \mu_0 \varepsilon_0 \frac{\partial^2 B}{\partial t^2}} \text{ ---------------------- } \textbf{(2-24)}$$

This is the wave equation of E.M field

Equation **(2-24)** describe**s** the dynamic of electromagnetic fields in dielectric media vaccum.[16]

2-7 Solution of Electromagnetic Waves in Free Space:

One may pay attention to sinusoidal wave of frequency ω .Since different frequencies in the visible range correspond to different colors; such wave having single frequency is called monochromatic. Suppose, moreover, that the waves are traveling in Z direction inside matter and no X or Y dependence, this are called plane waves because the field are uniform over every plane perpendicular to the direction of propagation

One is interested, then in the field of form

$$\boldsymbol{E(z,t) = E_0 e^{i(KZ-\omega t)}} \ , \ \boldsymbol{H(z,t) = H_0 e^{i(KZ-\omega t)}} \text{ --------------- } \textbf{(2-25)}$$

Which are solutions of equations in **(2-24)** .

2-8 Energy and Momentum in Electromagnetic Waves:

The energy per unit volume stored in electromagnetic fields is:

$\boldsymbol{u} = \frac{1}{2}\left[\boldsymbol{\varepsilon E^2} + \frac{1}{\mu}\boldsymbol{B^2}\right]$ **-------------------------------------- (2-26)**

In the case of monochromatic plane wave

$\boldsymbol{B^2} = \frac{1}{V^2}\boldsymbol{E^2} = \mu\boldsymbol{E^2\varepsilon}$ **-------------------------------- (2-27)**

So the electric and magnetic contributions are equal

$\boldsymbol{u} = \frac{\varepsilon E^2}{2} = \frac{\varepsilon E^2}{2}\cos^2(kz - ab + \boldsymbol{S})$ **-------------------- (2-28)**

As the wave travels it carries this energy along with it. The energy flux density (energy per unit area, per unit time) transposed by the fields is giving by the Pointing vector

$\boldsymbol{S} = \frac{1}{\mu}(\boldsymbol{E} \times \boldsymbol{B})$ **----------------------------------- (2-29)**

For monochromatic plane waves propagating in the Z direction.

$\boldsymbol{S} = (\boldsymbol{\varepsilon_0 E^2}\cos^2(kz - \omega t + \delta)Z^{\sim}$ **----------------------- (2-30)**

2-9 Electromagnetic Waves in Conductors:

So far one can assume that the charge density $\rho_f$and the free current density J_f are zero and every thing that follows was predicted on that assumption. But in the case of conductors one does not independently have the control of the flow of charge and in general J_e in certainly not zero .In fact according to Ohms law the (free) current density in a conductor is proportional to the electric field.

$\boldsymbol{J_f} = \boldsymbol{\sigma E}$ **------------------------------------ (2-31)**

With this Maxwell's equations for linear media assume the form

$(\boldsymbol{i})\ \boldsymbol{\nabla . E} = \frac{1}{\varepsilon}\boldsymbol{\rho_f}$, $(\boldsymbol{ii})\ \boldsymbol{\nabla \times B} = \mu\boldsymbol{\varepsilon_0}\frac{\partial \boldsymbol{E}}{\partial t} + \mu\frac{\partial \rho}{\partial t}$ **------------------- (2-32)**

Now the continuity equation for free charge takes the form

$\boldsymbol{\nabla . J_f} = -\frac{\partial \rho_f}{\partial t}$ **--------------------- (2-33)**

Together with Ohm's law and Gauss's law (i) one obtains

$\frac{\partial \rho_f}{\partial t} = -\sigma(\nabla . E) = -\frac{\sigma}{\varepsilon}\rho_f$---------------------- **(2-34)**

The solution of this equation for homogeneous linear medium is given to be $\rho_f(t) = e^{-\left(\frac{\sigma}{\varepsilon}\right)t} . \rho_f(0)$ ------------------------------ **(2-35)**

Thus any initial free charge density $\rho_f(0)$ dissipates a characteristic time $\tau = \frac{\varepsilon}{\sigma}$ .Thus reflects the familiar fact that if one put some free charge on a conductor; it will flow out to the edges. The constant τ affords a measure of how "good" a conductor for "a perfect" conductor $\sigma = \infty$

and $\tau = 0$ for "a good " conductor τ is much less than the other relevant times in the problem (in oscillatory systems that means $\ll \frac{1}{\omega}$); for "a poor" conductor t is greater than the characteristic times in a good conductor for $\rho = 0$ and for a medium of a good conductivity relation **(2-32)** together with **(2-6)** and **(2-8)** yield

$\nabla \times B = \mu\varepsilon_0 \frac{\partial E}{\partial t} + \frac{\partial \rho}{\partial t} + \mu\sigma E$ -------------------------- **(2-36)**

These differ from the corresponding equations for free space eq **(2-19)** only in addition of the last term in (iv).Applying the curl to (iii) and (iv) and having in mind equation **(2-24)** one obtains modified wave equation for $E$and B in the form

$$\nabla E^2 = \mu\varepsilon_0 \frac{\partial^2 E}{\partial t^2} + \mu\sigma \frac{\partial E}{\partial t} + \mu \frac{\partial^2 \rho}{\partial t^2} + \mu\varepsilon \frac{\partial^2 E}{\partial t^2}$$

$$\nabla B^2 = \mu\varepsilon \frac{\partial^2 B}{\partial t^2} + \mu\sigma \frac{\partial B}{\partial t} \text{ ------------------------------ } \textbf{(2-37)}$$

These equations still admit plane –wave solutions in the form

$E^{\rightarrow}(z,t) = E_0 e^{i(kz-\omega t)}$, $B^{\rightarrow}(z,t) = B_0 e^{i(kz-\omega t)}$ --------------- **(2-38)**

But this time the "wave number $k^{\sim}$ is complex identity **(2-37)** in **(2-36)**

Yield $k^{\sim 2} = \mu\varepsilon\omega^2 + i\mu\sigma\omega$ -------------------------- **(2-39)**

Thus $k^{\sim}$ can written as a complex quantity in the form

$k^{\sim} = k_1 + ik_2$ ------------------------------------- **(2-40)**

Where

$$\boldsymbol{K_1} \equiv \boldsymbol{\omega}\sqrt{\frac{\varepsilon\mu}{2}}\left[\left[\sqrt{\mathbf{1} + \left[\frac{\sigma}{\varepsilon\omega}\right]^{2}} + \mathbf{1}\right]^{\frac{1}{2}}\right]$$

$$\boldsymbol{K_2} \equiv \boldsymbol{\omega}\sqrt{\frac{\varepsilon\mu}{2}}\left[\left[\sqrt{\mathbf{1} + \left[\frac{\sigma}{\varepsilon\omega}\right]^{2}} - \mathbf{1}\right]^{\frac{1}{2}}\right] \text{ ---------------------------- } \mathbf{(2\text{-}41)}$$

The imaginary part of $k^{\sim}$ results in attenuation of the wave (decreasing amplitude with increasing Z):

$$\boldsymbol{E}^{\rightarrow}(\mathbf{z,t}) = \mathbf{E_0 e^{-k_2 Z} e^{i(kZ-\omega t)}}, \quad \mathbf{B^{\rightarrow}(z,t) = B_0 e^{-k_2 Z} e^{i(K_1 Z-\omega t)}} \text{ -- } \mathbf{(2\text{-}42)}$$

It is a measure of how far the wave penetrates into the conductor.

Mean while the real part of $k^{\sim}$ determines the wave length, the propagation speed, and the index of refraction, in the usual way

$$\boldsymbol{\lambda} = \frac{\boldsymbol{2\Pi}}{\boldsymbol{K_1}} \quad , \quad \boldsymbol{v} = \frac{\boldsymbol{\omega}}{\boldsymbol{K_1}} \quad , \quad \boldsymbol{c} = \frac{\boldsymbol{K_1}}{\boldsymbol{\omega}} \text{ ------------------- } \mathbf{(2\text{-}43)}$$

The attenuated plane waves **(2-38)** satisfy the modified wave equation eq **(2-38)** for any E_0 *and* B_0 but Maxwell's equations **(2-36)** inpose further constrain which serve to determine the relative amplitudes phases and polarizations of E *and* B .As before (i)*and* (ii) rule out any Z components: the field are transverse one way as well oriented its axes so that E is polarized along the X direction.[17]

$$\boldsymbol{E}^{\rightarrow}(\mathbf{z,t}) = \mathbf{E_0 e^{-kZ} e^{i(k_1 Z-\omega t)}}\, \boldsymbol{X}^{\sim} \text{ ---------------------------- } \mathbf{(2\text{-}44)}$$

$$\mathbf{B^{\rightarrow}(z,t) = E_0 \frac{K^{\sim}}{\omega} e^{-K_2 Z} e^{i(K_1 Z-\omega t)} Y^{\sim}} \text{ -------------------------- } \mathbf{(2\text{-}45)}$$

Once again the electric and magnetic fields are mutually perpendicular .Like any complex number, $K^{\sim}$ can expressed in terms of modulus and phase

$k^{\sim} = ke^{i\theta}$ -- **(2-46)**

Where the complex number $K^{\sim}$ is given as

$\boldsymbol{K^{\sim} \equiv \|K^{\sim}\| = \sqrt{K_1 + K_2} = \omega + \sqrt{\varepsilon\mu\sqrt{1 + \left[\frac{\sigma}{\varepsilon\omega}\right]^2}}}$ ----------------- **(2-47)**

Therefore the phase angle is $\boldsymbol{\Phi = \tan^{-1}\left[\frac{K_2}{K_1}\right]}$ ---------------------- (**2-48)**

According to equation **(2-44)** and equation **(2-45)** the complex amplitudes of

$\boldsymbol{E_0{}^{\sim} = E_0 e^{i\delta E}\ and\ B^{\sim}{}_0 = B_0 e^{i\delta E}}$ are related by

$\boldsymbol{B_0 e^{i\delta E} = K\frac{e^{i\Phi}}{\omega} E_0 e^{i\delta E}}$ ----------------------------------- **(2-49)**

Evidently the electric and magnetic fields are no longer in phase, then

$\boldsymbol{\delta_B - \delta_E = \Phi}$ ---------------------- **(2-50)**

In this case the magnetic field lags behind the electric field, mean while, the real amplitudes of $E\ and\ B$ obtained as

$\boldsymbol{\frac{B_0}{E_0} = \frac{K}{\omega} = \sqrt{\varepsilon\mu\sqrt{1 + \left[\frac{\sigma}{\varepsilon\omega}\right]^2}}}$ ----------------------------------- **(2-51)**

Therefore the real electric and magnetic fields are finally given by

$\boldsymbol{E(z, t) = E_0 e^{-K_2 Z}\cos(K_1 Z - \omega t + \delta E)\, X^{\sim}}$

$\boldsymbol{B(z, t) = B_0 e^{-K_2 Z}\cos(K_1 Z - \omega t + \delta E + \Phi)\, Y^{\sim}}$ ---------------- **(2-52)**

2-10 Vibrating atoms and electrons in the presence of electric and magnetic field:

Ionized atoms emit radiation according to the electromagnetic theory. As accelerated and oscillated charged particles emit electromagnetic radiation, two cases are considered here;

The first case concerns with ionic crystals vibrations while the second one concerns the free electron vibrations.

When ions in a crystal is vibrating the equation of motion of ions in the presence of oscillating electric field at a constant magnetic field takes the form;

$\boldsymbol{m\ddot{u}_n = -c(2u_n - u_{n-1} - u_{n+1}) + eE + Be\dot{u}_n}$ ------------ **(2-53)**

$$m\ddot{u}_{n+1} = -c(2u_{n+1} - u_n - u_{n+2}) + eE + Be\dot{u}_{n+1} \text{ ------------- } \mathbf{(2\text{-}54)}$$

Where

$$E = E_0 e^{i\omega t}\,,\ \ u_n = u_{0n} e^{i\omega t} e^{iKna} \text{ ------------------------- } \mathbf{(2\text{-}55)}$$

For insulator medium the solution of this equation requires

$$\chi_2 = \frac{\beta_1 n_0 e^2}{({\alpha_1}^2 + {\beta_1}^2)} + \frac{\beta_2 n_0 e^2}{({\alpha_1}^2 + {\beta_1}^2)} \text{ ------------------------------------- } \mathbf{(2\text{-}56)}$$

With $\beta_1 = \beta_2 = e\omega\beta$ --------------------------------------- **(2-57)**

The gain coefficient is given according to the relation below

$$\beta = \alpha^2\chi = \left(\frac{mk}{\hbar^2}\right)^{\frac{1}{2}}\chi = \frac{\sqrt{m}}{\hbar}\left(\frac{\frac{mv_0 - eE_0 - F_O}{2}}{\chi_0}\right)^{\frac{1}{2}} \times \beta = -\frac{\varepsilon_0\omega\mu\chi_0}{n_1} \text{ --------- } \mathbf{(2\text{-}58)}$$

In view of equations **(2-57)** and **(2-58)** amplification takes place when

$$\chi_2 = - \ ,\ \beta_1 = e\omega\beta = -e\omega\|\beta\| \text{ -------------------------------- } \mathbf{(2\text{-}59)}$$

I.e when the magnetic field B is oriented in such a way that the force exerated by it opposes that exerated by the electric field.

In this case $\beta = -|\beta|$, $\chi_2 = -$, $\beta = +$ ---------------- **(2-60)**

Laser can also be induced by vibrating electron in a resistive medium with aid of oscillating electric field E and constant magnetic field B.

With effect of all these forces the equation of motion of electron is given by

$$m\frac{\partial v}{\partial t} = eE + Bev - \frac{mv}{\tau} \text{ --------------------------------- } \mathbf{(2\text{-}61)}$$

Where

$$E = E_0 e^{i\omega t} \text{ -- } \mathbf{(2\text{-}62)}$$

For conductor medium the solution of **(2-61)** requires

$$\chi_2 = \frac{-n_0 e^2 \beta_3}{({\alpha_3}^2 + {\beta_3}^2)} \text{ -- } \mathbf{(2\text{-}63)}$$

$\boldsymbol{\alpha_3 = -\omega^l m}$, $\boldsymbol{\beta_3 = \omega\left(\frac{m}{\tau} - \beta e\right)}$ ------------------------ **(2-64)**

In view of eq **(2-58)** , **(2-64)** and the equation **(2-65)** below

$\boldsymbol{m > \beta e\tau}$, $\boldsymbol{\frac{mv}{\tau} > \beta ev}$, $\boldsymbol{F_r > F_m}$ --------------------- **(2-65)**

Lasing takes places when

$\chi_2 = -$, $\beta_3 = \pm$, $\frac{m}{\tau} - \beta e > 0$ --------------------- **(2-66)**

$\boldsymbol{\frac{mv}{\tau} > ev\beta}$, $\boldsymbol{F_r > F_m}$ --------------------------- **(2-67)**

Again the condition of amplification requires the resistive force to be large.

2-11Amplification due to Photon Perturbation:

The photon wave function can be obtained by using the relativistic relation

$\boldsymbol{E^2 = P^2C^2 + {m_0}^2C^4}$ ----------------------------------- **(2-68)**

Since the photon rest mass vanishes it follows that

$\boldsymbol{m_0 = 0}$, $\boldsymbol{E = PC}$ --------------------------- **(2-69)**

The operator for $E \text{ and } P$ can be obtained again from the relation

$\boldsymbol{\Psi = Ae^{\frac{i}{\hbar}(PX-Et)}}$ ------------------------------ **(2-70)**

Where

$\boldsymbol{i\hbar\frac{\partial\Psi}{\partial t} = E\Psi}$, $\boldsymbol{\frac{\hbar}{i}\nabla\Psi = P\Psi}$ ----------------------- **(2-71)**

Thus the free photon wave function is given according to **(2-69)** and

(2-67) by

$\boldsymbol{i\hbar\frac{\partial\Psi}{\partial t} = \frac{\hbar}{i}c\nabla\Psi}$ ------------------------------ **(2-72)**

To check that this equation describe the photon consider the solution

$\boldsymbol{\Psi = Ae^{\frac{i}{\hbar}(PX-Et)}}$---------------------- **(2-73)**

With $\boldsymbol{P = \frac{h}{\lambda} = \frac{h}{2\Pi}\frac{2\Pi}{\lambda} = \hbar K}$ -- **(2-74)**

Substituting **(2-73)** in **(2-72)** with aid of **(2-74)** yields

$\boldsymbol{i\hbar\left[\frac{-iE}{\hbar}\right]\Psi = \frac{\hbar c}{i}\left(\frac{i}{\hbar}P\Psi\right)}$ ------------------------------------- **(2-75)**

$\boldsymbol{E\Psi = PC\Psi = \frac{h}{\lambda}C = hf\Psi}$, $\boldsymbol{hence\ E = hf}$ -------------------- **(2-76)**

This ordinary expression of the photon energy, thus expression **(2-70)**

Stands for the wave function of the photon . To see how the photon wave function look like with in a medium one can recall Doppler effect and Compton effects which shoe the photon frequency is affected by the motion of radiation source beside the fields and oscillation.

Equation **(2-72)** can be made time dependent by making the substitution

$\boldsymbol{\Psi = e^{\frac{iEt}{\hbar}}u}$ --------------------------------------- **(2-77)**

In equation **(2-72)** to get $\boldsymbol{Eu = i\alpha u}$ ----------------------- **(2-78)**

The solution of this in one dimensional space takes the form

$\boldsymbol{u = Ae^{i\alpha X}}$, $\boldsymbol{\nabla u = i\alpha u}$ ------------------------------ **(2-79)**

Hence $\boldsymbol{\frac{iE}{\hbar C} = \nabla u = i\alpha u \quad thus}$, $\boldsymbol{\alpha = \frac{E}{\hbar c}}$ we obtain

$\boldsymbol{u = Ae^{\frac{iEX}{\hbar c}}}$ -- **(2-80)**

Since $E = \hbar\omega$ it follows that the photon wave function becomes

$\boldsymbol{u = Ae^{iX\frac{\omega}{c}}}$ --- **(2-81)**

One can assume that the frequency of the oscillating polarized atoms is the same as the frequency of the photon, as suggested by harmonic oscillator solution of Schrodinger equation and proposed by classical electromagnetic theory. In this case the frequency of the photon can be found from the equation of the classical harmonic oscillator in which polarized field acts on electronic, i.e

$\boldsymbol{F = eC_0E = -eE = e(C_0 - 1)E_0e^{i\omega t} = \left[e\,\frac{(C_{0-1})}{X_0}\right]X_0e^{i\omega t} =}$
$\boldsymbol{[e(C_0 - 1)]E_0X = -KX}$ ------------------------------------- **(2-82)**

$$F = -m\omega^2 X \quad \text{-- (2-83)}$$

Thus form $K = \left(\frac{(1-C_0)}{X_0}E_0 = m\omega^2\right)$ the photon frequency is given by

$$\omega = \pm\sqrt{\frac{(1-C_0)}{X_0 m}}E_0 \quad \text{-- (2-84)}$$

In the case when $C_0 > 1$

$$\omega = \pm\sqrt{\frac{(1-C_0)}{X_0 m}}E_0 = \pm i\omega \quad , \omega_0 = \pm\sqrt{\frac{(C_0-1)}{X_0 m}}E_0 \text{ -------------------- (2-85)}$$

As a result equation **(2-81)**

$$u = Ae^{\pm\frac{\omega_0}{c}X} \text{ -- (2-86)}$$

Since the intensity of radiation is

$$I = hf\rho c|C|^2 = hfcAe^{\pm\frac{\omega_0}{c}X} = I_0 e^{\beta X} \text{ --------------------------- (2-87)}$$

$$I = I_0 e^{\frac{2\omega_0}{c}X} = I_0 e^{\beta X} \text{ -- (2-88)}$$

In view of **(2-85)** lasing is possible when

$$\beta = \frac{2\omega_0}{C} = \frac{2}{C}\sqrt{\frac{(1-C_0)}{X_0 m}}E_0 \text{ ------------------------------------ (2-89)}$$

This requires the polarization field E to exceed the external field

$$\omega_O > 0 \ , \quad C_0E_0 > E_0 \ , \quad P_0 = C_0E_0 > E_0 \text{ ----------------- (2-90)}$$

This not surprising as far as the polarization field reflect the number of photon emitted by the medium i.e

$$n_m = |C_0E_0|^2 \text{ --- (2-91)}$$

This called exceed the incident photons

$$n_2 = |E_0|^2 \text{ -- (2-92)}$$

Where equation **(2-90)**

Requires $|C_0E_0| > |E_0|^2$ one find $n_m > n_i$ ----------------------- **(2-93)**

2-12 The Energy Exchange Relation:

When the electromagnetic field passes through a medium it exchange energy and momentum with the medium. This causes the wave length, frequency and amplitude to change.

To see how the medium change the frequency and the energy of electromagnetic waves, can solve the equation of Maxwell.

$-\nabla^2 E + \mu\sigma\frac{\partial E}{\partial t} + \mu\varepsilon_T\frac{\partial y}{\partial x} = 0$ -- **(2-94)**

Where $\varepsilon_T = (\varepsilon + \chi)$ .The solution of this equation is

$E = E_0 e^{i(KX-\omega t)}$--- **(2-95)**

$\frac{\partial^2 E}{\partial x^2} = -K^2 E$, $\frac{\partial E}{\partial x} = iKE$, $\frac{\partial y}{\partial x} = -i\omega E$ $\;$ *and* $\frac{\partial^2 E}{\partial t^2} = -\omega^2 E$ ----- **(2-96)**

Utilizing equation **(2-94)** in equation **(2-96)** yields

$\mu\varepsilon_T\omega^2 + \mu\sigma_i\omega - K^2 = 0$ --- **(2-97)**

Using the relation $X = \frac{-b\pm\sqrt{b^2-4ac}}{2a}$ with
$X = \omega$, $a = \mu\varepsilon_r$, $b = i\mu\sigma$, $c = -K^2$ one gets

$\omega = \frac{-i\mu\sigma\pm\sqrt{(i\mu\sigma)^2+4K^2\mu\varepsilon_T}}{2\mu\varepsilon_T}$ -- **(2-98)**

For very small wave length $K \gg 1$ hence

$\omega = \frac{i\mu\sigma}{2\mu\varepsilon_T} + 2\frac{\sqrt{\mu\varepsilon_T}}{2\mu\varepsilon_T}K$ Therefore $\omega = \frac{-i\sigma}{2\varepsilon_T} + \frac{K}{\sqrt{\mu\varepsilon_T}}$ ------------ **(2-99)**

This relation can be simplified further if one considers

$$\frac{1}{\sqrt{\mu\varepsilon_T}} = \frac{1}{\sqrt{\mu(\varepsilon+\chi)}} = \frac{1}{\sqrt{\mu\varepsilon\left(1+\frac{\chi}{\varepsilon}\right)}} \;,\; \frac{1}{\sqrt{\varepsilon_T\mu}} = \frac{1}{\sqrt{\mu\varepsilon}\sqrt{1+\frac{\chi}{\varepsilon}}}$$

With $v = \frac{1}{\sqrt{\mu\varepsilon}}$ then $\frac{1}{\sqrt{\mu\varepsilon_T}} \approx v\left(1+\frac{\chi}{\varepsilon}\right)^{-\frac{1}{2}}$ ------------------------- **(2-100)**

Since $\varepsilon = 1 + 4\Pi\chi$ *and* $\varepsilon \gg \chi$ then $\frac{1}{\sqrt{\mu\varepsilon_T}} \approx v\left[1-\frac{1}{2}\frac{\chi}{\varepsilon}\right]$ as a result one gets $\frac{K}{\sqrt{\mu\varepsilon_T}} \cong vK\left[1-\frac{1}{2}\frac{\chi}{\varepsilon}\right] \cong \omega_0\left(1-\frac{\chi}{2\varepsilon}\right)$

$$\boldsymbol{vK = f_0\lambda\left[\frac{2\Pi}{\lambda}\right] = \omega_0}$$ -- **(2-101)**

When no matter exists, $\boldsymbol{\sigma = 0}$, $\boldsymbol{\chi = 0 \;\; and \;\; \varepsilon_T = \varepsilon}$

Then the equation **(2-101)** becomes

$$\boldsymbol{\omega = \frac{1}{\sqrt{\mu\varepsilon}} = vK = \omega_0}$$ --- **(2-102)**

Thus from equations (**2-102), (2-101)** and **(2-99) one gets**

$$\boldsymbol{\omega_0 = -\frac{-i\sigma}{2\varepsilon_T} \pm \frac{K}{\mu\varepsilon_T} = -i\frac{\sigma}{2\varepsilon_T} \pm \omega_0\left[1 - \frac{\chi_c}{2\varepsilon}\right] = \frac{-i\sigma}{2\varepsilon_T} - \omega_0 C_1}$$ -------- **(2-103a)**

Where $\boldsymbol{C_1 = \pm\left[1 - \frac{\chi_0}{2\varepsilon}\right]}$ --- **(2-104b)**

Since $\varepsilon \gg \chi$ hence $\varepsilon_r \approx \varepsilon$

$$\boldsymbol{\omega_c = \omega_0 - \frac{\omega_0\chi}{2\varepsilon} - \frac{i\sigma}{\varepsilon}}$$ -- **(2-105c)**

Substituting this relation in equation **(2-95)** yield

$$\boldsymbol{E = E_0 e^{-\frac{\sigma}{\varepsilon}} e^{i(Kx-\omega t)}}$$ --- **(2-106)**

Where $\boldsymbol{\beta = \frac{\sigma}{\varepsilon}}$, $\boldsymbol{\omega = \omega_0 + \frac{\omega_0\chi}{2\varepsilon}}$

In view of equation **(2-106)** it is apparent that the conductivity and electric permittivity affect the amplitude and frequency of the electromagnetic wave.

Thus they affect flux energy and number of photons.

2-13 The Wave number Relation:

The medium does not affect the frequency of electromagnetic wave only, but bay also affect the wave number K.This can be done by relating K to the refractive index of the medium n and then relating n to electric permittivity ε which depends on the susceptibility χ . Utilizing the definition of K one gets

$$\boldsymbol{K = \frac{2\Pi}{\lambda} = \frac{2\Pi f}{\lambda f} = \frac{\omega}{v} = \frac{\omega}{c}n}$$ --------------------------------------- **(2-107)**

Where the refractive index n is given as the ratio of the speed of light in free space c and the speed of light in the medium v

$\boldsymbol{n = \frac{c}{v}}$ --- **(2-108)**

While the term v is given by:

$\boldsymbol{v = \frac{1}{\sqrt{\varepsilon\mu}}}$ -- **(2-109)**

On the other hand the electric susceptibility is defined to be

$\boldsymbol{P = \chi E = (\chi_1 + i\chi_2)E}$ ---------------------------------- **(2-110)**

Where presents the polarization while E stand for the electric field intensity, the electric flux density is also given by

$\boldsymbol{D = \varepsilon E = E + 4\Pi\rho = E + 4\Pi\chi E}$

$\boldsymbol{D = (1 + 4\Pi\chi)E}$--------------------------------- **(2-111)**

Thus electric permittivity is given by

$\boldsymbol{\varepsilon = 1 + 4\Pi\chi}$ --- **(2-112)**

If it happens that the polarization P is not parallel to E then its better to compose P to two components χ , E which are parallel to E and imaginary part $\chi_2 E$ which is perpendicular to E i.e

$\boldsymbol{P = \chi E = (\chi_1 + i\chi_2)E}$ As the result the permittivity ε can be written also in a complex form

$\boldsymbol{\varepsilon = \varepsilon_1 + i\varepsilon_2}$ --- **(2-113)**

Thus $\boldsymbol{\varepsilon_1 + i\varepsilon_2 = 1 + 4\Pi\chi_1 + 4\Pi\chi_2 i}$ ---------------- **(2-114)**

Then $\boldsymbol{\varepsilon_1 = 1 + 4\Pi\chi_1}$ and $\varepsilon_2 = \boldsymbol{4\Pi\chi_2}$

In view the relation **(2-107), (2-109)** and **(2-114)** it is clear that n is also complex parameter, i.e

$\boldsymbol{n = n_1 + in_2 = \frac{c}{v} = c\sqrt{\varepsilon\mu}}$ --------------------------------- **(2-115)**

Squaring both side yield

$\boldsymbol{n_1^2 = (n_1 + in_2)^2 = c^2\mu\varepsilon = c^2\mu\varepsilon(\varepsilon_1 + i\varepsilon_2)}$

$\boldsymbol{n_1^2 - n_2^2 + 2n_1 n_2 = c^2\mu\varepsilon_1 + ic^2\mu\varepsilon_2}$ ---------------------------- **(2-116)**

For equation **(2-116)** one gets

$n_1{}^2 - n_2{}^2 = c^2\mu\varepsilon_1$

$n_1 n_2 = c^2\mu\varepsilon_2$ --- **(2-117)**

Eliminating n_2 from the relation we obtained:

$n_1{}^2 - \left[\frac{c^2\mu\varepsilon_2}{2n_1}\right]^2 = c^2\mu\varepsilon_1$, $n_2 - \frac{\mu^2\varepsilon_2{}^2c^4}{4n_1{}^2} = c^2\mu\varepsilon_1$

$4n_1{}^2 - 4c^2\mu\varepsilon_1 n_1{}^2 - \mu^2\varepsilon_2{}^2c^4 = 0$ -------------------------------- **(2-118)**

Utilizing the identity $X = \frac{-b\pm\sqrt{b^2-4ac}}{2a}$

With $X = n_1{}^2$, $a = 4$, $b = -4c^2\mu\varepsilon_1$, $c = -\mu^2\varepsilon_2{}^2c^4$ yields

$n_1{}^2 = \frac{4c^2\mu\varepsilon_1 \pm\sqrt{16c^4\mu^2\varepsilon_1{}^2+16c^4\mu^2\varepsilon_2{}^2}}{8}$

$n_1{}^2 = \frac{1}{2}\mu c^2\left[\varepsilon_1 + \sqrt{\varepsilon_1{}^2 + \varepsilon_2{}^2}\right]$ -------------------------------- **(2-119)**

Hence relations **(2-119)** and **(2-117)** yield

$n_2{}^2 = n_1{}^2 - c^2\mu\varepsilon_1 = \frac{\mu c^4\varepsilon_1}{2} \pm \frac{\mu c^2}{2}\sqrt{\varepsilon_1{}^2 + \varepsilon_2{}^2} - \mu c^2\varepsilon_1 = \frac{1}{2}\mu c^2\left[-\varepsilon_1 \pm \sqrt{\varepsilon_1{}^2 + \varepsilon_2{}^2}\right]$ --------------------------- **(2-120)**

Thus the wave number K can be given from **(2-116)** and **(2-107)** be

$K = \frac{\omega}{c}n = \frac{\omega}{c}(n_1 + in_2)$

$K = K_1 + iK_2 = \frac{\omega}{c}n_1 + i\frac{\omega}{c}n_2$ -------------------- **(2-121)**

From equation **(2-121)** one gets

$K_1 = \frac{\omega}{c}n_1$, and $K_2 = \frac{\omega}{c}n_2$ ----------------------- **(2-122)**

But $K_0 = \frac{\omega}{C}$ --- **(2-123)**

$K_1 = K_0 n_1$ -- **(2-124)**

$n_1 = \frac{c}{v}$ --- **(2-125)**

Then $K_1 = \frac{\omega}{c}\times\frac{c}{v} = \frac{\omega}{v} = \frac{2\Pi f}{\lambda f} = \frac{2\Pi}{\lambda}$ ---------------- **(2-126)**

Where K_0 is the wave number in vacuum while K_1 stand for the wave number in the medium. Using **(2-121)** and **(2-125)** in equation $\boldsymbol{E_0 = e^{-i(Kx-\omega t)}}$ one obtains

$\boldsymbol{E = E_0 e^{-i(K_1+iK_2)x-\omega t)}}$

$\boldsymbol{E = E_0 e^{-K_2 x} e^{-i(K_1 x-\omega t)} = E_0 e^{-\alpha X} e^{i(K_1 x-\omega t)}}$ -------------------- **(2-127)**

In view equation **(2-122)** let $\boldsymbol{\alpha = K_2 = \frac{\omega}{C} n_2}$ ---------------------- **(2-128)**

When n_2 is given from equation **(2-117)** to be

$\boldsymbol{n_2 = \frac{C^2 \mu \varepsilon_2}{n_2} \qquad where \;\; \varepsilon_2 = \frac{4\Pi\sigma_1}{\omega}}$

The relation between $\varepsilon_2 \; and \; \sigma_1$ can be found by utilizing equation **(2.114)** and the definition of the current density $\boldsymbol{J}$ to get

$\boldsymbol{n_2 = \frac{C^2 \mu}{2n_1}(4\Pi\chi_2)}$ ---------------------------------- **(2-129)**

But since $\boldsymbol{J = \frac{\partial \rho}{\partial t} = \chi \frac{\partial E_0 e^{-i\omega t}}{\partial t}}$

$\boldsymbol{J = -i\omega(\chi_1 - i\chi_2)E = (\omega\chi_2 - i\omega\chi_1)E = E\sigma(\sigma_1 + i\sigma_2)E}$ --- **(2-130)**

From relation (**2-129)** and **(2-114)** one gets

Hence $\boldsymbol{\chi_2 = \frac{\sigma_1}{\omega}}$, $\boldsymbol{\varepsilon_2 = 4\Pi\chi_2 = \frac{4\Pi\sigma_1}{\omega}}$ ------------------------------ **(2-131)**

This equation **(2-127)** can be written with aid of **(2-129)** and **(2-131)**

In the form

$\boldsymbol{\alpha = K_2 = \frac{\omega}{C} n_2 = \frac{2\Pi C \mu \chi_2 \omega}{n_2} = \frac{2\Pi C \mu \chi_2 \sigma_1}{n_2}}$ --------------------------- **(2-132)**

In view of equation **(2-121), (2-131)** and **(2-132)** one can decide that the wave number and the absorption coefficient (which affect the electromagnetic amplitude) are affected by the refractive index $\boldsymbol{n}$,magnetic susceptibility as well as conductivity.

2-14 The Wave Equation:

Let us derive the wave equation for electric vector $\boldsymbol{E}$ and the magnetic field B in a volume with in net charge $\boldsymbol{= 0}$, and no electromotive force $\boldsymbol{E^{EMF} = 0}$ and compare the results.

2-14-1 The wave Relation for E:

I n order to derive the wave equation for E we take the curl of

$\boldsymbol{\nabla} \times \boldsymbol{E} = -\frac{\partial \boldsymbol{B}}{\partial \boldsymbol{t}}$ and using $\boldsymbol{\nabla} \times \boldsymbol{B} = \mu_0 \boldsymbol{J}(\boldsymbol{t}, \boldsymbol{x}) + \boldsymbol{\varepsilon}_0 \mu_0 \frac{\partial \boldsymbol{E}}{\partial \boldsymbol{t}}$ to obtain

$\boldsymbol{\nabla} \times (\boldsymbol{\nabla} \times \boldsymbol{E}) = -\frac{\partial(\,\boldsymbol{\nabla} \times \boldsymbol{B})}{\partial \boldsymbol{E}} = -\mu_0 \frac{\partial y}{\partial x}\left(\boldsymbol{J} + \boldsymbol{\varepsilon}_0 \frac{\partial E}{\partial t}\right)$--------------------- **(2-133)**

According to the operator triple product

$\boldsymbol{\nabla} \times (\boldsymbol{\nabla} \times \boldsymbol{E}) = \boldsymbol{\nabla}(\boldsymbol{\nabla}.\boldsymbol{E}) - \boldsymbol{\nabla}^2 \boldsymbol{E}$ -------------------------------------- **(2-134)**

Furthermore since $\rho = 0$ the equation $\boldsymbol{\nabla}.\boldsymbol{E} = \boldsymbol{\rho}\frac{(\boldsymbol{t},\boldsymbol{x})}{\boldsymbol{\varepsilon}_0}$ yields

$\boldsymbol{\nabla}.\boldsymbol{E} = \boldsymbol{0}$ --------------------------------- **(2-135)**

And since $\boldsymbol{E}^{\boldsymbol{EMF}} = \boldsymbol{0}$, Ohms law equation yields $\boldsymbol{J} = \boldsymbol{\sigma E}$ --------- **(2-136)**

We find that equation **(2-133)** can be written as

$\boldsymbol{\nabla}^2 \boldsymbol{E} - \mu_0 \frac{\partial}{\partial t}\left(\boldsymbol{\sigma E} + \boldsymbol{\varepsilon}_0 \frac{\partial \boldsymbol{E}}{\partial t}\right) = \boldsymbol{0}$ -------------------------------------- **(2-137)**

Or also using equation

$\boldsymbol{\nabla}^2 \boldsymbol{E} - \mu_0 \boldsymbol{\sigma} \frac{\partial \boldsymbol{E}}{\partial \boldsymbol{t}} - \frac{1}{C^2}\frac{\partial^2 E}{\partial t^2} = \boldsymbol{0}$ --- **(2-138)**

Which is homogenous wave equation for E.

2-14-2 The wave Relation for B:

The wave equation for B is derived in much the same way as the wave equation for E.Take the curl of equation

$\boldsymbol{\nabla} \times \boldsymbol{B} = \mu_0 \boldsymbol{J}(\boldsymbol{x}, \boldsymbol{t}) + \boldsymbol{\varepsilon}_0 \mu_0 \frac{\partial \boldsymbol{E}}{\partial \boldsymbol{t}}$ -------------------------- **(2-139)**

And use Ohms law $\boldsymbol{J} = \boldsymbol{\sigma E}$ to obtain

$\boldsymbol{\nabla} \times (\boldsymbol{\nabla} \times \boldsymbol{B}) = \mu_0 \boldsymbol{\nabla} \times \boldsymbol{J} + \boldsymbol{\varepsilon}_0 \mu_0 \frac{\partial(\boldsymbol{\nabla} \times \boldsymbol{E})}{\partial \boldsymbol{t}} = \mu_0 \boldsymbol{\sigma \nabla} \times \boldsymbol{E} + \boldsymbol{\varepsilon}_0 \mu_0 \frac{\partial(\boldsymbol{\nabla} \times \boldsymbol{E})}{\partial \boldsymbol{t}}$

------ **(2-140)**

Which with the use of equation

$\boldsymbol{\nabla}(\boldsymbol{\nabla}.\boldsymbol{B}) - \boldsymbol{\nabla}^2 \boldsymbol{B} = -\mu_0 \boldsymbol{\sigma} \frac{\partial \boldsymbol{B}}{\partial \boldsymbol{t}} - \boldsymbol{\varepsilon}_0 \mu_0 \frac{\partial^2 \boldsymbol{B}}{\partial \boldsymbol{t}^2}$ ------------------------------- **(2-141)**

Using the fact that a according $\boldsymbol{\nabla} . \boldsymbol{B} = \mathbf{0}$ ------------------------------ **(2-142)**

For any media we can rewrite this equation as

$$\boldsymbol{\nabla^2 B} - \mu_0 \boldsymbol{\sigma} \frac{\partial \boldsymbol{B}}{\partial \boldsymbol{t}} - \frac{\mathbf{1}}{\boldsymbol{C^2}} \frac{\partial^2 \boldsymbol{B}}{\partial \boldsymbol{t^2}} = \mathbf{0} \text{ -- } \textbf{(2-143)}$$

The wave equation for the magnetic field, we notice that it is of exactly the same form as the wave equation for the electric field.

2-14-3 The time-independent Wave Equation for E:

As is clear from the above, it suffices to consider only the E field, since the result for the B field follow trivially. We therefore make the following Fourier component

$$\boldsymbol{E} = \boldsymbol{E_0} \boldsymbol{e^{-i\omega t}} \text{ --- } \textbf{(2-144)}$$

And insert this into equation

$$\boldsymbol{\nabla^2 E} - \mu_0 \boldsymbol{\sigma} \frac{\partial \boldsymbol{E}}{\partial \boldsymbol{t}} - \frac{\mathbf{1}}{\boldsymbol{C^2}} \frac{\partial^2 \boldsymbol{E}}{\partial \boldsymbol{t^2}} = \mathbf{0} \text{ --- } \textbf{(2-145)}$$

These yields

$$\boldsymbol{\nabla^2 E} - \mu_0 \boldsymbol{\sigma} \frac{\partial \boldsymbol{E_0(x)}}{\partial \boldsymbol{t}} \boldsymbol{e^{-i\omega t}} - \frac{\mathbf{1}}{\boldsymbol{C^2}} \frac{\partial^2 \boldsymbol{E_0(x)}}{\partial \boldsymbol{t^2}} \boldsymbol{e^{-i\omega t}} = \boldsymbol{\nabla^2 E} - \mu_0 \boldsymbol{\sigma}(-\mathbf{i}\boldsymbol{\omega})\mathbf{E_0(x)}\mathbf{e^{-i\omega t}} - \frac{\mathbf{1}}{\mathbf{C^2}}(-\boldsymbol{i\omega})^2 \boldsymbol{E_0(x)} \boldsymbol{e^{-i\omega t}} = \boldsymbol{\nabla^2 E} - \mu_0 \boldsymbol{\sigma}(-\boldsymbol{i\omega})\boldsymbol{E} - \frac{\mathbf{1}}{\boldsymbol{C^2}}((-\boldsymbol{i\omega})^2)\boldsymbol{E} = \mathbf{0} \text{ ---------------------------} \mathbf{(2.146)}$$

Which we can rewrite as

$$\boldsymbol{\nabla^2 E} + \frac{\boldsymbol{\omega^2}}{\boldsymbol{C^2}}\left(\mathbf{1} + \boldsymbol{i}\frac{\boldsymbol{\sigma}}{\boldsymbol{\varepsilon_0 \omega}}\right)\boldsymbol{E} = \boldsymbol{\nabla^2 E} + \frac{\boldsymbol{\omega^2}}{\boldsymbol{C^2}}\left(\mathbf{1} + \frac{\boldsymbol{i}}{\boldsymbol{\tau\omega}}\right)\boldsymbol{E} = \mathbf{0} \text{ ------------- } \textbf{(2-147)}$$

The quantity $\boldsymbol{\tau} = \frac{\boldsymbol{\varepsilon_0}}{\boldsymbol{\sigma}}$ is called the relaxation time of the medium in the limit of long $\boldsymbol{\tau}$ equation **(2-147)** tends to

$$\boldsymbol{\nabla^2 E} + \frac{\boldsymbol{\omega^2}}{\boldsymbol{C^2}}\boldsymbol{E} = \mathbf{0} \text{ --- } \textbf{(2-148)}$$

Which is a time -independent wave equation for E,rresponding weakly domed propagation waves.

In the short time $\boldsymbol{\tau}$ limit we have instead

$$\boldsymbol{\nabla^2 E} + \boldsymbol{i\omega}\mu_0\boldsymbol{\sigma E} = \mathbf{0} \text{ -- } \textbf{(2-149)}$$

2-15 Spectroscopy:

Spectroscopy is the branch of science study of interaction of electromagnetic radiation with matter. The important consequence of such interaction is absorption or emission by the matter in discrete a mounts called quanta, the ways in which the measurement of radiation frequency (emitted or absorbed) made experimentally and the energy levels deduced from these, comprise the practical of spectroscopy.

The various branches of spectroscopy generally involve measurement of two experimental parameters

(i) The energy of radiation absorbed or emitted by the system.

(ii) Intensity of spectral lines.

In most branches of spectroscopy the system interacts with the electric component of the light.

Spectroscopy is one of the most power full tools available for the study of atomic and molecular structure and in use in the analysis of wide range of samples.[18]

2-15-1 Spectral Analysis:

Spectral analysis of light emitting objects yields information about elemental composition and relative abundance of elements by splitting the light given off into its component colours, each of these colours is indicative of specific atomic transition. All elements have a unique spectral “fingerprint” spectral; they are three types of spectra bright line or emission line spectra, continuous spectral, dark line or absorption line spectra.

Continuous spectra are produced by solids, liquids or dense gas. The spectrum appears as smooth transition of all colours in the visible spectrum from the shorter or longest wave length with any gap between the colours.

Absorption spectra are produced when a cooler gas absorbs specific wave lengths of light passing through it. The wave length absorbed are determined by the elements that compose the gap, since no two elements absorb the exact same wave length, it is possible to determine the elemental composition of the gas by examining the spectra.

2-15-2 Width and Shape of Spectral Lines:

The radiation emitted (or absorbed) by our oscillating atomic dipole is not exactly monochromatic, i.e. there will be a range of frequency values . The spectral line observed is broadened by one, or more, processes. A process that affects all the atoms in the same way is called “Homogeneous Broadening”. A process that affects different individual atoms differently is “Inhomogeneous Broadening". Examples of homogeneous broadening are lifetime (or natural) broadening or collision (or pressure) broadening. Examples of inhomogeneous broadening are Doppler broadening and crystal field
Broadening.

2-15-3Atomic Spectroscopy:

The atomic spectroscopy was the first application of spectroscopy developed .Atomic Absorption Spectroscopy (AAS) and Atomic Emission Spectroscopy (AES) involve visible and ultraviolet light,absorption and emission often referred to as atomic spectral lines are due to electronic transition of an outer shell electron to an excited state, atoms also have distinct x-ray spectra that are attributed to the excitation of inner shell electrons to excited state.

Atoms of different elements have distinct spectra and therefore atomic spectroscopy allows for the identification and quantitation of samples elements composition.[19]-[20]

2-16 The roles of elements in life:

Most of heavy metals are toxic if ingested or in hand at sufficiently high levels for long enough periods.

The intake absoption and toxic effects of some elements in human are discussed below.[21]

2-16-1 Lead (Pb):

Lead enters into the body system through air, water and food and cannot be removed by washing fruits and vegetables . It is a serious cumulative body poison, which can affect every organ and system in the body. Exposure to its high levels can severely damage the brain, kidneys and ultimately cause death and long-term exposure result in de-creased performance in some tests that measure the functions of the nervous system; weakness in fingers, wrists, or ankles; small increases in blood pressure; and anaemia. Others are abdominal pain, anaemia, arthritis, attention deficit, back problems, blindness, cancer, constipation, convulsions, depression, diabetes, migraine headaches, thyroid imbalances and tooth decay. Children exposed to high lead levels are particularly at risk.[22]

2-16-2 Nickel (Ni):

Nickel is known to be responsible for cancer(oral and intestinal), depression, heart attacks, haemorrhages, kidney dysfunction, low blood pressure, malaise, muscle tremors and paralysis, nausea, skin problems and vomiting [23].

2-16-3 Cadmium (Cd):

Cadmium is very toxic, its long-term exposure to lower levels leads to a build up in the kidneys and possible kidney disease, lung damage, and fragile bones. Hypertension, ar-thritis, diabetes, anaemia, cancer, cardiovascular disease, cirrhosis, reduced fertility; hypoglycemia, headaches, kidney disease. [23]

2-16-4 Chromium (Cr) :

Chromium (VI) compounds are toxics and known human carcinogens, whereas chromium (III) is an essential element. Breathing high levels can cause irritation to the lining of the nose; nose ulcers; running nose; and breathing problems, such as asthma, cough, shortness of breath, or wheezing. Long term exposure can cause damage to liver, kidney, circulatory and nerve disorders, as well as skin irritation [24].

2-16-5 Iron (Fe) and Copper (Cu) :

Toxicity of iron in humans has been found to bring about vomiting, cardiovascular collapse and diarrhoea. While iron deficiency may lead to failure of blood clotting . Copper is a common environmental metal and is essential in cellular metabolism but at high concentrations it can be highly toxic to fish [25].

2-16-6 Zinc (Zn) :

A higher level of zinc in hair may be indicative of low zinc in cells and functional zinc efficiency .Zinc is an essential element that is required in many very important biological process,however zinc can be toxic if exposoure is excessive.[25]

2-16-7 Calcium (Ca) :

Calcium is the most a bundant mineral in the body 99% of calcium in the body are deposited in bones and teeth and the remainder is in the soft tissure.The daily intake of calcium of 800mg was recommended by USA National Research Council.[25]

2-16-8 Magnesium (Mg) :

Magnesium required for processing ATP and related reactions(build bone causes strong peristalsis increases flexibility increases alkalinity. Approximately 50% is in bone, the remaining 50% is almost inside body cell.[25]

2-16-9 Selenium (Se) :

Selenium is a factor of glutathione peroxidese which protects human cells from free radicals damage.

Decreased level of level of selenium in children blood is connected with increased risk of osteoathritic cancer and cardiovascular diseases.[25]

2-16-10 Cobalt (Co) :

Cobalt activates a number of enzymes in the body,it is necessary for normal functioning and maintenance of red blood cells as well as other body cells.Cobalt is stored in the red blood cells ,some stage occurs ,also in the liver,kindneys,pancreas and spleen.

The advantage dailyintake of cobalt is 5 to 8 microgram this evidence that high intakes of cobalt may result in an enlarged the yroid gland.[25]

2-16-11 Manganese (Mn):

Manganese travels into the blood bound to transferrin in the trivalent state and to macroglobulin in the divalent state (Gibbons et al., 1976). The percentage of manganese bound to transferrin may increase over time as manganese is oxidized to MnIII. A small fraction is bound to unknown proteins (Harris & Chen, 1994).

The chemical speciation of manganese affects its distribution to the brain, but it is not clear whether there is a predominant manganese species crossing the blood–brain barrier (Roels et al., 1997;Dorman et al., 2001). The oxidation state of the manganese ion determines its mode of transport at the brain barrier system. MnIII, a major form of manganese ions in the circulation, enters the brain via a transferrin receptor–mediated mechanism, whereas MnII is readily taken up into the central nervous system, most likely as a free ion or as a nonspecific protein-bound species (Zheng et al., 2003). It is suggested that manganese citrate may be a major species entering the brain.

2-16-12 Vanadium (V):

the possibility has been considered that vanadium might play a role in the regulation of Na+/K+-exchanging ATPase,phosphoryl-transfer enzymes, adenylate cyclase and protein kinases. The possible role of the vanadyl ion as an enzyme cofactor, and its roles in hormone,glucose, lipid, bone and tooth metabolism have also been discussed. No specific biochemical function has yet been identified for vanadium in higher animals.

However, the recent discovery in lower forms of life of vanadium-activated enzymes lends credence to the view that vanadium has similar roles in higher animals. Vanadium-dependent enzymes in lower organisms include nitrogenase in bacteria which reduces molecular nitrogen to ammonia, and iodoperoxidase and bromoperoxidase in algae)an d lichens (ZO), which catalyse theoxidation of halide ions by hydrogen peroxide, thus facilitating the formation of a carbon-halogen bond. Hal~~eroxidasessu,c h as thyroid peroxidase, play essential roles in higher animals, and it was recently shown that vanadium deprivation in rats affected the response of thyroid peroxidase to changing dietary iodine .

CHAPTER (III)

Spectroscopy Analysis Techniques

3-1 Introduction:

Spectroscopy techniques all work on the principle of that under certain conditions materials absorb or emit energy. Different spectroscopy techniques operate over different limited frequency range with this broad spectrum depending on the processes and magnitudes of the energy changes.

3-2 Spectroscopy and Regions of the Spectrum:

Different regions of the spectrum means different types of energy levels of an atomic or molecular system. It is not uncommon to refer to a spectroscopic technique by the region of the electromagnetic spectrum involved; synonymously, a type of spectroscopy may be referred to by using the types of energy levels involved. Thus, the term vibration spectroscopy is sometimes used interchangeably with infrared spectroscopy, although some vibration transitions may occur in the microwave region of the spectrum and some electronic transitions may occur in the IR region of the spectrum. In other cases, no such substitution is done; rarely, if ever, are nuclear magnetic resonances (NMR) or electron paramagnetic resonance (EPR) spectroscopy referred to as radio spectroscopy or microwave spectroscopy, respectively.

3-3 Visible and Ultraviolet Spectroscopy:

Transitions in the electronic energy levels of the bonds of a molecule come from excitation of electrons from ground state to excited state.[26]

Four types of transitions:

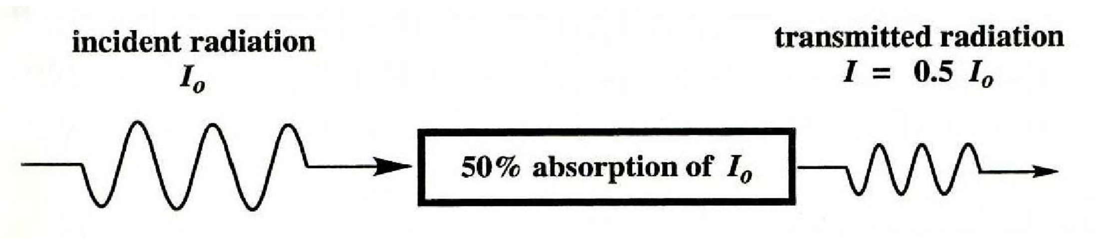
(i) Within the same atom e.g. d-d or f-f transition

(ii) To adjacent atom (charge transfer)

(iii) To a delocalized energy band, conduction band (photoconductivity)

(iv) Promotion of an electron from valence band to conduction band (band gap in semiconductors.

Beer-Lambert Law:



$$Log\left(\frac{I_\circ}{I}\right) = \varepsilon cl \text{ ----------------------(3.1)}$$

$$\varepsilon = A/cl$$

ε: extinction coefficient

c: concentration

l: Path length

$I_\circ$: incident radiation

I: transmitted radiation

A: absorbance

ε: value determine transition is allowed or forbidden.[26]

3-4 Atomic Absorption Spectroscopy(AAS):

Is a spectrum analytical procedure for the quantitative determination of chemical element employing the absorbance of optical radiation (light) by free atoms in gaseous state, the technique is used for determent the concentration of a particular element in a sample to be analyzed, (AAS) can be used to determine over 70 different elements in solution or directly in solid sample.[27]

3-5 Atomic Emission Spectroscopy (AES):

AES is method of technique that uses the intensity of light emitted from a flame, plasma or spark at a particular wave length to determine the quantity of an element in a sample. The wave length of the atomic spectral line gives the intensity of the emitted light is proportional to the number of atoms of the element.[28]

3-6 Inductively Coupled Plasma Mass Spectroscopy (ICP-MS):

Inductively Coupled Plasma Mass Spectroscopy (ICP-MS) is a type of mass spectroscopy which is capable of detecting metals and several non-metal at concentrations as low as one part in 10^{12} (part per million).

This achieved by ionization the sample with inductively coupled plasma and then using a mass spectrometer to separate and quantify those ions.[29]

3-7 Infra Red Spectroscopy (IRS):

The study of the interaction of materials system with electromagnetic radiation in the infra red region of spectrum is the infra red spectroscopy.

The main spectroscopy employed detect chemical element are based on the processes of infra red absorption. There are widely used to provide information on chemical structures and physical forms to identify substance from characteristic spectral pattern and to determine quantatively the amount of substance in sample. Samples can be examined in whole range physical states, for example, as solid, liquids, or gas or as surface layers.

The techniques are very wide ranging and provide solutions to a host of interesting challenging and analytical problems.[30]

3-8 Laser-Induced Break down Spectroscopy (LIBS):

Laser-induced breakdown spectroscopy (LIBS) is a type of atomic emission spectroscopy which uses a highly energetic laser pulse as the excitation source. The laser is focused to form plasma, which atomizes and excites samples. In principle, LIBS can analyze any matter regardless of its physical state, be it solid, liquid or gas. Because all elements emit light of characteristic frequencies when excited to sufficiently high temperatures, LIBS can (in principle) detect all elements, limited only by the power of the laser as well as the sensitivity and wavelength range of the spectrograph and detector. In practice, detection limits are a function of : a) the plasma excitation temperature b) the light collection window a c) the line strength of the viewed transition. (LIBS) makes use of optical emission spectrometry and is to this extent very similar to arc/spark emission spectroscopy.[31]

(LIBS) operates by focusing the laser onto a small area at the surface of the specimen; when the laser is discharged it ablates a very small amount of material, in the range of nano grams to pico grams, which generates a plasma plume with temperatures in excess of 100,000 K. During data collection, typically after local thermodynamic equilibrium is established, plasma temperatures range from 5,000–20,000 K. At the high temperatures during the early plasma, the ablated material dissociates (breaks down) into excited ionic and atomic species. During this time, the plasma emits a continuum of radiation which does not contain any useful information about the species present, but within a very small timeframe the plasma expands at supersonic velocities and cools. At this point the characteristic atomic emission lines of the elements can be observed. The delay between the emission of continuum radiation and characteristic radiation is in the order of 10 µs, this is why it is necessary to temporally gate the detector.[32]

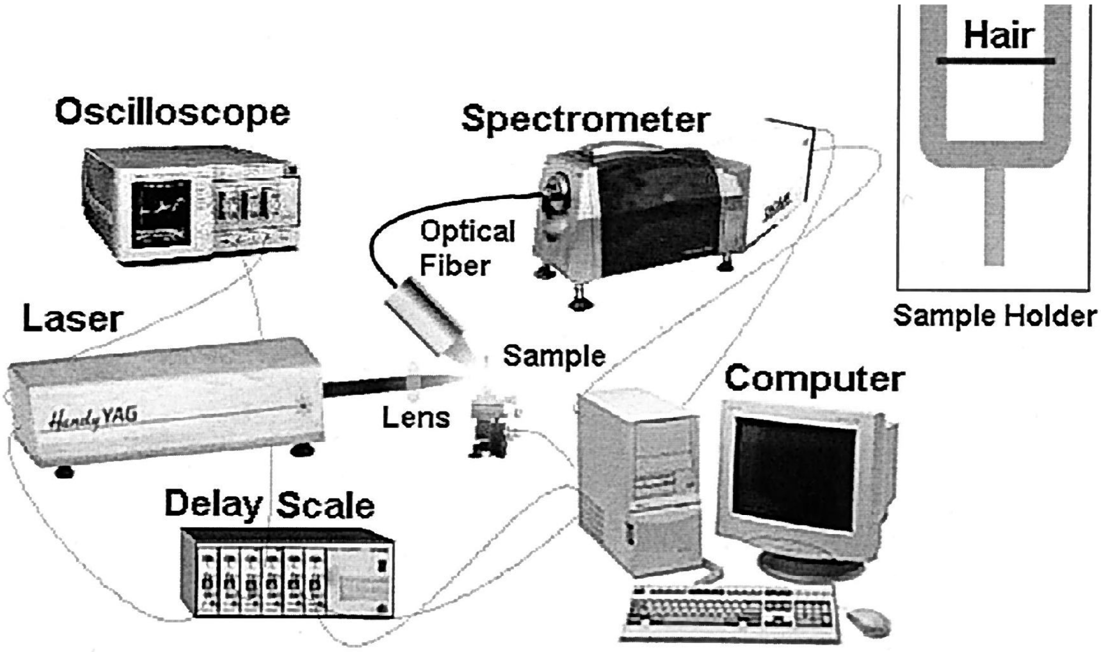


Figure (3-1): Experimental LIBS setup used for hair tissue mineral analysis.

3-9 Mossbaur Spectroscopy:

Mossbaur spectroscopy is spectroscopic technique based on the Mossbaur effect, this effect is discovered by Rudlof Mossbur in 1957 consist of the recoil free resonant absorption and emission of gamma rays in solid, Mossbaur spectroscopy probes tiny changes in the energy levels of an atomic nucleus.[33]

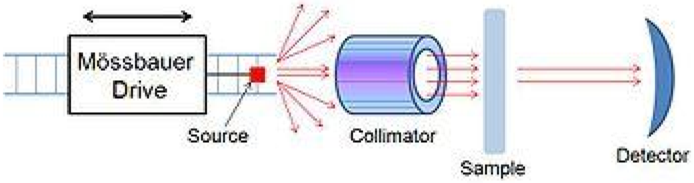


Figure (3-2): A schematic view of Mössbauer spectrometer

3-10 Nuclear Magnetic Resonance Spectroscopy (NMR):

Nuclear magnetic resonance spectroscopy most commonly known as (NMR) spectroscopy is a research technique that exploits the magnetic properties of certain atomic nuclei to determine physical and chemical properties of atoms or molecules in which they are contained.[34]

3-11 Raman Spectroscopy :

Raman spectroscopy is a spectroscopic technique used to study vibration, rotation, and other low-frequency modes in a system. It relies on inelastic scattering, or Raman scattering, of monochromatic light, usually from a laser in the visible, near infrared, or near ultraviolet range. The laser light interacts with molecular vibrations, phonons or other excitations in the system, resulting in the energy of the laser photons being shifted up or down. The shift in energy gives information about the vibration modes in the system.[35]-[36]

3-11-1 Raman Shift:

In colloquial usage, Raman shifts are typically in wave numbers, which have units of inverse length. In order to convert between spectral wavelength and wave numbers of shift in the Raman spectrum, the following formula can be used:

$$\Delta w = \left(\frac{1}{\lambda_0} - \frac{1}{\lambda_1}\right) , \text{---------------------------} \quad \textbf{(3.2)}$$

Where $\Delta w$the Raman shift expressed in wave number,$\lambda_0$is the excitation wavelength, and λ_1 is the Raman spectrum wavelength. Most commonly, the units chosen for expressing wave number in Raman spectra is inverse centimeters (cm^{-1}). Since wavelength is often expressed in units of nanometers (nm), the formula above can scale for this units conversion explicitly, giving in equation -----------------**(3.3)**

$$\Delta w(\mathrm{cm}^{-1}) = \left(\frac{1}{\lambda_0(\mathrm{nm})} - \frac{1}{\lambda_1(\mathrm{nm})}\right) \times 10^7, \text{effectively multiplying by } \frac{(\mathrm{nm}}{(\mathrm{cm}}$$

Table (3-1): Comparison between Raman spectra and IR spectra

Raman spectra	IR spectra
Originate from scattering of radiation	Originate from absorption of radiation
Change in molecular polarizability	Change in dipole moment
Weak in intensity	Strong in intensity
Water can be used as solvent	Water lead to strong absorption and attack the holder
Optical system: Glass, quartz	Optical system: NaCl, KBr
Record by using a beam of monochromatic radiation	Record by using a beam of radiation having a large number of frequencies
Homonuclear diatomic molecules are Raman active	Homonuclear diatomic molecules are IR inactive

3-12 Characteristics of X-Rays:

X-rays of a single energy characteristic of a particular atom and equal to the difference in energy levels of that particular atom, they are electromagnetic wave forms possessing no charge and no mass, and they can be characterized by frequency, wavelength, and velocity, and they are not influenced by electrical and magnetic fields and will travel in straight lines. [37]

3-13 Production of X-Rays:

X-rays are produced when a fast-moving electron is decelerated suddenly by colliding with a much heavier nucleus this radiation is termed Bremsstrahlug (braking radiation) as shown in the figure (3-3).

The electrons can be stopped by interaction with the electrons in the target atoms either by giving up all their energy in a single collision or by successive interactions, each one resulting in a loss of energy and the production of either heat (mainly) or x-rays is produced, the maximum photon energy being decided by the maximum voltage a cross the x-ray tube then the maximum energy of any x-ray photon will thus be 100kv.

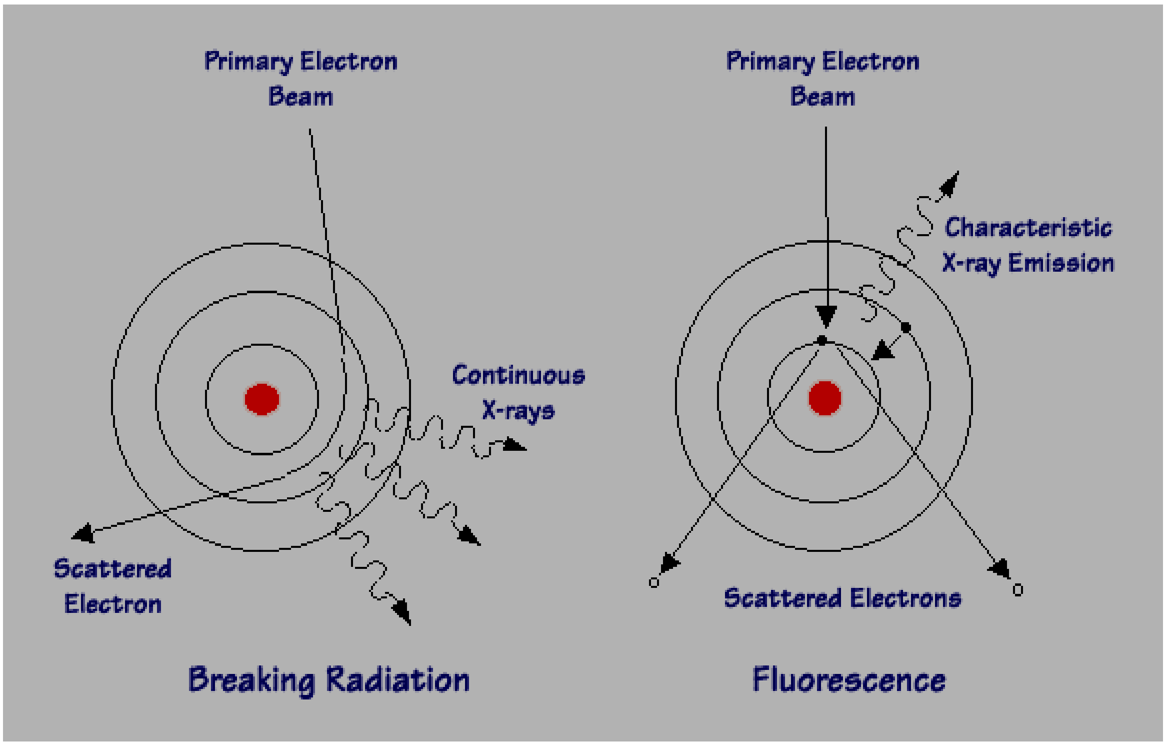


Figure (3-3): X-Ray Production

For medical and industrial purposes the original type of x-ray tube consists of a glass tube from which air has been removed. The tube contains two electrodes, a negatively charged electrode called the cathode and a positively charged target called the anode. The two electrodes are attached to a source of direct (DC) current. When the current is turned on, electrons are ejected from the cathode. They travel through the glass tube and strike a target.

The energy released when the electron hit the target is emitted in the form of x-rays. The wavelength of the x-ray produced is determined by the metal used for the target and the energy of the electrons released from the cathode.

The cathode consists of a spiral of tungsten wire which can be heated by passing a current, the tungsten chosen because of its high melting point (3370°C).

The tungsten is embedded in a sleeve of caper which uses its high thermal conductivity to remove the heat from the target into some form of cooling system. [38]

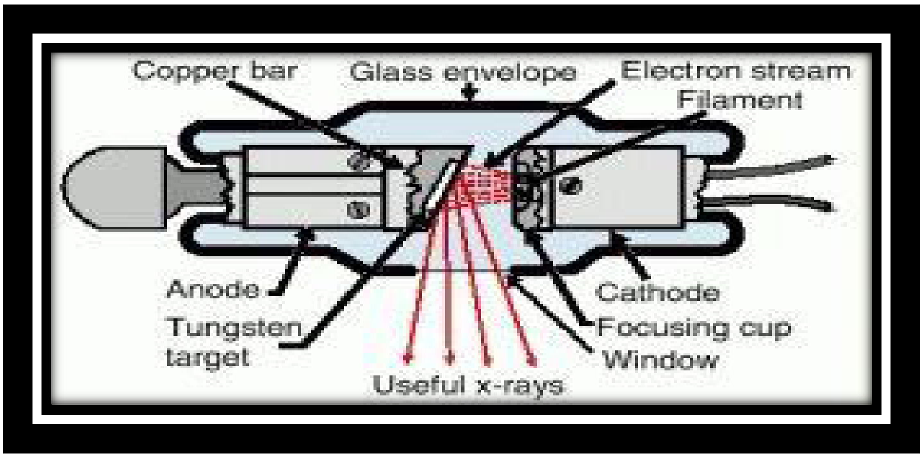


Figure (3-4): X-ray tube

3-13-1 Continuous and Characteristic X-Ray Spectra:

When the target material of the X-ray tube is bombarded with electrons accelerated from the cathode filament, two types of X-ray spectra are produced. The first is called the continuous spectra.

The continuous spectrum consists of a range of wavelengths of X-rays with minimum wavelength and intensity (measured in counts per second) dependent on the target material and the voltage across the X-ray tube. The minimum wavelength decreases and the intensity increases as voltage increases.

The second type of spectra, called the characteristic spectra, is produced at high voltage as a result of specific electronic transitions that take place within individual atoms of the target material.

This is easiest to see using the simple Bohr model of the atom. In such a model, the nucleus of the atom containing the protons and neutrons is surrounded by shells of electrons. The innermost shell, called the K-shell, is surrounded by the L- and M - shells. When the energy of the electrons accelerated toward the target becomes high enough to dislodge K- shell electrons, electrons from the L - and M - shells move in to take the place of those dislodged.

Each of these electronic transitions produces an X-ray with a wavelength that depends on the exact structure of the atom being bombarded. A

Transition from the L - shell to the K- shell produces K_αX-ray, while the transition from an M - shell to the K- shells K_βX-ray.

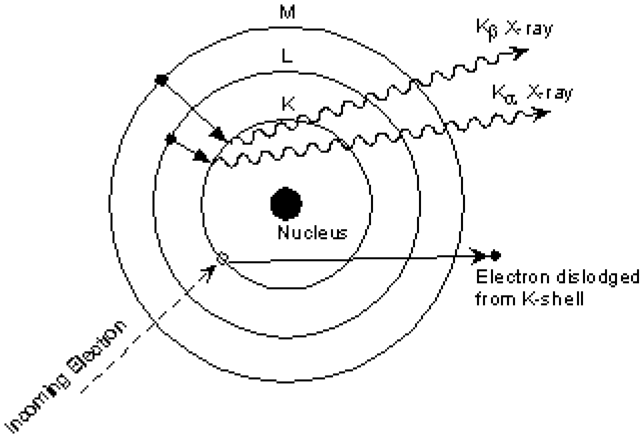


Figure (3-5): The electronic transition produces an X-Ray.

These characteristic X-rays have a much higher intensity than those produced by the continuous spectra, K_αX-rays having higher intensity than K_βX-rays. The important point here is that the wavelength of these characteristic x-rays is different for each atom in the periodic table (of course only those elements with higher atomic number have L- and M - shell electrons that can undergo transitions to produce X-rays). [39]

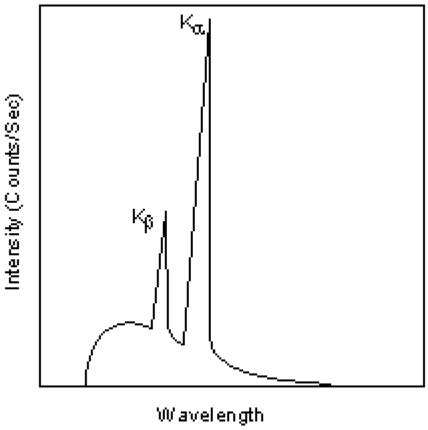


Figure (3-6): $K_\alpha$and K_βX-Rays.

3-13-2 Interaction of X-Rays with Matter:

Figure (3-5) illustrates the three possible fates the individual photons when a beam of x-rays travels through matter, they may be:

Transmitted: pass through unaffected, as primary or direct radiation.

Absorbed: transferring to the matter all of their energy (the photon disappearing completely) or some of it (partial absorption).

Scattered: diverted in a new direction, with or without loss of energy.

And so may leave the beam (as scattered secondary radiation).

X-ray absorption and scattering processes are stochastic processes, governed by the statistical low of chance. It’s impossible to predict which of photons in a beam will be transmitted by 1mm of a material, but it’s possible to be quite precise about the fraction of the large numbers of photons the beam contains.

Attenuation:

Attenuation refers to the fact that there are fewer photons in the emerging beam than in the beam entering the material.

Attenuation =absorption + scatter

In practice, x-ray beams are usually both large and composed of a range (or spectrum) of photon energies. It's helpful to consider first the simpler case.

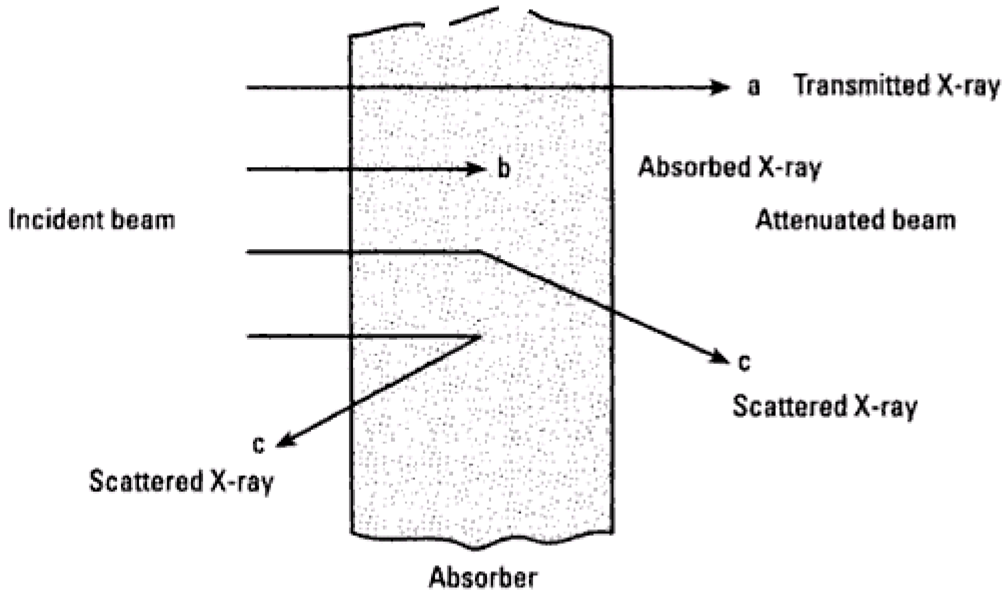


Figure (3-7): interaction of x-rays with matter.

3-13-3 Applications of X-Rays:

3-13-3-1 Medical:

The earliest uses of x-rays were based on the discoveries mode by Roentgen, namely their ability to distinguish bone and teeth from flesh in x-ray photographs.

When an x-ray beam is focused on a person’s hand or jaw, for example, the beam passes through flesh rather easily but is absorbed by bones or teeth. The picture produced in this case consists of light areas that represent bone and teeth and dark areas that represent flesh. Some applications of this principle in medicine are the diagnosis of broken bones and torn ligaments, the detection of breast cancer in women, or discovery of cavities and impacted wisdom teeth.

X-rays can be produced with energies sufficient to ionize the atoms that make up human tissue.

Thus, x-rays can be used to kill cells. This is just what is done in some types of cancer therapy.

X-radiation is directed against cancer cells in the hope of destroying them while doing minimal damage to nearby normal cells to x-rays can cause the development of cancer. For this reason, great care is taken by physicians and dentists when taking x-rays of any type to be sure that the exposure to the rest of the patient’s body is kept at an absolute minimum.

A relatively new technique for using x-rays in the field of medicine is called computerized axial tomography, producing what are CAT scans.

A CAT scan produces a cross-sectional picture of a part of the body that is much sharper than a normal x-ray.

Normal x-rays are taken through the body, producing a picture that may show organs and body parts super-imposed on one another. In contrast, in making a CAT scan, a narrow beam of x-rays is sent through the region of interest from many different angles. A computer is then used to reconstruct the cross-sectional picture of that region.

3-13-3-2 Nondestructive Testing:

The term nondestructive testing refers to x-rays can be used to study the structure of a material without actually destroying it. One approach is based on the usual method of producing x-rays.

A sample of unknown material is used as the target in an x-ray machine and bombarded with high energy electrons. The x-ray pattern produced by the sample can be compared with the x-ray patterns for all known elements. Based on this comparison, the elements present in the unknown sample can be identified. Atypical application of this technique is the analysis of hair or blood samples or some other material being used as evidence in a criminal investigation.

3-13-3-3 Synchrotron Radiation:

In recent years an interesting new source of x-rays has been developed called synchrotron radiation.

Synchrotron radiation is often produced by particle accelerators (atom-smashers). A particle accelerator is a machine used to accelerate charged particles; x-rays are used for nondestructive testing in business and industry in many other ways. For example, x-ray pictures of whole engines or engine parts can be taken to look for defects without having to take an engine a part. Similarly, sections of oil and natural gas pipelines can be examined for cracks or defective welds.

Airlines also use x-ray detectors to check the baggage of passengers for guns or other illegal objects.

As these particles travel in a circle around a particle accelerator, they may give off energy in the form of x-rays. These x-rays are what make up synchrotron radiation.

X-ray lithography is a technique used in electronics industry for the manufacture of high density integrated circuits. (A circuit is a complete path of electric current, including the source of electric energy.) The size of the circuit elements is limited by the wavelength of the light used in them.

The shorter the wavelength the smaller the circuit elements. If x-rays are used instead of light, the circuits can be made much smaller, thereby permitting the manufacture of smaller electronic devices such as computers.[40]

3-14 Scanning Electron Microscopes (SEM):

The electron microscopes are scientific instruments that use a beam of energy of electrons to examine objects on very fine scale.

The Scanning Electron Microscope (SEM) uses a focused beam of higher energy electrons to generate a variety signals at the surface of the solid samples. The signals that drive from electron sample interactions reveal information about the sample including external morphology, chemical composition, crystalline structure and orientation of materials making up the sample.[41]

3-15 Transition Electron Microscopes (TEM):

When electrons are accelerated up to high energy levels (few hundreds keV) and focused on a material, they can scatter or backscatter elastically or in elastically, or produce many interactions, source of different signals such as X-rays, Auger electrons or light some of them are used in transmission electron microscopy.[42]

3-16 Scanning Tunneling Spectroscopy (STS):

Scanning tunneling spectroscopy (STS), an extension of scanning tunneling microscopy (STM), is used to provide information about the density of electrons in a sample as a function of their energy.

In scanning tunneling microscopy, a metal tip is moved over a conducting sample without making mechanical contact. A bias voltage between the sample and tip allows a current to flow between the tip and the sample even though they are not in contact. This can occur because of quantum mechanical tunneling, hence the name of the instrument.[43]

3-17 Scanning Tunneling Spectroscopy (STM):

Scanning Tunneling Spectroscopy (STM) is a technique reliant upon the wave like nature of electrons. If two conductors are brought close together (to a separation of the order$4A$) and potential applied between them, then the overlap of the electron wave functions permits quantum mechanical tunneling and current flow across the cap at low temperatures and voltages, if the current is kept constant (to within a few percent), then the gap should remain constant to within around $0.1A°$

In STM an atomically sharp electrode tip is scanned mechanically in a raster pattern to cover the surface.

By altering the height of the tip above the surface using a feedback loop to maintain a constant tunneling current, the electronic morphology of the surface can be determine. Alternatively, the tunneling current can be recorded for a constant height. This is faster to measure but more complexes to interpret, since the tunneling current is related to the surface morphology by convolution of the electronic structure of the tip and surface.[44]

3-18 Secondary ion mass spectrometry (SIMS) :

Secondary ion mass spectrometry (SIMS) is a technique used in materials science and surface science to analyze the composition of solid surfaces and thin films by sputtering the surface of the specimen with a focused primary ion beam and collecting and analyzing ejected secondary ions. The mass/charge ratios of these secondary ions are measured with a mass spectrometer to determine the elemental, isotopic, or molecular composition of the surface to a depth of 1 to 2 nm. Due to the large variation in ionization probabilities among different materials, SIMS is generally considered to be a qualitative technique, although quantitation is possible with the use of standards. SIMS is the most sensitive surface analysis technique, with elemental detection limits ranging from parts per million to parts per billion.

3-19 Auger Electron Spectroscopy(AES):

The Auger process x-ray and high energy electron bombardment of atom, can create core hole will eventually decay via either

(i) Photon emission x-ray fluorescence more likely for deep core hole (high Binding Energy (BE) and high Z elements.

(ii) Radiation less internal rearrangement more likely for shallow core hole (low BE and low Z elements).

Auger process is three electron process and leaves atoms doubly ionized occurs independently of incident excitation.[45]

3-20 X-ray photoelectron spectroscopy (XPS):

X-ray photoelectron spectroscopy (XPS or ESCA) of course owes its quantification to Einstein's explanation of the photoelectric effect in 1905 ,and the technique in fact has a long history that can be traced to contemporary measurements in which either X-rays or gamma rays were used to excite photoelectrons from solids.

In the period since the late 1950s, the photoelectric effect has been developed into one of our most powerful tools for studying the composition and electronic structure of matter, with Kai Siegbahn Receiving the Nobel Prize in 1981 for the development of high resolution XPS. His group's early pioneering work is documented in the two well-known ESCA. The most interesting domain for basic and applied scientists using XPS. As a convenient operational definition of XPS.The excitation energies above a few hundred eV and going into the hard X-ray regime up to 15 keV. Thus, both core levels and valence levels are readily observable in spectra.[46]

3-21 Ion Scattering Spectroscopy(ISS) :

When a beam of ions hits a solid surface part of the projectiles will be scattered back into the vacuum after one or more collisions with target atoms of the top few layers. Measurement of the energy of the backscattered particles can be used to identify the mass of these atoms. The technique is called Ion Scattering Spectroscopy (ISS). The term encompasses actually several techniques depending on the energy of the primary ion beam. LEIS (Low Energy Ion Scattering) spectroscopy is referred to primary energies in the range of 100 eV to 10 keV, Medium Energy Ion Scattering (MEIS) to a range from 100 to 200 keV, and High Energy Ion Scattering (HEIS) to energies between 1 and several MeV. Often the LEIS technique is called Ion Scattering Spectroscopy (ISS), the term we will use below meaning LEIS, while HEIS technique is best known as Rutherford Backscattering Spectroscopy (RBS).

3-21-1Backscattering of kilovolt ions:

The process can be considered as a series of elastic collisions with the atoms in the top layers. In this (kilovolt) energy ranges one can assume that the collisions are binary and the atoms are free, so that the ion-atom interaction is described by repulsion inter atomic potentials only. According to the classical mechanics, the energy of scattered particle is given by:

$$\frac{E_1}{E_\circ} = \left[[\pm(M^2{}_2 - M^2{}_1 sin^2\theta_1)]^{\frac{1}{2}} + M_1 cos\theta_1\right] \Big/ [M_1 + M_2]^2 \quad \text{-------(3.4)}$$

(both signs hold for $M_1 > M_2$ and only the positive signs otherwise), where E_O is the initial energy, Θ_1 is the scattering angle M_1 and M_2 are the ion and target atom mass respectively. This equation directly relates the energy of the scattered particle to the mass of the target. It can be used also to evaluate the energy after two, three or more collisions.

3-21-2 Applications:

The practical use of ISS is determined by its extreme sensitivity to only the top surface layer (for standard experimental arrangements) or two mono layers (for grazing incidence). Typical applications include composition of catalytic surfaces, thin film coatings, adhesion, as well as arrangement of surface atoms incl. the localization of adsorbed atoms.

3-22 Electrons Paramagnetic Resonance Spectroscopy (EPRS):

Electron spin resonance (ESR) spectroscopy, also referred to as electron paramagnetic resonance (EPR) spectroscopy, is a versatile, nondestructive analytical technique which can be used for a variety of applications including: oxidation and reduction processes, birdcalls and triplet state molecules, reaction kinetics, as well as numerous additional applications in biology, medicine and physics. However, this technique can only be applied to samples having one or more unpaired electrons.

Spectroscopy is the measurement and interpretation of the energy difference between atomic or molecular states. According to Plank’s law, electromagnetic radiation will be absorbed if:

$$\Delta E = h\nu \text{------------------} (3.5)$$

where ΔE is the difference in energy of the two states, h is Plank’s constant and ν is the frequency of the radiation. The absorption of this energy causes a transition of an electron from the lower energy state to the higher energy state. In EPR spectroscopy the radiation used is in the gigahertz range. Unlike most traditional spectroscopy techniques, in EPR spectroscopy the frequency of the radiation is held constant while the magnetic field is varied in order to obtain an absorption spectrum.[47]-[48]

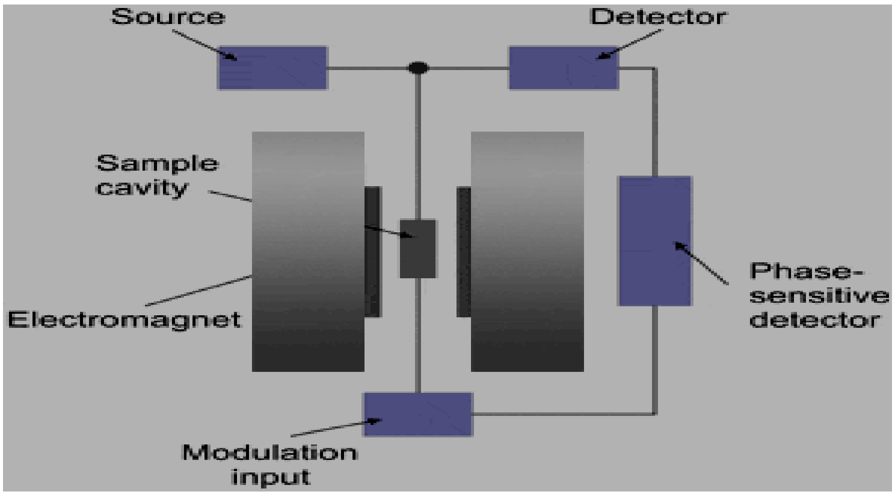


Figure (3-8): Diagram for a typical EPR spectrometer

Figure (3-8) show a block diagram for a typical EPR spectrometer. The radiation source usually used is called a klystron. Klystrons are vacuum tubes known to be stable high power microwave sources which have low-noise characteristics and thus give high sensitivity. A majority of EPR spectrometers operate at approximately 9.5 GHz, which corresponds to about 32 mm. The radiation may be incident on the sample continuously (i.e., continuous wave, abbreviated cw) or pulsed. The sample is placed in a resonant cavity which admits microwaves through an iris. The cavity is located in the middle of an electromagnet and helps to amplify the weak signals from the sample. Numerous types of solid-state diodes are sensitive to microwave energy and absorption lines then be detected when the separation of the energy levels is equal or very close to the frequency of the incident microwave photons. In practice, most of the external components, such as the source and detector, are contained within a microwave bridge control. Additionally, other components, such as an attenuator, field modulator, and amplifier, are also included to enhance the performance of the instrument.

The basis of EPR spectroscopy lies in the spin of an electron and its associated magnetic moment. When an electron is placed within an applied magnetic field, *Bo*, the two possible spin states of the electron have different energies. This energy difference is a result of the Zeeman effect. The lower energy state occurs when the magnetic moment of the electron, μ, is aligned with the magnetic field and a higher energy state occurs where μ is aligned against the magnetic field. The two states are labeled by the projection of the electron spin, M_S, on the direction of the magnetic field, where M_S = -1/2 is the parallel state, and M_S = +1/2 is the antiparallel state.

So for a molecule with one unpaired electron in a magnetic field, the energy states of the electron can be defined as:

$$E = g\mu_B BoM_S = \pm 1/2 g\mu_B Bo \qquad \text{---- (3.6)}$$

Where g is the proportionality factor (or g-factor), μ_B is the Bohr magneton, B_0 is the magnetic field, and M_S is the electron spin quantum number. From this relationship, there are two important factors to note: the two spin states have the same energy when there is no applied magnetic field and the energy difference between the two spin states increases linearly with increasing magnetic field strength. [49]

3-23 Fourier Transform Spectroscopy:

Fourier transform spectroscopy is a measurement technique whereby spectra are collected based on measurements of the coherence of a radiative source, using time-domain or space-domain measurements of the electromagnetic radiation or other type of radiation. It can be applied to a variety of types of spectroscopy including optical spectroscopy, infrared spectroscopy (FTIR, FT-NIRS), nuclear magnetic resonance (NMR) and magnetic resonance spectroscopic imaging (MRSI) mass spectrometry and electron spin resonance spectroscopy. There are several methods for measuring the temporal coherence of the light (field-autocorrelation), including the continuous wave Michelson or Fourier transform spectrometer and the pulsed Fourier transform spectrograph (which is more sensitive and has a much shorter sampling time than conventional spectroscopic techniques, but is only applicable in a laboratory environment).

The term Fourier transform spectroscopy reflects the fact that in all these techniques, a Fourier transform is required to turn the raw data into the actual spectrum, and in many of the cases in optics involving interferometers, is based on the Wiener–Khinchin theorem.[50]

3-23-1Measuring an emission spectrum:

An example of a spectrum: The spectrum of light emitted by the blue flame of a butane torch. The horizontal axis is the wavelength of light, and the vertical axis represents how much light is emitted by the torch at that wavelength.

One of the most basic tasks in spectroscopy is to characterize the spectrum of a light source: How much light is emitted at each different wavelength. The most straightforward way to measure a spectrum is to pass the light through a monochromator, an instrument that blocks all of the light except the light at a certain wavelength (the un-blocked wavelength is set by a knob on the monochromator). Then the intensity of this remaining (single-wavelength) light is measured. The measured intensity directly indicates how much light is emitted at that wavelength. By varying the mono chromator's wavelength setting, the full spectrum can be measured. This simple scheme in fact describes how some spectrometers work.

Fourier transform spectroscopy is a less intuitive way to get the same information. Rather than allowing only one wavelength at a time to pass through to the detector, this technique lets through a beam containing many different wavelengths of light at once, and measures the total beam intensity. Next, the beam is modified to contain a different combination of wavelengths, giving a second data point. This process is repeated many times. Afterwards, a computer takes all this data and works backwards to infer how much light there is at each wavelength.

To be more specific, between the light source and the detector, there is a certain configuration of mirrors that allows some wavelengths to pass through but blocks others (due to wave interference). The beam is modified for each new data point by moving one of the mirrors; this changes the set of wavelengths that can pass through.

As mentioned, computer processing is required to turn the raw data (light intensity for each mirror position) into the desired result (light intensity for each wavelength). The processing required turns out to be a common algorithm called the Fourier transform (hence the name, "Fourier transform spectroscopy"). The raw data is sometimes called an "interferogram". Because of the existing computer equipment requirements, and the ability of light to analyze very small amounts of substance, it is often beneficial to automate many aspects of the sample preparation. The sample can be better preserved and the results are much easier to replicate. Both of these benefits are important in testing situations that may later involve legal action, such as those involving drug specimens.[51]

3-23-2 Measuring an absorption spectrum:

The method of Fourier transform spectroscopy can also be used for absorption spectroscopy. The primary example is "FTIR Spectroscopy", a common technique in chemistry.

In general, the goal of absorption spectroscopy is to measure how well a sample absorbs or transmits light at each different wavelength. Although absorption spectroscopy and emission spectroscopy are different in principle, they are closely related in practice; any technique for emission spectroscopy can also be used for absorption spectroscopy. First, the emission spectrum of a broadband lamp is measured (this is called the "background spectrum"). Second, the emission spectrum of the same lamp shining through the sample is measured (this is called the "sample spectrum"). The sample will absorb some of the light, causing the spectra to be different. The ratio of the "sample spectrum" to the "background spectrum" is directly related to the sample's absorption spectrum.

Accordingly, the technique of "Fourier transform spectroscopy" can be used both for measuring emission spectra (for example, the emission spectrum of a star), and absorption spectra (for example, the absorption spectrum of a liquid).

3-24 Photo thermal Spectroscopy:

Photo thermal spectroscopy is a group of high sensitivity methods used to measure optical absorption and thermal characteristics of a sample. The basis of photo thermal spectroscopy is a photo-induced change in the thermal state of the sample. Light energy absorbed and not lost by subsequent emission results in sample heating. This heating results in a temperature change as well as changes in thermodynamic parameters of the sample which are related to temperature. Measurements of the temperature, pressure, or density changes that occur due to optical absorption are ultimately the basis for the photo thermal spectroscopic methods.[52]

3-24-1 Basic Processes in Photo thermal Spectroscopy:

The basic processes responsible for photo thermal spectroscopy signal generation are shown in Figure (3-9). Optical radiation, usually from a laser, is used to excite a sample. The sample absorbs some of this radiation resulting in an increase in the internal energy. The internal energy is dispersed in two different modes of hydrodynamic relaxation. The increased internal energy results in a temperature change in the sample or the coupling fluid placed next to the sample. This temperature change results in a change in sample or coupling fluid density.

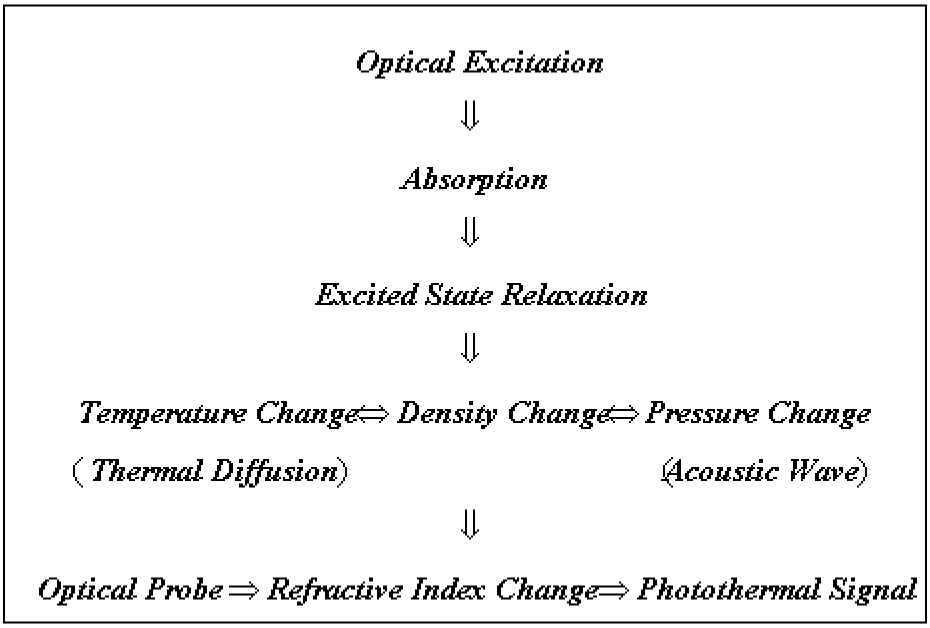


Figure (3-9): Processes involved in photo thermal spectroscopy.

If the photo thermal induced temperature change occurs faster than the time required for the fluid to expand or in a few cases contract, then the rapid temperature change will result in a pressure change. The pressure perturbation will disperse in an acoustic wave. Once the pressure has relaxed to the equilibrium pressure, a density change proportional to the temperature will remain.

In either case there will be a change in temperature induced by the absorption of optical energy. This temperature change will in turn result in a density change in the sample. In combination, temperature and density changes affect other properties of the sample. Photo thermal spectroscopy is based on a measurement of these properties. In particular, the sensitive photo thermal methods are based on measurement of the refractive index change that occurs with changes in temperature and density of the sample.[53]

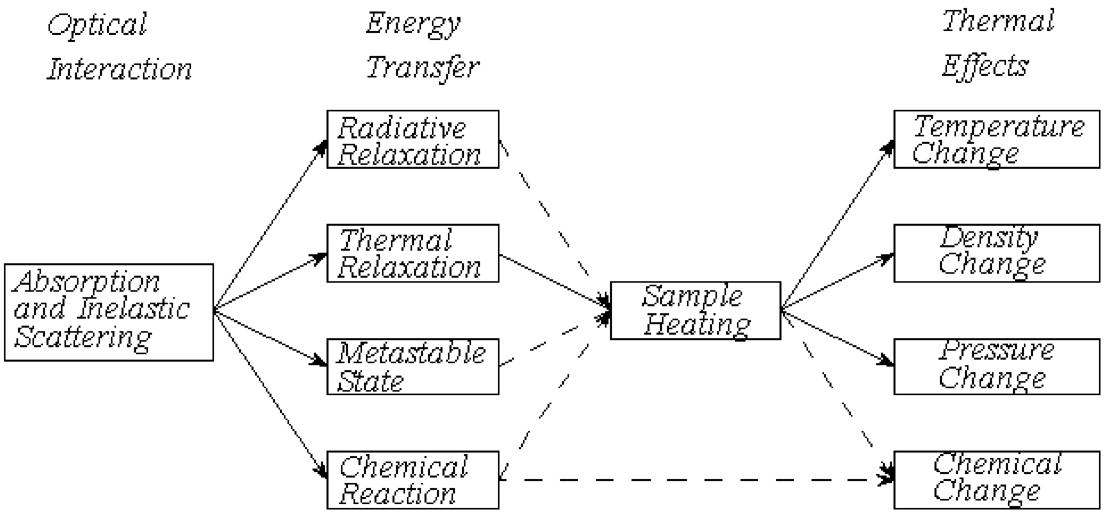


Figure (3-10): Several of the mechanisms for excited state relaxation .

There are three main areas that must be considered when attempting to obtain a quantitative description of the photo thermal spectroscopy signal. The first is a description of the optical absorption and excited state relaxation processes. Optical excitation followed by excited state relaxation results in sample heating. The rates and amounts of excited state excitation and relaxation will control the rate and magnitude of heat production. The energy transfer steps that need be accounted for are shown in Figure (3-10). Energy can be transferred to the sample by optical absorption and inelastic scattering process such as Raman. Scattering is inefficient and the amount of energy lost to sample is usually small enough to be neglected. After absorption, the molecules are in an excited state. Excited state relaxation transfers energy to the solvent or sample matrix. Radiative relaxation does not result in complete loss of the absorbed energy to the sample. Some of the energy is lost in the form of the radiated light. Thermal relaxation transfers the energy to the sample matrix and results in sample heating. Excited species may also form long lived metastable states that trap energy and prevent further optical absorption. This will result in a delayed heating of the sample. The excited state species may also participate in photochemical reactions.

Photochemical reaction can produce heat but also produce new chemical species which alter the thermal and optical characteristics of the sample.

These relaxation processes may all produce excess energy in the form of heat. The heat increases the internal energy of the sample. The sample will respond to this increased energy. The second area is that of the hydrodynamic relaxation. After optical heating, the sample is not at thermal equilibrium with itself or with the surrounding environment during a measurement. Heat generated by the optical excitation and relaxation processes will result in thermal gradients between the excited sample and the surroundings. The thermal gradients result in heat transport. Heat is transferred within the sample in a fashion such as to move toward thermal equilibrium. Hydrodynamic relaxation produces changes in the temperature, pressure, and density of the sample.

The third area is that of the signal generation process. Photo thermal spectroscopy signals are based on changes in sample temperature or related thermodynamic properties of the sample. These are usually monitored through the refractive index of the sample or a thermal coupling fluid placed in contact with the sample. Several properties may affect the refractive index of the medium. The most common is the density. However the refractive index may also change with temperature, population in optically excited states, and with chemical composition if photochemical reaction occurs. There are a variety of instrumental methods used to probe the changes in the sample's refractive index. Other instrumental methods used for photo thermal spectroscopy directly probe the temperature or related thermodynamic properties, but the most sensitive methods probe the spatial or temporal gradients of these properties.[54]

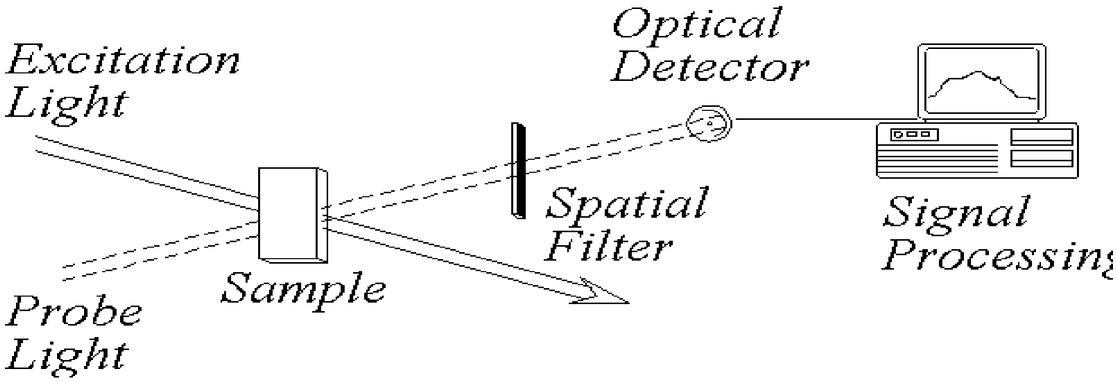


Figure (3-11): A generic photo thermal spectrometer showing essential features.

Table (3-2): Detection techniques used in photo thermal spectroscopy

Thermodynamic Parameter	Measured Property	Detection Technique
Temperature	Temperature Infrared Emission	Calorimetry Photothermal Radiometry
Pressure	Acoustic Wave	Photoacoustic Spectroscopy
Density	Refractive Index Surface Deformation	Photothermal Lens Photothermal Interferometry Photothermal Deflection Photothermal Refraction Photothermal Diffraction Surface Deflection

A schematic diagram illustrating the main components to apparatuses used for photo thermal spectroscopy is shown in Figure (3-11). Most apparatuses consist of six main components;

1. sample
2. light used for sample excitation
3. light used to monitor refractive index perturbations
4. a mask, aperture, or other form of spatial filter for the probe light
5. an optical detector used to detect the optically filtered probe light
6. electronic signal processing equipment

The excitation light heats the sample. The probe light monitors changes in the refractive index of the sample resulting from heating. The spatial and propagation characteristics of the probe light will be altered by the refractive index. The spatial filter selects those components of the altered probe light that change with the samples' refractive index. The optical detector monitors changes in the probe light power past the spatial filter. In some apparatuses, a spatial filter and a single channel detector are combined using an image detector. Signals generated by the photo detector are processed to enhance the signal to noise ratio.

In addition, an apparatus may also be equipped with detectors to monitor the excitation and probe light power, a thermostatic sample holder, and optical spatial filters to control the spatial profiles of the excitation and probe light. This additional equipment is used to control the experiment environment and to measure the optical power required to accurately quantify changes that occur in the sample. These components are necessary when the data must be used to determine absolute absorption of the sample.

In theory, the photo thermal spectroscopy signal can be accurately calculated based on knowledge of the experimental apparatus, the parameters that characterize light propagation, and the optical parameters of the sample. The following items must all be calculations;

1. determine the optical absorption resulting in sample heating
2. determine the rate of heat production
3. determine the temporal and spatial temperature and density change
4. relate the refractive index change to the temperature or density change using the thermal-optical parameters of the sample
5. calculate the strength of the optical element formed from the spatial-dependent refractive index change
6. Calculate the optical and electronic signal resulting from passage of light through apertures or using specialized detectors.

Each of these apparatuses detects the change in refractive index that accompanies optical absorption. Photo detectors are used to monitor probe power changes. These power signals are time dependent. The analytical signal is usually related to the change in detected power relative to the incident power of the probe. There are three main types of time dependence that analytical signals can have. These in turn depend on the temporal character of the excitation source. The main excitation and detection schemes are given in table (3-3).

3-24-2 Application of Photo thermal Spectroscopy:

There have been many applications of photo thermal methods for chemical and material analysis.

1. Photo thermal spectroscopy: the signal magnitude is measured as a function of wavelength in this application. The photo thermal signal is proportional to the absorbed light. So the spectrum is technically an excitation spectrum. The resulting excitation spectrum can be an accurate measure of the absorption spectrum if the thermal quantum yield and fraction of light transmitted to the absorber do not change with wavelength. This technique has found widespread use for solid sample analysis where incoherent excitation light sources can be used. Applications to liquid and gas sample analysis has been limited because of the difficulties encountered when attempting to scan the wavelengths of lasers while keeping them focused at a particular position.
2. Photo thermal detection: is similar to photo thermal spectroscopy only a single wavelength source is used to excite the sample. The signal magnitude can be related to sample absorbance or analyze concentration. Samples must be prepared and separated so that there is no interference absorption and so that the sample matrix is

the same for all measured samples. The main application is for trace analysis. Although not restricted to coherent sources, this application is normally performed using laser excitation sources to enhance the limits of detection. The application is also suited for effluent detection in chromatography. The spatial coherence of lasers allows the use of small volume detection cells or on-column detection.

3. Photo thermal monitoring of excitation and relaxation process: in this application the signal magnitude is measured as a function of time or excitation irradiance. The time dependent data is used to deduce photo physical and photochemical parameters such as excited state lifetimes, enthalpies of formation, lifetimes of meta stable states, and thermalization times. The excitation irradiance dependent data can be used to calculate multi photon absorption cross-sections and parameters relating to optical saturation and bleaching.
4. Photo thermal probing of the physical properties: many of the physical properties of a sample can be determined using photo thermal methods. Photo thermal methods have been used to measure temperature, thermal diffusivities, sound velocity, bulk flow velocities, surface thickness, and specific heats. In homogeneous samples, the full photo thermal transient is typically analyzed in order to obtain this information. However, some of these parameters can be determined by measuring signal magnitudes, signal decay times, and signal onset times for carefully designed experiments. Thermal properties of heterogeneous samples can be obtained by raster scanning the optical excitation source over the sample surface. In this case the signal magnitude and phase is measured as a function of spatial coordinate.

3-25 Force Spectroscopy:

Force spectroscopy is a dynamic analytical technique that allows the study of the mechanical properties of single polymer molecules or proteins, or individual chemical bonds. It is performed by pulling on the system under scrutiny with controlled forces. As a single-molecule technique, as opposed to typical ensemble spectroscopies, it allows a researcher to determine properties of the particular molecule under study. In particular, rare events such as conformational change, which are masked in an ensemble, may be observed.

The name "force spectroscopy", although widely used in the scientific community, is somewhat misleading, because there is no true matter-radiation interaction. Force spectroscopy measures the behavior of a molecule under stretching or torsion mechanical force.[55]

3-26 Flow Injection Analysis Spectroscopy (FIAS) :

Flow Injection Analysis (FIA) is a simple rapid and versatile technique that is now firmly established with wide spread application in quantitative chemical analysis.[56]

3-27 X-Ray Absorption Fine Structures Spectroscopy:

X-Ray Absorption Fine Structures Spectroscopy uses the x-ray photo electric effect and the wave nature of electron to determine local structures a round selected atomic species in materials , unlike x-ray diffraction it does not require long range transitional order it works equally well in amorphous materials, liquids, solids and molecular gases.[57]

CHAPTER (IV)

X-Ray Fluorescence (XRF)

4-1 Introduction:

XRF analysis is a powerful analytical tool for spectrochemical determination of almost all the elements present in a sample, XRF radiation is induced when photons of sufficiently high energy emitted from an X-ray source impinge on a material. These X-rays undergo interaction processes with analytic atoms. High energy photons induced ionization of inner shell electrons by photoelectric effect and thus electron vacancies in inner shells $(K, L, M, \dots\dots)$ are created. The prompt transition of outer shall electrons into these vacancies can cause the emission of characteristic fluorescence radiation. The family of characteristic X-rays from each element including all transitions allows of identification of the element.

The working principle of XRF analysis is the measurement of wave length or energy and intensity of characteristic X-ray photons emitted from the sample. This allows the identification of the element present in the analyzed and the determination of their mass or concentration.

All the information for the analysis is stored in the measured spectrum, which is a line spectrum with all characteristic lines superimposed above a certain fluctuating background.

XRF samples are submitted to excitation either by X-rays from isotopic source or X-ray tube or through bombardment by accelerated particles such as protons or alpha rays. When an element in the sample is excited electrons from inner shells may be ejected leading to unfilled orbital levels .The element regains its initial state by transference of the outer orbital electrons to unfilled inner levels with energy.

X-ray fluorescence (XRF) analysis is one of the most common non destructive methods for qualitative as well as quantitative determination elemental composition of the materials. It is suitable for solids, powder and liquids.

XRF are two main methodological techniques that are wave length dispersive analysis (WD-XRF) and energy dispersive analysis (ED-XRF) where the spectra are collected simultaneously in wide energy range.

The range of detectable elements varies a according to instrument configuration and setup, but typically (ED-XRF) covers all elements from sodium to uranium, while (WD-XRF) can extend this down to beryllium.

X-rays fluorescence is defined as" the emission of characteristic secondary or fluorescence x-rays from a material that has been excited"

The phenomena are widely used in elements analysis.[58]

4-2 Bremsstrahlung:

We have obvious that whenever charged particles are accelerated, radiation will be produced. For elementary particles this effect was first observed when high-energy electrons entered material and quickly lost their energy, which was therefore called braking radiation (in German). For relativistic particles this can be an appreciable deposition of the energy when a particle enters material, in addition to the energy transferred to the particles on which the scattering takes place. Experimentalists use this to measure the energy of electrons, as the radiation produced (as photons) often pair-produce, so the measurement of all the energy of charged particles produced measures that of the original electron.[59]

The process of scattering occurs on an atomic or subatomic scale, and therefore over a very short time interval, so the details of the scattering should be irrelevant when discussing frequencies corresponding to wavelengths larger than an angstrom.

$$\boldsymbol{A(\omega)} = \sqrt{\frac{q^2}{8\Pi^2 c}}\; e^{\frac{i\omega_k}{c}} \int_{-\infty}^{+\infty} e^{i\omega_l \frac{(t-n^{\rightarrow}.r^{\rightarrow}(t))}{c}} \frac{d}{dx}\left[\frac{n^{\rightarrow}\times(n^{\rightarrow}\times B)}{1-n^{\rightarrow}B}\right] dt \text{-----} \textbf{(4-1)}$$

We can assume that the $\frac{d}{dt}$factor contributes over such a small range of t values that the phase $\frac{i\omega(t-n^{\rightarrow}r^{\rightarrow}(t))}{c}$can be taken to be an irrelevant constant phase, and therefore we have an integral of a total derivative, given by the difference of its final and initial values. Projecting the contribution of a single polarization $\xi^{\rightarrow}$, which is perpendicular to $n^{\rightarrow}$, we have

$$\frac{d^2 I}{d\omega d\Omega} = \frac{q^2}{4\Pi^2 c}\xi^{\rightarrow}\left[\frac{\beta_f}{1-n^{\rightarrow}\beta_f} - \frac{\beta_i}{1-n^{\rightarrow}\beta_i}\right]^2 \text{-------------------} \textbf{(4-2)}$$

This formula has a disturbing feature with difficulties at both ends of the frequency spectrum, as it is independent of frequency. This is problematic at the high frequency end because it seems to say that integrating over all frequencies, the total power into any solid angle is infinite. This is not a serious problem, however, because for high frequency our approximation that the acceleration occurs in a time interval small compared to $\frac{1}{\omega}$ is unphysical, and we expect there to be modifications at that end. At the other end, however, our approximation is valid. There is no divergence in the energy radiated, but the quantum-mechanical interpretation is a problem. Quantum mechanically, radiation consists of photons, each of energy $\hbar\omega$, and if we get a classical prediction that we should have an energy deposit of ΔEin a small range of frequencies nearω, we need to interpret that quantum-mechanically that we have an expected number of photons $\frac{\Delta E}{\hbar\omega}$ in that range. But we are predicting energy/unit frequency to be constant and nonzero down to zero frequency, so the expected number of photons per energy range diverges as $\omega \rightarrow 0$. Usually in quantum physics we ask for the probability that, starting from some initial state, we wind up in a given final state, and here we are finding that the probability that an electron scatters from a nucleus, for example, without any additional particles in the final state, is zero. This is known as infrared divergence, and in quantum field theory we need to take into account that any experimental arrangement has a lowest energy cutoff ∂E, below which a photon could not have been detected, so when we measure the cross section for elastic scattering$\beta_i \rightarrow \beta_f$, we are actually including processes for which an arbitrary number of very soft photons, with total energy totaling less than ∂E.

Beyond those difficulties, the most noticeable feature of bremsstrahlung radiation for ultra relativistic particles is the strong peaking in the directions of the final particle and the initial particle. We can think of these as parts of the Coulomb field that have travelled on without noticing that the particle got bumped. In quantum field theory, what is relevant is that the state of the charged particle, of mass m with momentum $P^{\propto}$ together with the photon of momentum $K^{\propto}$has a mass.

$$\boldsymbol{M^2 = \frac{1}{c^2}(p^{\propto} + k^{\propto}) = m^2 + \frac{2}{c^2}p^{\propto}k_{\propto} = \frac{2m|k|\gamma}{c}(1 - n^{\rightarrow}\beta^{\rightarrow}) \approx m^2 + \frac{m|k|}{\gamma_c}(1 + \gamma^2\theta^2)} \text{ --- } \textbf{(4-3)}$$

Which goes to m^2as $\beta \rightarrow 1$and the angle between the photon and the charged particle goes to zero. Thus in some ways it acts as if this combination were the single charged particle.

4-2-1 Bremsstrahlung in Beta Decay:

Beta decay is a weak interaction process in which a neutron or proton in a nucleus emits an electron or positron and an antineutrino or neutrino, turning into a proton or neutron respectively, and thereby changing the charge of the nucleus by one unit.

$$\boldsymbol{Z \rightarrow (Z \pm 1) + e^{\mp} + \nu} \text{ ------------------------------------- } \textbf{(4-4)}$$

While the electron or positron was created, and not previously residing in the nucleus, its charge was there, so as far as the electromagnetic field is concerned, we have a charge at rest until the sudden decay, and then a pretty-much instantaneous acceleration to a large final velocity. Assuming the decay takes place at $t = 0$, we have

$$\frac{d^2I}{d\omega d\Omega} = \frac{q^2}{4\Pi^2 c}\left[\frac{\xi^{\rightarrow}.\beta^{\rightarrow}}{1-n^{\rightarrow}\beta^{\rightarrow}}\right]^2 \text{-----------------------------------} \textbf{(4-5)}$$

Where $c\beta$is the final velocity of the$e^{\mp}$, and we are assuming $\omega$is small enough. Small enough might mean compared to the scale of the nucleus or nucleon size, as we might imagine the acceleration occurs on this distance scale, but more obviously, if we take into account the fact that any radiation will be quantized in units of ђω , we must have

ђω $< (m_z - m_{z\pm1} - m_e)c^2$------------------------- **(4-6)**

The radiation in the $n^{\wedge}$direction is polar-ized, as the component perpendicular to the plane containing $n^{\wedge}$ and $\beta^{\rightarrow}$ is not excited (by $\xi^{\rightarrow}.\beta^{\rightarrow}$ for the direction that is excited $\xi^{\rightarrow}.\beta^{\rightarrow} = \beta\sin\theta$ and

$$\frac{d^2I}{d\omega d\Omega} = \frac{q^2}{4\Pi^2 c}\beta^2\frac{\sin^2\theta}{(1-n^{\rightarrow}\beta^{\rightarrow})^2} \text{-----------------------------} \textbf{(4-7)}$$

Integrating over all angles,

$$\int d\Omega = \int \sin\theta\, d\theta d\Phi = 2\Pi\int_{-1}^{1} du \text{ -----------------------} \textbf{(4-8)}$$

We have

$$\frac{dI}{dW} = \frac{e^2}{4\Pi^2 c}2\Pi\int_{-1}^{1}\beta^2\frac{(1-u^2)}{(1-\beta u)^2}\,du$$

$$= \frac{e^2}{2\Pi\beta c}\int_{1-\beta}^{1+\beta}\frac{\beta^2 - 1 + 2x - x^2}{x}\,dx$$

$$= \frac{e^2}{\Pi c}\left[\frac{1}{\beta}\ln\frac{1+\beta}{1-\beta} - 2\right] \qquad \textbf{(4-9)}$$

The predicted intensity distribution has no ω! dependence, but we have already discussed that there is a cutoffω_{max}. The energy per frequency value is not large. For small β the term in brackets is $\frac{2\beta^2}{3}$, and we have

$\frac{dI}{dW} = \frac{2e^2\beta^2}{3\Pi c}$.--------------------------------- **(4-10)**

Let's compare the energy radiated to the lost rest mass energy ΔEwhich gives the upper limit $\omega_{max} = \frac{\Delta E}{\hbar}$. Multiplying $\frac{dI}{dW}$ by the cutoff frequency we see that the fraction of energy lost going into radiation is less than$\frac{2e^2\beta^2}{3\Pi\hbar c}$. At the fine structure constant$\propto = \frac{e^2}{\hbar c} \approx \frac{1}{137}$, we see this is well less than 1% .As for bremsstrahlung in scattering, the low frequency limit predicts an infinity at zero frequency in the number spectrum for photons emitted, though the total energy emitted is small.

There is some interest in this lost energy, though it is often ignored, because one way to try to measure neutrino masses is to look for a cutoff in the energy spectrum of the electrons. The energy difference between the parent and daughter nucleus is shared between the electron, the neutrino, and any photons which accompany them. If the neutrino has a mass, there is a lower limit on the energy it can have, and thus an upper limit on the electron energy distribution which is slightly less than$(m_z - m_{z+1})c^2$. The expected energy distribution from quantum mechanics, ignoring photon production, might be misleading, however, if inner bremsstrahlung photons are taking off some of the energy.[60]

4-2-2 Bremsstrahlung radiation :

When the negatively charged high-speed electron approaches the positively charged nuclear field of the target atom, it is deviated from the original path because of the attraction between the opposite charges. As the electron is slowed down, it loses some of its kinetic energy. The lost kinetic energy is in the form of an x-ray. The energy of the x-ray is equivalent to the loss of kinetic energy. This process is given the name Bremsstrahlung or braking radiation it is polyenergetic or non-uniform in energy and wavelength because the amount of deceleration varies among electrons according to their speed and how closely they approach the nucleus.[61]

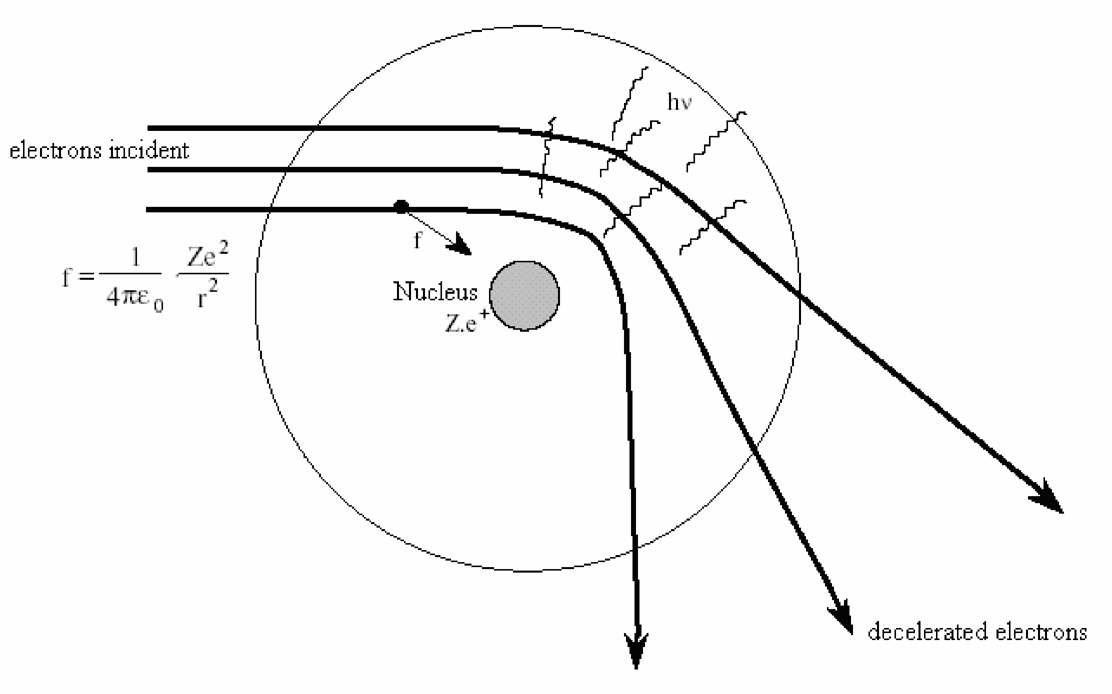
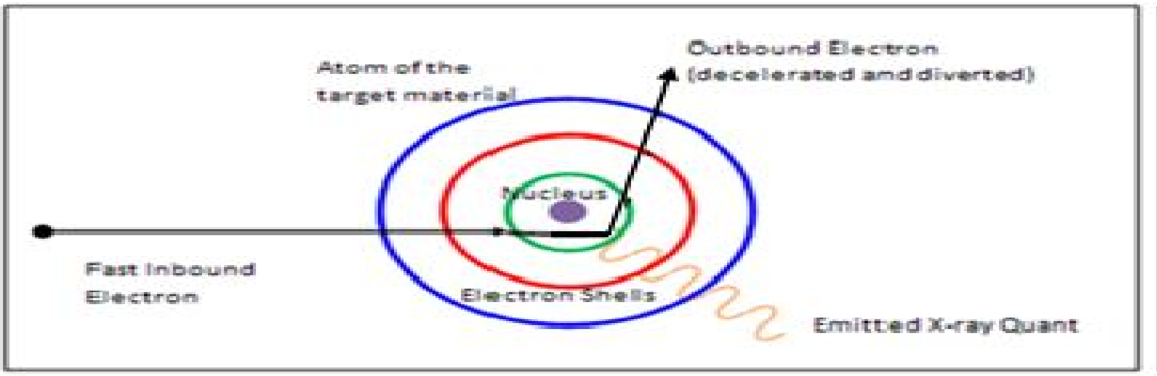


Figure (4-1): Classical model showing the production of Bremsstrahlung.



Figure(4-2): Diagram of the Bremsstrahlung effect

4-3 Bohr's Atomic Model:

Bohr's atomic model describes the structure of an atom as an atomic nucleus surrounded by electron shells (Figure 4-2). The positively charged nucleus is surrounded by electrons that move within defined areas (shell). The differences in the strength of the electron's bonds to the atomic nucleus are very clear depending on the area or level they occupy, i.e., they vary in their energy. When we talk about this, we refer to energy levels or energy shells. This means that a clearly defined minimum

amount of energy is required to release an electron of the innermost shell from the atom. To release an electron of the second innermost shell from the atom, a clearly defined minimum amount of energy is required that is lower than that needed to release an innermost electron. An electron's bond to an atom is weaker the further away it is from the atom's nucleus. The minimum amount of energy required .to release an electron from an atom, and thus the energy with which it is bound to the atom, is also referred to as the binding energy of the electron to the atom. The binding energy of an electron in an atom is established mainly by determining the incident. It is for this reason that the term absorption edge is very often found in Energy level = binding energy = absorption edge
The individual shells are labelled with the letters K, L; M; N, …, the innermost shell being the K-shell, the second innermost the L-shell etc. the K-shell is occupied by 2 electrons;the L-shell has three sub-levels and can contain up to a total of 8 electrons. The M-shell has five sub-levels and can contain up to 18 electrons.

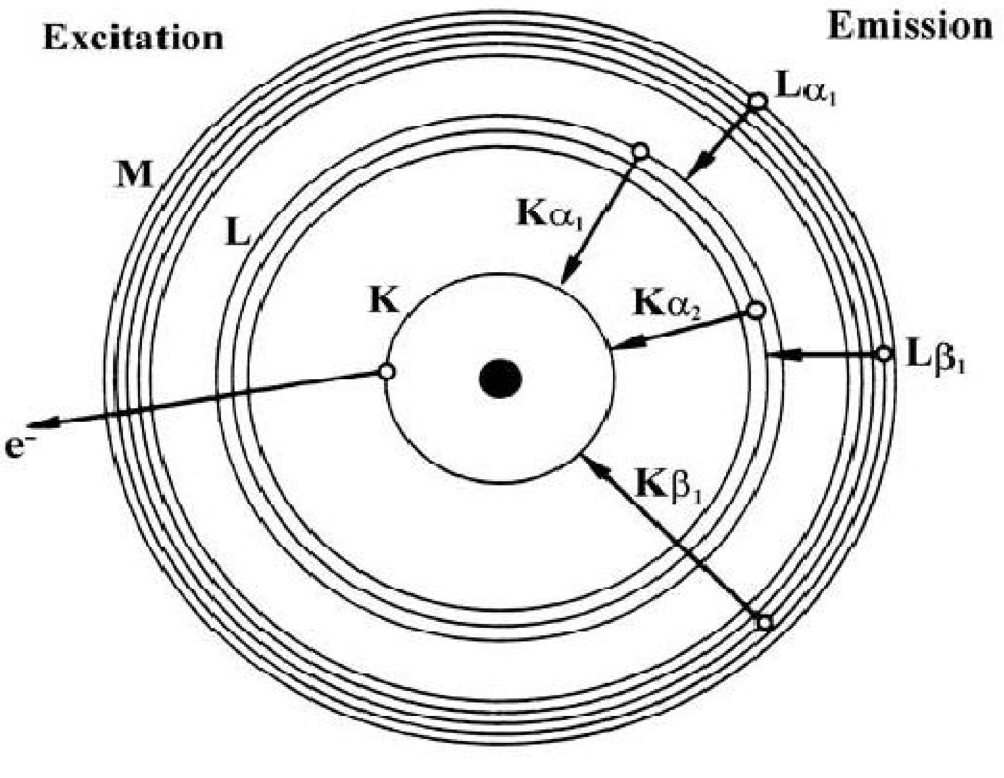


Figure (4-3): Bohr's atomic model, shell model**.**

4-4 Theoretical Principles of X-ray fluorescence Spectroscopy:

The principle of XRF methodologies is based in the use of some excitation radiation to produced of the ionization of the atom present in the sample due to photo electric absorption, the process of the atom ionization and X-ray characteristic emission in **figure (4-4).**If the photon with energy $E_\circ$ large than the binding energy of inner electron orbital $\left(E^{a,b}{}_{K,L,M}\right)$impinges into the atom, part of the energy can absorbed with certain probability $\tau(E_O)$ photo electric absorption and the atom ionized. The atom can return to it is rest energy by one of two possible processes (c, d) being $\boldsymbol{\omega}$ the probability of the X-ray characteristic emission to occur fluorescence yield.

The fluorescent yield takes a value around unity of higher atomic numbers to less than 0.01for the low atomic elements. It is mainly for this reason that the sensitivity of X-ray spectrometric technique is rather poor for light elements.

Moseley write the formula of wave length of the characteristic emission with atomic number as:$v = k(z - \sigma)^2$ where K and σ are constants with values are specific for the energy distribution levels and sub-levels involved in given transition.

The wavelength and the energy of photon can be related using the Plank constant ђ and speed of light $E = ђcv = \frac{ђc}{\lambda}$

The XRF signal is the intensity of measured characteristic radiation in counts per seconds which is proportional to the mass fraction of the element originating it in the analyzed sample. However this relationship is not linear in the more general case, since it depends on physical and chemical matrix effects.

Physical matrix effects are results of variations in the physical characteristic of the sample including particle size, uniformity and surface condition although and consistent sample.

The term fluorescent is applied to phenomena in which the absorption of higher energy radiation results in the re-emission of lower energy radiation.

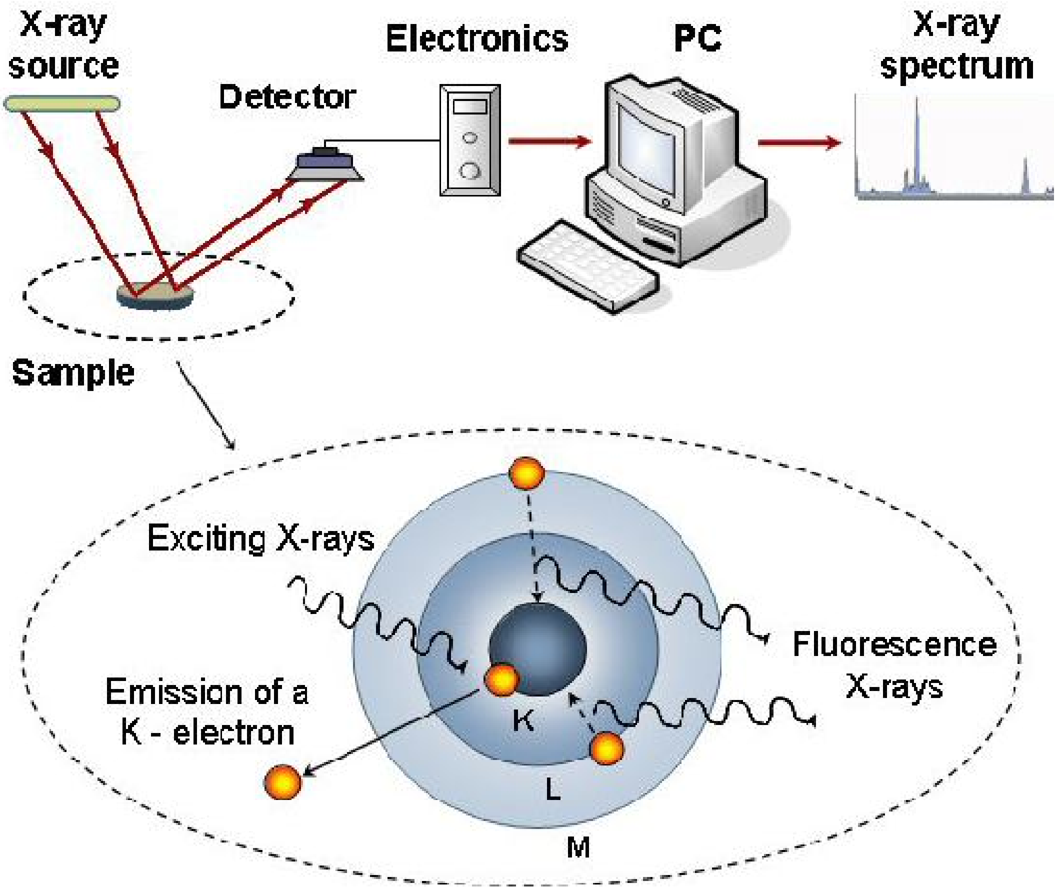


Figure (4-4): A schematic view of the XRF principle.

4-4-1 X-Ray Fluorescence basic process:

X-Ray Fluorescence (XRF) can be considered in a simple three step process occurring at the atomic level:

1- An incoming x –ray knocks out an electron from one of the orbital's surrounding the nucleus with in an atom of the materials.

2- A hole is produced in the orbital resulting in a high energy unstable configuration for the atom.

3- To restore equilibrium, an electron from a higher energy, outer orbital falls into the hole. Since this is lawer energy position, the excess energy is emitted in the form of a fluorescence x-ray.

The energy difference between the expelled and replacement electrons is characteristic of the element atom in which the fluorescence process is occurring, these the energy of the emitted fluorescence-ray is directly like to specific element, being analyzed.

The important feature of the XRF is the possibility of performing a chemical analysis in rapid and non destructive way.

In particular this technique allows us:

(a) Qualitative analysis for the identification of elements through the position of the typical X-ray emission lines in the XRF spectra.

(b) Quantitative analysis needs an accurate data, analysis a counting for the intensity of the different X-ray emission lines.

4-5 Production of Characteristic Fluorescence Radiation:

The classical model of an atom is a nucleus with positively charged protons and none charged neutron, surrounded by electron grouped in shell (K, L, M…) the L shell has three sub shells and M shell has five sub shells.

The K shell contain two electrons, the L shell contain eight electrons and the M shell contain18 electrons , the energy of an electron depends on the shell it occupies , and on the element to which it belong.

When irradiating atom particles such as X-ray photons and electrons with sufficient energy can expel an electron from the atom, this produce a hole in a shell, a hole the K –shell putting the atom in an unstable excited state with high energy. The atoms want to be restoring the original configuration and this done by transferring an electron from outer shell such as the L-shell to the hole in the K-shell. An L-shell electron has a high energy than a K-shell electron, and when L-shell electron is transferred to K-shell, the energy surplus can be emitted as an X-ray photon in spectrum; this is seen as a line. [62]

The energy of the emitted X-rays depends on the difference in energy between the shell with the initial hole and the energy of the electron that fill the hole. Each atom has its specific energy level, so the emitted radiation is characteristic of that atom .An atom emits more than a single energy (or line) because different holes can be produced, and different electron s can fill these.

The collection of the emitted lines is characteristic of the element and can be considered a finger print of the element.

To expel an electron from atom the X-rays must have a higher energy level than the binding energy of the electron. If an electron is expelled the incoming radiation is absorbed and the higher the absorption the higher fluorescence.

If the energy of incident photons is lower and comes closer to the binding energy of the K-shell electrons more and more of the radiation is absorbed. The highest yield is reached when the energy of the photon is just above the binding energy of the electron to be expelled.

The fluorescent yield is the ratio of the emitted fluorescent photons and the number of the initial vacancies.

4-6 Fluorescence Yield:

When an electron is ejected from an atomic orbital by the photoelectric process, there are two possible results: X-ray emission, or Auger electron ejection (Figure 4-5). One of these two events occurs for each excited atom, but not both. Therefore, Auger electron production is a process which is competitive with X-ray photon emission from excited atoms in a sample.

The faction of the excited atoms which emits X-rays is called the Fluorescent yield. This value is a property of the element and the X-ray line under consideration. (Figure 4-6) shows a plot of X-ray fluorescent yield versus atomic number of the elements for the K and L lines. It is an unfortunate fact that low atomic number elements also have low fluorescent yield.[63]

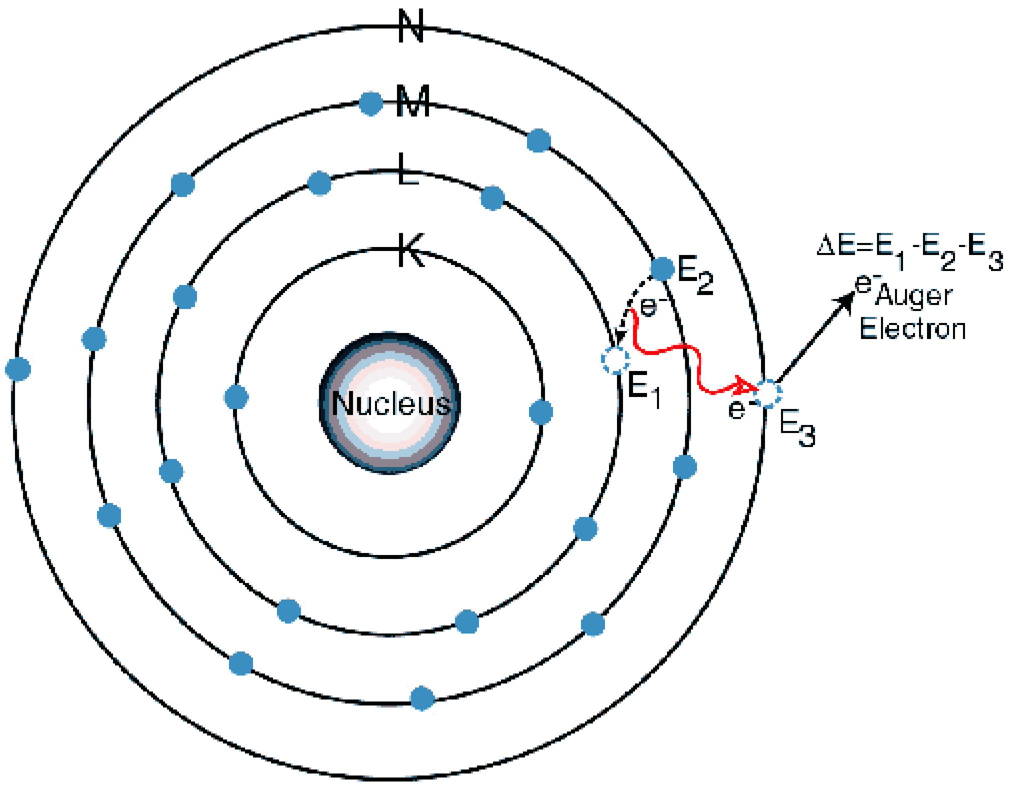


Figure (4-5): The excitation energy from the inner atom is transferred to one of the outer electrons causing it to be ejected from the atom (Auger electron).

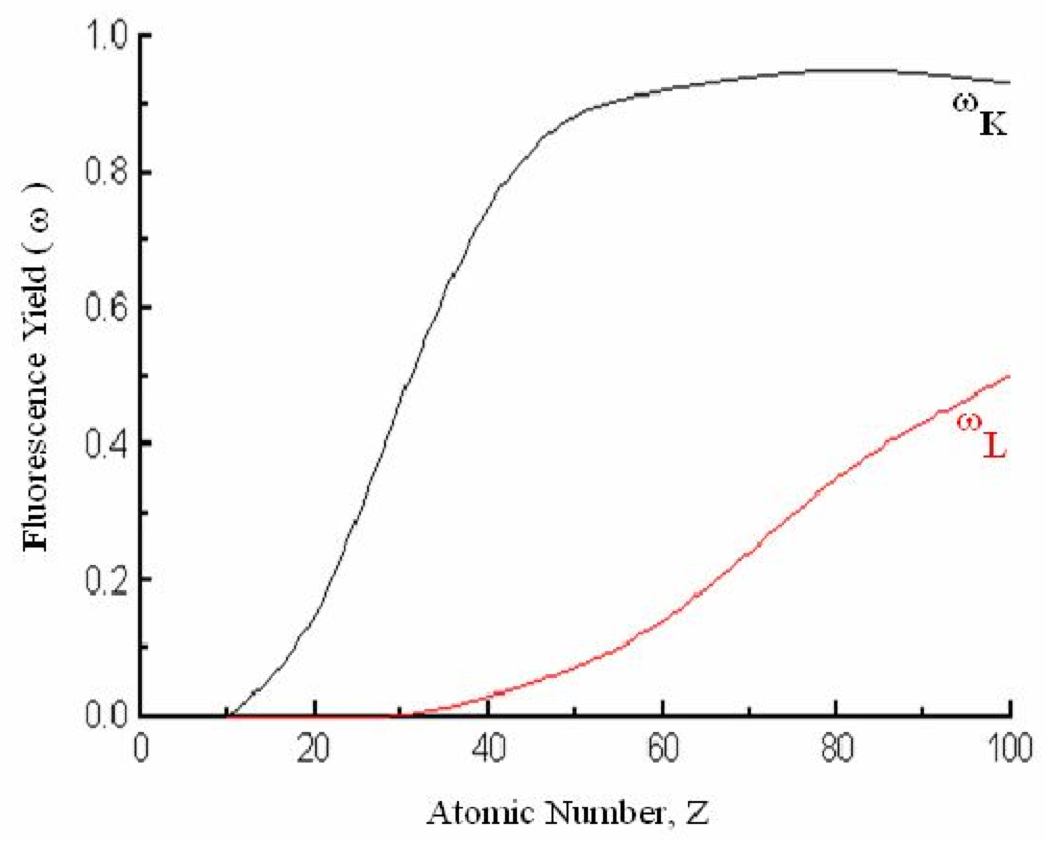


Figure (4-6): Fluorescent yield versus atomic number for K and L lines.

4-7 Radioisotope Sources of XRF:

Radioisotopes are commonly used because of their stability and small size when continuous and monochromatic sources are required.

Radioisotope XRF systems are often tailored to a specific but limited range of applications. They are simpler and often considerably less expensive than analysis systems based on X-ray tubes, but these attributes are often gained at the expense and flexibility.

Radioisotope excitation is preferred to X-ray tubes when simplicity, ruggedness, reliability and cost of equipment are important; when a minimum size, weight and power consumption are necessary; when a very constant and predictable X-ray output is required; and when the use of high energy X-rays is advantageous. Radioisotope systems, especially those involving scintillation or proportional detectors, must be carefully matched to the specific application.[64]

Table (4-1): Typical radioisotope sources used for XRF.

Isotope	**Fe-55**	**Cm-244**	**Cd-109**	**Am-241**	**Co-57**
Energy (keV)	**5.9**	**14.3 - 18.3**	**22.88**	**59.5**	**122**
Elements (K-lines)	**Al –v**	**Ti –Br**	**Fe -Mo**	**Ru -Er**	**Ba- U**
Elements (L-lines)	**Br – I**	**I – Pb**	**Yb - Pu**	**None**	**None**

4-8 X-Ray Fluorescence Analysis (XRF):

4-8-1 Source of radiation:

(i) Conventional X-ray tubes most commonly used because their output can readily be "tuned" for the application and because very high power can be deployed.

(ii)γ -ray sources used without the need for an elaborate power supply allowing use in a small portable instrument.

(iii)Synchrotron focused by an optic, X-ray beam can be very small and very intense, and atomic information on the sub micrometer scale can be obtained.

4-8-2 Dispersion:

In the energy dispersive analysis the fluorescence X-rays emitted by the material sample are directed into a solid state detector which produces a continuous distribution of pulse, the voltage of which is proportional to the incoming photon energies. This signal is processed by multichannel analyzer (MCA) which produces an accumulating digital spectrum that can be processed to obtain analytical data.

In the wave length dispersive analysis the fluorescence X-rays emitted by the material sample are directed into a diffraction grating monochromatic. The diffraction grating used is usually a single crystal .

4-8-3 X-ray Intensity:

The secondary radiation is much weaker than the primary beam, furthermore, the secondary radiation from lighter elements is of low energy (long wave length) and has penetrating power and is severely attenuated if the beam passes through air from any distance.[65]

4-8-4 Energy Dispersive Spectrometry:

In energy dispersive spectrometry (EDX or EDS) the detector allows the determination of the energy of the photon when it is detected. Detectors based on silicon semiconductors in the form of lithium drifted silicon crystal or high purity silicon wafers.

4-9 Energy Dispersive X-ray Fluorescence (ED-XRF):

In Energy Dispersive X-Ray Fluorescence spectrometry (ED-XRF), the identification of characteristic lines is performed using detectors that directly measure the energy of the photons. In the simplest case an electron is ejected from an atom of the detector material by photo absorption. The loss of energy of this just created primary election results in a shower of electron-ion pairs in the case of a proportional counter, optical excitations in the case of scintillation counter, or showers of electron-hole pairs in a semiconductor detector. The resulting detector signal is proportional to the energy of the incident photon, in contrast to wavelength dispersion in which the Bragg reflecting properties of a crystal are used to disperse X-rays at different reflection angles according to their wavelengths. Although energy dispersive detectors generally exhibit poorer energy resolution than wavelength dispersive analyzers, they are capable of detecting simultaneously a wide range of energies.

The most frequently used detector in EDXRF is the silicon semiconductor detector, which nowadays can have excellent energy resolution. The two other types of detectors, mentioned above, with their poorer energy resolution are limited to special cases where certain features of semiconductors are not acceptable. Also the germanium semiconductor detector with its comparable characteristics has a major drawback for conventional XRF: inherently the escape peaks of intense lines can obscure other lines of interest.[66]

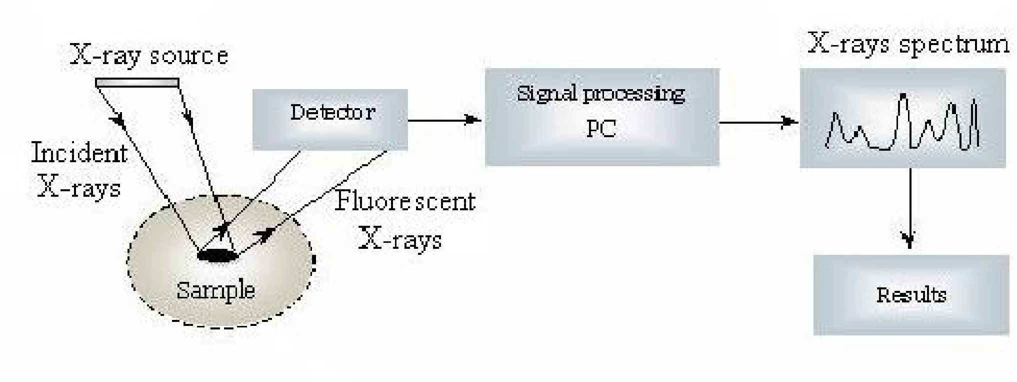


Figure (4-7): Typical ED-XRF detection arrangement.

4-10 Wavelength Dispersive X-ray Fluorescence (WD-XRF):

Wavelength Dispersive X-Ray Fluorescence Spectrometry (WD-XRF) is the oldest method of measurement of X-rays, introduced commercially in the 1950’s. This name is descriptive in that the radiation emitted from the sample is collimated with a Soller collimator, and then impinges upon an analyzing crystal. The crystal diffracts the radiation to different extents, according to Bragg’s law, depending upon the wavelength or energy of the X-radiation.

This angular dispersion of the radiation permits the sequential or simultaneous detection of X-rays emitted by elements in the sample. Simultaneous instruments normally contain several sets of analyzing crystals and detectors; one is adjusted for each desired analyze in the sample. These instruments tend to be very expensive, but efficient for the routine determination or preselected elements.

WD-XRF is a technique that has become indispensable when fast, accurate elemental analysis is needed, as when controlling.

WD-XRF spectrometers are usually larger and more expensive than other spectrometers. Because the analyzing crystal d-spacing determines wavelength sensitivity, they are usually more sensitive than other spectrometers. To overcome losses in X-ray optics of the WD-XRF spectrometers and to maximize primary radiation intensity, X-ray tubes are usually employed. The sample is usually held under vacuum to reduce contamination and avoid absorption of light element characteristic radiation in air.

Typical uses of WD-XRF include the analysis of oils and fuel, plastics, rubber and textiles, pharmaceutical products, foodstuffs, cosmetics and body care products, fertilizers, minerals, ores, rocks, sands, slags, cements, heat-resistant materials glass, ceramics, semiconductor wafers; the determination of coatings on paper, film, polyester and metals; the sorting or compositional analysis of metal alloys, glass and polymeric materials; and the monitoring of soil contamination.

WD-XRF spectrometers measure x-ray intensity as a function of wave length, this done by passing radiation emitting from the sample through an analyzing diffraction crystal mounted on a 2θ goniometric. By Bragg's law the angle between the sample and detector yields the wave length of the radiation.[67]

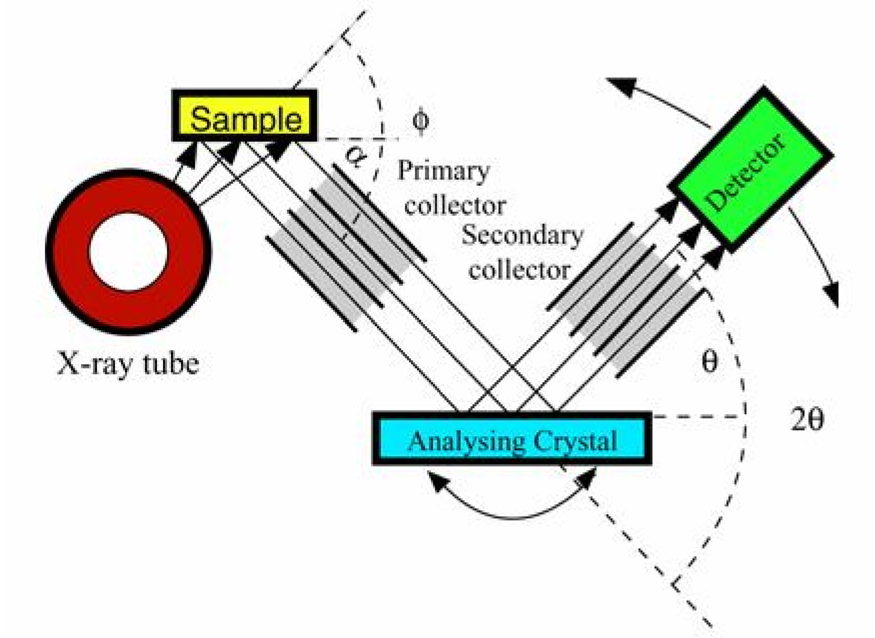


Figure (4-8): Schematic description of WD-XRF principle.

4-11 Total Reflection X-Ray Fluorescence (TXRF):

The phenomenon of total reflection of X-rays had been discovered by Compton (1923).He found that the reflectivity of a flat target strongly increased below a critical angle of only 0.1°. In 1971, Yoneda and Horiuchi (1971) first took advantage to this effect for X-ray fluorescence (XRF). They proposed the analysis of a small amount of material deposited on a flat totally reflecting support. This idea was subsequently implemented in the so-called total reflection X-ray fluorescence (TXRF) analysis which has spread out worldwide. It is now recognized analytical tool with high sensitivity and low detection limits, down to the femtogram range.

Total reflection X-ray fluorescence (TXRF) has become increasingly popular in micro and trace elemental analysis. It is being used in geology, biology, materials science, medicine, forensics, archaeology, art history, and more. Unlike the high incident angles (~ 40 °) used in traditional XRF, TXRF involves very low incident angles. These low angles allow the X-rays to undergo total reflection. This minimizes the adsorption of the X-rays and greatly enhances the lower limits of detection. The fluorescent X-rays illuminating from the sample are then discriminated using an energy dispersive detector. [68]

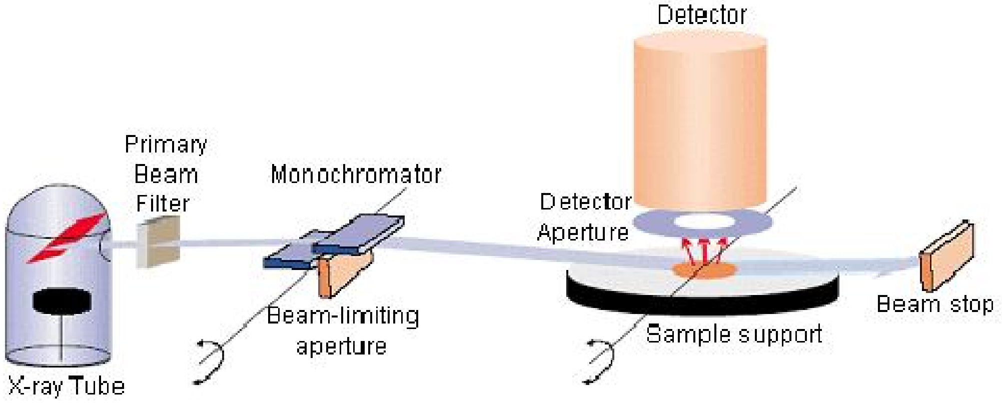


Figure (4-9): Major components of a TXRF spectrometer.

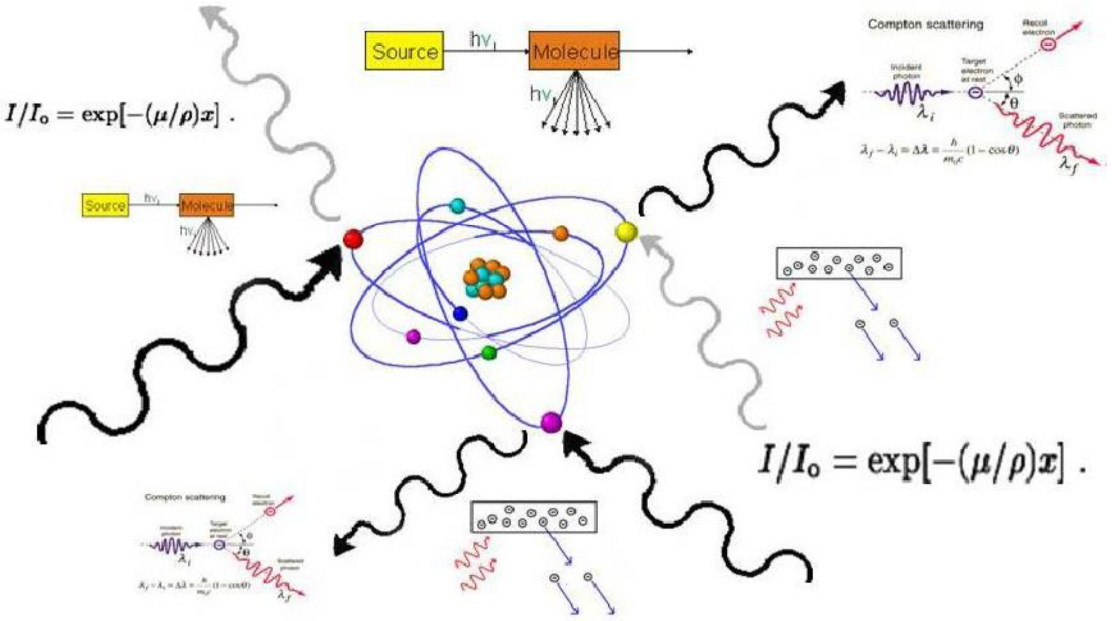
4-12 Micro X-ray Fluorescence Spectroscopy:

The micro analytical variant of XRF is based on the localization excitation and analysis of microscopically small area on the surface of a large , providing information on the lateral distribution of major or minor trace elements in material under study.

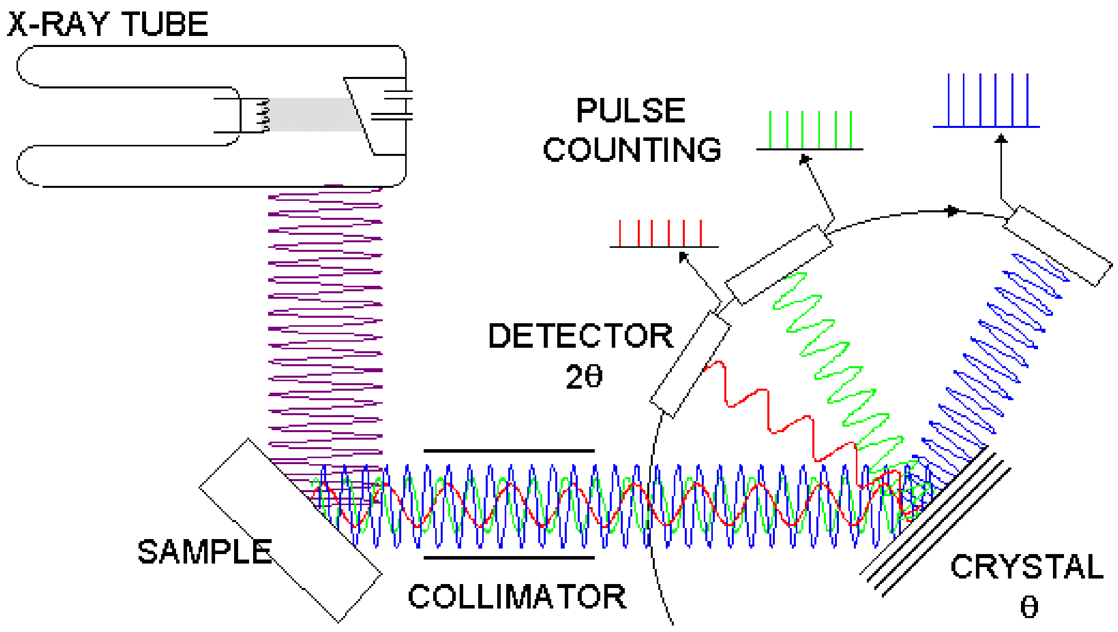
Basically a beam of primary X-rays with (microscopically) small cross-section irradiates a sample and induces the emission of fluorescence X-rays from micro spot.

A suitable detector system collects the fluorescence radiation that carries information on the local composition of the sample.

A standard micro XRF instrument consists of an X-ray source, a focusing device, a sample holder and a detection system. The first two components define the spectral properties of the primary beam; the sample holder should allow accurate remote control of the sample position and the detection system for the detection of the fluorescence radiation.[69]



Figure(4-10): X-ray Spectroscopy



Fig(4-11): Wave length Dispersive XRF Spectroscopy Instrumentation

4-13 General relationship between radiation intensity and concentration:

In 1955, Sherman proposed a mathematical formula to calculate radiation intensity of analyte in a specimen of a known composition. Later, Shiraiwa and Fujino corrected the enhancement part of this formula by introducing a missing factor of ½ .The general equation to calculate X-ray fluorescence intensity I_i emitted by an analyte in the specimen of thickness *t* when it is irradiated by a polychromatic X-ray beam can be expressed as follows:

$$\boldsymbol{I_i = \frac{d\Omega}{4\Pi \sin \Phi_1} Q_i q_i W_i \int_{\lambda_{min}}^{\lambda_{edge}} \tau_i(\lambda) I_o(\lambda) \frac{1 - exp[-\chi(\lambda, \lambda_i)\rho t]}{\chi(\lambda, \lambda_i)} \left[1 + \sum_j W_j S_{ij}\right] d\lambda}$$

-------------- **(4-11)**

Where $d\Omega$ is the differential solid angle for the characteristic radiation; i, *j* are the subscripts for the analyze and matrix element, respectively; Q_i is the sensitivity of the spectrometer for characteristic radiation of analyze i; W_i, W_j are weight fractions of the analyte i and matrix element *j*, respectively; $\lambda_{min}$and λ_{edge} are short-wavelength limit and wavelength limit of analyze absorption edge, respectively; $\tau_i(\lambda)$ is the photoelectric absorption coefficient for analyze i,and primary radiation of wavelength λ; $I_o(\lambda)$ is intensity of the primary radiation, ρ is the density of the sample; t is the sample thickness; q_i is sensitivity of the analyze i (if the $K_\propto$line is chosen then $q_i = \omega_{k,i} f_{i,k_a} \left(1 - \frac{1}{J_{i,k}}\right)$, where $\omega_{k,i}$is fluorescence yield of *K* radiation; f_{i,k_a} is weight of $K_\propto$line within k series; $J_{i,k}$ is absorption edge jump ratio. If the $L_\propto$or L_β is chosen as the analytical line, then the Coster–Kronig transition probabilities have to be additionally

taken into consideration;); $\chi(\lambda, \lambda_i)$ is total mass-attenuation coefficient of the sample for the incident and fluorescent radiation:

$$\boldsymbol{\chi(\lambda, \lambda_i)} = \frac{\mu(\boldsymbol{\lambda})}{\mathbf{\sin \emptyset_1}} + \frac{\mu\boldsymbol{\lambda_i}}{\mathbf{\sin \emptyset_2}}$$

$$\mu(\boldsymbol{\lambda}) = \boldsymbol{W_i}\mu_{\boldsymbol{i}}(\boldsymbol{\lambda}) + \sum_{\boldsymbol{j}} \boldsymbol{W_i}\mu_{\boldsymbol{i}}(\boldsymbol{\lambda}) + \sum_{\boldsymbol{j}} \boldsymbol{W_j}\mu_{\boldsymbol{j}}(\boldsymbol{\lambda})$$

$\mu(\boldsymbol{\lambda_i}) = \boldsymbol{W_i}\mu_{\boldsymbol{i}}(\boldsymbol{\lambda_i}) + \sum_{\boldsymbol{j}} \boldsymbol{W_i}\mu_{\boldsymbol{i}}(\boldsymbol{\lambda_i}) + \sum_{\boldsymbol{j}} \boldsymbol{W_j}\mu_{\boldsymbol{j}}(\boldsymbol{\lambda_i})$ ------------------- **(4-12)**

Where $\mu(\lambda)$ and $\mu(\lambda_i)$are the total mass-attenuation coefficients of the specimen for the incident radiation λ and characteristic radiationλ_i, respectively; $\emptyset_1$ $and \emptyset_2$ are the incidence and take-off angles, respectively; $\mu_i(\lambda)$, $\mu_i(\lambda_i)$, $\mu_j(\lambda)$, $\mu_j(\lambda_i)$ are the mass-attenuation coefficients of the analyte i and matrix element j present in the specimen for the incident radiation λ and characteristic radiation λ_i.The $S_{i,j}$ is the enhancement term for the matrix element j,which can enhance the analyte i(if analyte is not enhanced by matrix element j then$S_{i,j} = 0$):

$$\boldsymbol{S_{i,j} = \frac{1}{2} q_j Z_J(\lambda) \frac{\tau_i(\lambda_i)}{\tau_i(\lambda)} \frac{\chi(\lambda, \lambda_i)}{1 - exp[-\chi(\lambda, \lambda_i)\rho t]} D_{i,j}}$$

$$\boldsymbol{D_{i,j}} = \int_0^{\frac{\Pi}{2}} \tan\theta \left[\frac{1 - exp\left[-\chi_1\left((\lambda_i, \lambda_j)\right)\rho t\right]}{\chi_1[\lambda_i, \lambda_j]\chi_2[\lambda, \lambda_j]} - 1 - exp \frac{[-\chi(\lambda, \lambda_i)\rho t]}{\chi(\lambda, \lambda_i)\chi_{2(\lambda, \lambda_j)}} \right] d\theta +$$

$$\int_{\frac{\Pi}{2}}^{\Pi} \tan\theta \left[\frac{\left[-\chi_{2(\lambda, \lambda_i)\rho t}\right] - \exp\left(-\chi(\lambda, \lambda_i)\rho t\right]}{\chi_1[\lambda_i, \lambda_j]\chi_2[\lambda, \lambda_j]} - \frac{1 - \exp[-\chi(\lambda, \lambda_i)\rho t}{\chi(\lambda, \lambda_i)\chi_2(\lambda, \lambda_j)} \right] d\theta$$

$$\chi_1[\lambda_i, \lambda_j] = \frac{\mu(\lambda_i)}{\sin\emptyset_1} + \frac{\mu\lambda_j}{\cos\theta}$$

$$\chi_2[\lambda, \lambda_i] = \frac{\mu(\lambda)}{\sin\emptyset_1} - \frac{\mu(\lambda_j)}{\cos\theta} \text{ ---------------------------- } \mathbf{(4\text{-}13)}$$

The intensity of characteristic radiation is the complex function of sample composition and sample thickness. The primary and fluorescent radiation are attenuated by atoms of the analyte and by any other atoms present in the matrix (see Eq. (4-12)). If matrix element emits a characteristic line that has sufficient energy to excite the analyte, the fluorescent intensity is higher than expected from primary excitation only (the enhancement term $S_{i,j}$ in Eq. (4-11)). The so-called matrix effects (absorption and enhancement) .If the thickness of the sample is greater than the so-called saturation thickness (t →∞), Eq. (4-11) simplifies to:

$$\boldsymbol{I_i} = \frac{\boldsymbol{d\Omega}}{\boldsymbol{4\Pi \sin \Phi_1}} \boldsymbol{Q_i q_i W_i} \int_{\lambda_{min}}^{\lambda_{edge}} \frac{\boldsymbol{\tau_i(\lambda) I_o(\lambda)}}{\boldsymbol{\chi(\lambda, \lambda_i)}} \left[\mathbf{1} + \sum_j \boldsymbol{W_j S_{i,j}} \right] \boldsymbol{d\lambda}$$

$$\boldsymbol{S_{i,j}} = \frac{1}{2} \boldsymbol{q_j \tau_j(\lambda)} \frac{\tau_i(\lambda_j)}{\tau_i(\lambda)} \left[\mathbf{ln}[\,\mathbf{1} + \frac{\mu(\lambda)}{\mu(\lambda_j) \sin \emptyset_1}] \frac{\sin \emptyset_1}{\mu(\lambda)} + \mathbf{ln}[\mathbf{1} + \frac{\mu(\lambda_i)}{\mu(\lambda_j) \sin \emptyset_2}] \frac{\sin \emptyset_2}{\mu(\lambda_i)} \right]$$

--- (4-14)

As seen from Eq. (4-15), the intensity of characteristic radiation of analyte present in infinitely thick sample depends not only on analyte concentration but also on full matrix composition .Because sample thickness is greater than the saturation thickness, the intensity of characteristic radiation of analyte does not depend on sample thickness. which considerably simplifies mathematical treatment.

If the sample is infinitely thin (t → 0), then the enhancement effects can be neglected (S_{ij}→0) and the approximation $\exp(-\chi) \approx 1 - \chi$ can be applied and the Eq. (4-12) simplifies to:

$$\boldsymbol{I} = \frac{\boldsymbol{d\Omega}}{\boldsymbol{4\Pi \sin \Phi_1}} \boldsymbol{Q_i q_i W_i \rho t} \int_{\lambda_{min}}^{\lambda_{edge}} \boldsymbol{\tau_i(\lambda) I(\lambda) d\lambda} \text{ --------------------- } \mathbf{(4\text{-}15)}$$

Table (4-2): Periodic table of element and XRF energy (kev)-[70]

No	Atomic number	Element	$K_{\propto_1}$	K_{β_1}	$L_{\propto_1}$	L_{β_1}
1	3	Li	-	-	-	-
2	4	Be	0.108	-	-	-
3	5	B	0.183	-	-	-
4	6	C	0.277	-	-	-
5	7	N	0.392	-	-	-
6	8	O	0.525	-	-	-
7	9	F	0.677	-	-	-
8	10	Ne	0.849	-	-	-
9	11	Na	1.040	-	-	-
10	12	Mg	1.254	1.302	-	-

11	13	Al	1.486	1.557	-	-
12	14	Si	1.740	1.837	-	-
13	15	P	2.010	2.139	-	-
14	16	S	2.309	2.465	-	-
15	17	Cl	2.622	2.812	-	-
16	18	Ar	2.958	3.190	-	-
17	19	K	3.314	3.590	-	-
18	20	Ca	3.692	4.013	0.341	0.345
19	21	Sc	4.093	4.464	0.395	0.400
20	22	Ti	4.512	4.933	0.452	0.458
21	23	V	4.953	5.428	0.510	0.518
22	24	Cr	5.415	5.947	0.572	0.582
23	25	Mn	5.900	6.492	0.637	0.648
24	26	Fe	6.405	7.059	0.705	0.718
25	27	Co	6.931	7.649	0.775	0.790
26	28	Ni	7.480	8.267	0.849	0.866
27	29	Cu	8.046	8.904	0.928	0.947
28	30	Zn	8.637	9.570	1.012	1.035
29	31	Ga	9.251	10.267	1.098	2.215
30	32	Ge	9.886	10.982	1.188	1.218
31	33	As	10.543	11.726	1.282	1.317
32	34	Se	11.224	12.497	1.379	1.419
33	35	Br	11.924	13.292	1.481	1.526
34	36	Kr	12.648	14.112	1.585	1.636
35	37	Rb	13.396	14.961	1.692	1.751
36	38	Sr	14.165	15.836	1.806	1.871
37	39	Y	14.958	16.739	1.924	1.998
38	40	Zr	15.775	17.668	2.044	2.126
39	41	Nb	16.615	18.625	2.169	2.260

40	42	Mo	17.480	19.606	2.292	2.394
41	43	Tc	18.367	20.626	2.423	2.535
42	44	Ru	19.279	21.656	2.558	2.683
43	45	Rh	20.216	22.724	2.697	2.834
44	46	Pd	21.177	23.818	2.838	2.990
45	47	Ag	22.163	24.941	2.983	3.150
46	48	Cd	23.173	26.093	3.133	3.315
47	49	In	24.210	27.275	3.286	3.487
48	50	Sn	25.271	28.485	3.444	3.663
49	51	Sb	26.359	29.725	3.604	3.842
50	52	Te	27.473	30.993	3.768	4.029
51	53	I	28.612	32.294	3.938	4.221
52	54	Xe	29.775	33.620	4.110	4.418
53	55	Cs	30.973	34.982	4.285	4.618
54	56	Ba	32.194	36.378	4.466	4.828
55	57	La	33.442	37.797	4.647	5.038
56	58	Ce	34.720	39.256	4.839	5.262
57	59	Pr	36.027	40.749	5.035	4.492
58	60	Nd	37.361	42.272	5.228	5.790
59	61	Pm	38.725	43.827	5.432	5.961
60	62	Sm	40.118	45.414	5.633	6.201
61	63	Eu	41.542	47.038	5.849	6.458
62	64	Gd	42.695	48.695	6.053	6.708

No	atomic number	Element	$K_{\propto_1}$	K_{β_1}	$L_{\propto_1}$	L_{β_1}	$M_{\propto_1}$	M_{β_1}
63	65	Tb	44.482	50.385	6.273	6.975	1.240	1.269
64	66	DY	45.999	52.113	6.498	7.248	1.293	1.325
65	67	Ho	47.547	53.877	6.720	7.526	1.348	1.383

66	68	Er	49.128	55.674	6.949	7.811	1.404	1.448
67	69	Tm	50.742	57.505	7.180	8.102	1.462	1.503
68	70	Yb	52.388	59.382	7.416	8.402	1.526	1.573
69	71	Lu	54.070	61.290	7.656	8.710	1.580	1.630
70	72	Hf	55.790	63.244	7.899	9.023	1.646	1.700
71	73	Ta	57.535	65.222	8.146	9.343	1.712	1.770
72	74	W	59.318	67.244	8.396	9.672	1.775	1.838
73	75	Re	61.141	69.309	8.652	10.010	1.843	1.906
74	76	Os	63.000	71.414	8.911	10.354	1.907	1.978
75	77	Ir	64.896	73.560	9.175	10.708	1.980	2.052
76	78	Pt	66.831	75.750	9.442	11.071	2.050	2.127
77	79	Au	68.806	77.982	9.713	11.443	2.123	2.203
78	80	Hg	70.818	80.255	9.989	11.824	2.195	2.282
79	81	Ti	72.872	82.573	10.269	12.213	2.271	2.363
80	82	Pb	74.970	84.939	10.551	12.614	2.342	2.444
81	83	Bi	77.107	87.349	10.839	13.023	2.423	2.526
82	84	Po	79.291	89.803	11.131	13.446	2.499	2.614
83	85	At	81.516	92.304	11.427	13.876	2.577	2.699
84	86	Rn	83.785	94.866	11.727	14.415	2.654	2.784
85	87	Fr	86.106	97.474	12.031	14.771	2.732	2.868
86	88	Ra	88.478	100.130	12.339	15.236	2.806	2.949
87	89	Ac	90.8841	102.846	12.652	15.713	2.900	3.051
88	90	Th	93.351	105.605	12.968	16.202	2.996	3.149
89	91	Pa	95.868	108.427	13.291	16.703	3.082	3.240
90	92	U	98.440	111.303	13.614	17.220	3.171	3.336
91	93	Np	101.059	114.234	13.949	17.751	3.250	3.435
92	94	Pu	103.734	117.228	14.282	18.296	3.339	3.534
93	95	Am	106.472	120.284	14.620	18.856	3.438	3.646

Table (4-3): Element not detected by XRF energy and so also not detected by X-ray energy

No	Atomic number	Element
1	1	H
2	2	He
3	3	Li
96	243	Cm
97	247	Bk
98	251	Cf
99	252	Es
100	257	Fm
101	258	Md
102	259	No
103	262	Lr

4-14 Advantage of XRF:

1- The spectra are relatively simple and not subject to much interference.

2- Non destructive technique.

3- Speed and convenience of the procedure.

4- Precision and accuracy are comparable to established methods in classical techniques.

5- XRF can be completely non destructive leading to use of very interesting and unusual samples.Where is little or no sample preparation

6- Non dangerous chemical do dispose of acids.

7- No expensive argon or explosive gasses needed.

8- Low operating costs.

4-15 Disadvantage of XRF:

1- The concentration range varies from 0.01 – 100%.

2- Not usefull for light element.

3- High cost of the instrument.

CHAPTER (V)

Materials and Methods

5-1 Introduction:

This was a prospective analytical case conducted in Kassala State in eastern Sudan to detect the nutrition products through spectroscopic analysis of human hair and nails by determining the elements components of hair and finger nails.

5-2 Study Population:

A cross-sectional community(some localaties of Kassala State-Eastern Suadn) based study was conducted.

5-3 Research tools:

Simple questionaire consisting of needed information (residence area, sex, age).

5-4 Study Techniques:

X-Ray Fluorescence (XRF) Spectroscopy device

5-5 Materials :

5-5-1 Sample of hair and finger nails:

Sample (A) contents of hair and finger nails from (students in basic schools and secondary schools)

Sample (B) contents of hair and finger nails from (citizens of different works and different occupations)

Table (5-1) Samples Locations:

No	Locations	Locality
1	Mukram, Dirwa,Baray,Hi ElNor	Kassala town
2	Wadsharefi,Aawad,Hafarat,Shanbob	Refi Kassala
3	Aroma, Tahjar ,Hadali ,Matatib	Refi Aroma
4	Wager, Amadam ,Digain, Makli	Refi Shamal Eldelta
5	Wad Elhelaw , Shgarab, Aboda ,	Refi Wad Elhelaw
6	Twayiet, Maman,Darasta,Oli,Edoroot	Telkok
7	Rasay,Kotanaib, Hameshkoreb,Tahday	Refi Hameshkoreb

5-5-2 Samples of finger nails (male, female):

Kassala town (40,40), Refi Kassala (40,40), Refi Aroma(40,40), Refi Shamal Eldelta (10,10), Refi Wad Elhelaw (10,10), Telkok (10,10), Refi Hameshkoreb (10,10).

5-5-3 Samples of Hair (male, female):

Kassala town (20,10), Refi Kassala (20,10), Refi Aroma(20,10), Refi Shamal Eldelta (10,5), Refi Wad Elhelaw (10,5), Telkok (10,5), Refi Hameshkoreb (10,5).

5-6 Methods :

5-6-1Experimental procedures:

5-6-1-1 Apparatus:

A sequential X-Ray Fluorescence(XRF) portable spectrometer with dispersal of the wave lengths with a rhodium lamp(PHILIPS MODEL PW2400)was used with programme parameters of XRF for qualitative and quantitative analysis.

5-6-1-2 Sample Preparation:

For the purpose of the study natural hair (no dye, no bleach) was taken exclusively, without distinguishing the part of the head they have been taken from. 150 samples of hair and 200 samples of finger nails were collected. The samples were analyzed by XRF immediately with out preparation (as solid sample).[71]

5-6-2 XRF analysis methodology:

1- Mix the sample in side the plastic bag to achieve a relatively homogenous sample.

2- Compress the sample inside the plastic bag to ensure minimum void space within the sample.

3- Undertake a 60 second analysis of the sample through the plastic bag.

4- Repeat the analysis on different parts of the sample to achive a three test results for each sample.

CHAPTER (VI)

Results and Discussion

6-1 Introduction:

The human body hair and nails contains a great number of minerals which are necessary to our survival; (the deficiency of this mineral can cause death, the access of this mineral concentration my lead to some troubles).

6-2 Results:

Table (6-2-1): Analysis of Human Nails Samples (Kassala town locality:Male)

NO	Sample code	Age	Zr	Bi	Pb	W	Zn	Cu	Ni	Co	Fe	Mn	Cr	V	Ti
1	Bm1	70	0.01	ND	0.03	0.36	0.02	0.04	ND	ND	0.41	0.40	ND	1.95	0.45
2	Bm2	65	ND	0.01	0.03	0.61	ND	ND	0.23	0.04	0.51	0.42	ND	0.36	ND
3	Bm3	21	0.01	ND	0.03	ND	0.17	0.11	0.18	ND	0.93	0.29	0.15	0.08	2.73
4	Bm4	30	ND	0.05	ND	0.33	ND	0.04	ND	0.02	0.85	0.01	0.89	0.15	1.49
5	Bm5	25	0.01	ND	0.01	0.24	0.05	ND	ND	ND	0.59	ND	0.88	0.12	1.33
6	Bm6	22	0.02	ND	0.05	0.20	0.09	0.10	0.04	0.05	0.62	0.64	0.19	ND	4.41
7	Bm7	20	0.01	0.01	0.01	0.50	0.05	0.08	ND	0.05	0.73	0.30	0.19	1.44	1.07
8	Bm8	10	ND	ND	ND	0.32	0.02	ND	0.11	0.24	0.59	0.37	ND	0.52	1.07
9	Bm9	15	ND	ND	0.02	0.20	0.02	0.18	ND	ND	0.08	0.28	ND	ND	0.67
10	Bm10	14	0.01	0.04	ND	0.32	0.02	0.08	0.11	0.01	1.24	0.31	0.07	0.69	2.77
11	Am11	15	ND	ND	0.04	0.33	0.05	0.02	ND	ND	0.58	0.03	0.46	0.86	ND
12	Am12	12	ND	0.04	ND	0.34	ND	0.12	0.06	0.15	0.12	0.59	0.12	ND	2.30
13	Am13	18	0.01	0.01	ND	0.54	ND	0.02	ND	ND	0.92	ND	1.63	ND	ND
14	Am14	09	0.01	0.04	0.01	0.31	ND	0.05	ND	0.25	0.58	0.11	0.17	0.22	ND
15	Am15	08	0.01	0.01	0.04	0.40	ND	0.02	0.01	0.03	0.41	0.66	0.63	ND	4.49
16	Am16	07	ND	0.03	ND	0.20	0.05	ND	0.08	ND	0.50	ND	0.98	ND	1.45
17	Am17	10	0.01	ND	0.06	0.13	0.08	0.06	ND	0.26	0.58	0.67	ND	0.41	ND
18	Am18	16	ND	0.01	0.01	0.30	ND	0.03	ND	0.04	0.88	0.12	ND	0.19	1.81
19	Am19	17	ND	0.01	ND	0.14	0.12	0.05	0.26	0.03	0.12	0.11	0.16	0.22	1.80
20	Am20	13	ND	0.01	0.11	0.67	0.10	ND	0.13	0.50	1.73	0.99	ND	ND	1.40

Table (6-2-2): Analysis of Human Nails Samples (Kassala town locality:Female)

NO	Sample code	Age	Zr	Bi	Pb	W	Zn	Cu	Ni	Co	Fe	Mn	Cr	V	Ti
1	Bf 101	37	0.01	ND	0.01	0.19	0.03	0.13	0.05	0.09	0.33	0.28	0.38	0.94	0.60
2	Bf 102	35	0.01	ND	0.03	0.29	ND	0.17	0.09	ND	0.90	0.29	ND	0.27	3.19
3	Bf 103	23	0.01	0.02	0.03	0.31	0.06	ND	0.06	ND	0.52	0.49	0.48	ND	3.55
4	Bf 104	24	ND	ND	0.02	0.30	0.04	0.07	0.09	0.18	0.36	ND	0.38	ND	ND
5	Bf 105	27	ND	ND	0.02	0.19	ND	ND	0.17	0.24	0.26	0.12	ND	1.55	ND
6	Bf 106	21	ND	ND	0.03	0.46	ND	ND	ND	0.06	0.19	0.48	0.11	ND	1.32
7	Bf 107	28	ND	0.01	ND	ND	0.47	ND	0.04	0.51	ND	ND	0.35	1.32	1.66
8	Bf108	25	ND	ND	0.01	0.03	0.04	0.05	0.11	0.07	0.83	0.08	ND	ND	0.52
9	Bf 109	32	ND	ND	0.07	0.22	ND	0.21	0.03	0.15	0.09	ND	0.40	ND	ND
10	Bf 110	16	0.01	0.01	0.01	0.37	0.11	0.07	0.17	ND	1.21	0.35	0.12	0.18	1.94
11	Af 111	20	ND	ND	0.01	0.03	0.06	0.07	0.04	0.02	0.13	0.23	0.08	0.35	ND
12	Af 112	15	ND	0.03	ND	0.30	ND	0.20	0.13	ND	0.55	0.06	0.65	0.38	0.76
13	Af 113	11	ND	ND	0.07	0.27	ND	ND	ND	0.14	0.59	0.25	ND	0.59	1.21
14	Af 114	09	0.01	ND	ND	0.28	ND	0.06	0.16	ND	0.62	0.68	0.20	0.32	0.61
15	Af115	14	ND	0.01	ND	0.28	0.01	0.06	0.16	0.14	0.72	0.54	0.16	ND	3.93
16	Af 116	14	0.01	ND	0.07	0.30	ND	0.06	ND	0.04	ND	0.54	ND	0.83	0.52
17	Af 117	13	0.01	0.02	ND	0.29	ND	0.13	ND	0.29	0.52	0.11	0.64	0.19	ND
18	Af 118	12	ND	ND	0.04	0.15	0.12	0.17	0.18	ND	0.35	0.04	0.47	ND	0.60
19	Af 119	08	0.01	ND	ND	0.13	0.15	0.05	0.15	0.13	0.76	0.50	0.08	0.51	3.52
20	Af 120	06	ND	ND	0.01	0.16	0.05	0.04	0.05	ND	0.96	0.78	ND	1.26	0.42

Table (6-2-3): Analysis of Human Nails Samples (Refi Kassala locality:male)

NO	Sample code	Age	Zr	Bi	Pb	W	Zn	Cu	Ni	Co	Fe	Mn	Cr	V	Ti
1	Bm21	18	ND	0.01	0.03	0.17	0.02	0.02	012	ND	0.75	0.09	0.21	ND	1.78
2	Bm22	17	ND	ND	0.03	0.16	0.04	0.21	0.15	0.08	0.34	0.15	ND	1.46	0.66
3	Bm23	08	0.01	ND	ND	0.17	ND	0.04	ND	0.04	0.78	0.11	0.04	1.10	ND
4	Bm24	14	ND	ND	0.02	0.20	0.02	ND	0.08	0.14	0.27	0.22	0.35	0.31	2.35
5	Bm25	13	0.01	ND	ND	0.23	ND	ND	0.28	ND	0.87	0.13	ND	ND	0.79
6	Bm26	17	0.01	ND	0.07	0.27	0.01	0.20	0.19	0.15	0.39	1.57	0.70	ND	5.25
7	Bm27	09	ND	0.03	0.02	0.35	0.03	0.14	0.01	0.09	0.24	0.31	0.05	ND	2.38
8	Bm28	18	ND	ND	ND	0.18	0.04	ND	ND	0.13	0.46	0.81	0.29	ND	1.06
9	Bm29	19	0.01	0.01	ND	0.16	0.08	ND	0.23	ND	0.61	0.27	0.51	ND	1.92
10	Bm30	20	ND	ND	ND	0.08	0.08	0.10	0.22	0.02	0.82	ND	0.43	0.06	0.89
11	Am31	17	ND	0.01	ND	0.27	0.06	0.08	ND	0.16	0.53	0.01	0.13	0.62	1.29

12	Am32	15	ND	0.01	0.01	0.18	0.13	0.12	0.18	0.13	0.68	0.08	0.39	1.12	ND
13	Am33	14	ND	ND	0.08	0.21	0.07	0.15	0.04	0.10	0.89	ND	1.64	ND	1.04
14	Am34	13	0.01	0.04	0.01	0.18	ND	ND	0.03	0.22	0.52	ND	ND	ND	ND
15	Am35	13	0.01	0.01	0.04	0.39	ND	0.05	0.10	0.48	0.44	ND	1.16	1.25	1.88
16	Am36	12	ND	ND	0.03	0.12	ND	0.08	0.15	ND	0.90	0.10	ND	0.18	ND
17	Am37	11	0.01	0.01	ND	0.13	0.01	0.16	0.09	0.06	0.87	ND	0.57	0.23	2.22
18	Am38	10	0.01	0.01	ND	0.24	0.17	0.03	0.11	0.10	0.34	0.57	0.09	0.75	0.70
19	Am39	09	0.01	ND	0.03	0.36	ND	0.07	ND	0.08	0.51	0.46	0.15	2.23	1.32
20	Am40	07	ND	ND	0.02	0.16	0.08	0.07	0.38	0.08	0.81	0.06	0.10	0.04	0.45

Table (6-2-4): Analysis of Human Nails Samples (Refi Kassala locality:Female)

NO	Sample code	Age	Zr	Bi	Pb	W	Zn	Cu	Ni	Co	Fe	Mn	Cr	V	Ti
1	Bf 121	60	ND	ND	0.01	0.14	0.03	0.03	0.17	0.17	0.09	ND	0.90	0.65	1.42
2	Bf 122	40	0.01	0.01	0.01	0.29	0.02	ND	0.16	0.12	0.39	0.08	0.03	0.78	0.48
3	Bf 123	48	ND	ND	ND	0.20	ND	0.01	0.11	0.07	0.70	0.40	ND	0.58	1.19
4	Bf 124	30	ND	ND	0.04	0.33	ND	0.14	ND	0.06	0.73	0.26	0.07	0.38	ND
5	B 125	18	0.02	0.01	0.02	0.19	ND	0.15	0.09	0.52	0.30	0.79	0.03	0.14	ND
6	Bf 126	42	0.10	ND	0.01	0.27	0.09	ND	0.10	0.21	0.16	0.25	0.29	0.60	0.30
7	Bf 127	21	0.01	ND	0.03	0.22	ND	0.14	0.16	ND	0.21	0.31	0.16	ND	3.71
8	Bf 128	62	ND	ND	0.05	0.04	0.13	0.02	0.06	0.09	0.32	0.30	0.24	0.20	1.73
9	Bf 129	27	0.01	0.02	0.03	0.20	0.01	0.08	0.06	0.12	ND	0.08	0.41	0.80	1.71
10	Bf 130	30	0.01	0.02	0.01	0.16	0.01	0.05	0.24	0.13	0.27	0.21	0.43	ND	0.56
11	Af 131	14	ND	0.03	ND	0.36	ND	0.05	0.02	0.25	0.55	0.01	0.71	ND	ND
12	Af 132	14	ND	0.02	0.02	0.15	0.05	ND	0.01	ND	0.78	0.33	0.80	1.01	0.55
13	Af 133	13	0.01	ND	0.02	0.20	0.15	0.12	0.08	ND	0.39	0.36	0.23	ND	0.86
14	Af 134	13	0.01	ND	0.00	0.31	0.10	0.12	0.04	ND	0.93	ND	ND	2.21	0.76
15	Af 135	12	ND	ND	0.02	0.27	ND	ND	0.09	ND	0.27	0.19	0.97	ND	1.42
16	Af 136	11	ND	0.04	ND	0.19	0.13	0.02	0.00	0.11	0.36	0.37	ND	1.86	0.66
17	Af 137	10	ND	ND	ND	0.60	0.01	ND	0.13	0.06	0.54	0.45	0.54	1.34	0.44
18	Af 138	10	ND	0.02	ND	0.02	0.04	0.09	0.01	0.07	0.59	0.03	0.57	1.29	1.42
19	Af 139	09	ND	0.02	ND	0.60	ND	ND	0.30	0.18	0.68	0.62	0.21	1.43	2.23
20	Af 140	07	0.01	0.01	0.02	0.17	0.08	0.07	0.23	ND	0.32	ND	ND	ND	0.65

Table (6-2-5): Analysis of Human(Aroma locality:Male) Nails

NO	Sample code	Age	Zr	Bi	Pb	W	Zn	Cu	Ni	Co	Fe	Mn	Cr	V	Ti
1	Bm41	22	0.01	0.03	ND	0.35	0.04	0.05	0.36	ND	0.42	ND	1.11	0.51	1.85
2	Bm42	18	0.01	0.01	0.01	0.05	0.11	0.06	0.06	0.17	0.31	0.56	ND	0.23	1.79
3	Bm43	18	0.01	ND	0.01	0.30	ND	0.03	ND	0.28	0.42	0.16	1.14	ND	0.60
4	Bm44	17	ND	0.02	ND	0.07	0.09	0.06	0.05	ND	0.51	ND	0.89	0.52	2.23
5	Bm45	12	0.01	ND	0.05	0.13	0.07	ND	0.19	0.15	0.38	0.71	ND	ND	3.53
6	Bm46	21	ND	0.01	ND	0.18	0.08	ND	0.27	ND	0.97	0.53	0.55	0.86	ND

7	Bm47	15	0.02	0.01	0.04	0.47	ND	ND	0.12	0.28	0.57	ND	0.26	0.74	3.58
8	Bm48	07	0.01	0.06	ND	0.44	ND	0.03	0.10	0.08	0.73	0.23	0.05	0.35	ND
9	Bm49	11	0.01	0.01	0.01	0.27	0.04	0.01	0.23	0.22	0.80	0.10	1.22	ND	ND
10	Bm50	16	ND	0.01	0.03	0.20	0.03	0.10	0.05	0.11	0.28	0.08	0.93	0.05	1.18
11	Am51	17	ND	ND	0.01	0.23	0.02	0.02	0.06	0.18	0.38	0.24	0.49	0.21	ND
12	Am52	09	ND	0.01	ND	0.16	0.12	ND	0.18	ND	0.39	0.66	ND	ND	ND
13	Am53	15	0.01	ND	0.01	0.39	0.02	0.05	0.12	0.18	0.51	0.22	ND	0.04	0.40
14	Am54	15	0.01	0.01	ND	0.29	ND	ND	ND	ND	1.80	0.05	0.09	0.15	5.53
15	Am55	14	0.01	0.01	ND	0.29	ND	ND	ND	ND	0.85	ND	0.66	0.37	ND
16	Am56	13	0.01	0.01	0.01	0.18	ND	0.11	ND	0.08	0.30	0.11	0.25	1.30	3.87
17	Am57	12	0.01	ND	0.03	0.24	0.05	0.10	0.30	0.25	0.48	ND	ND	0.98	0.62
18	Am58	11	0.01	ND	0.01	0.29	0.05	0.10	0.15	0.03	0.17	0.65	0.27	1.41	0.48
19	Am59	10	ND	0.05	ND	0.58	ND	0.02	0.08	0.15	0.47	ND	1.41	ND	0.80
20	Am60	08	0.01	0.01	ND	0.18	0.07	0.09	0.01	0.05	0.85	0.32	0.05	0.97	0.63

Table (6-2-6): Analysis of Human Nails Samples (Aroma locality:Female)

NO	Sample code	Age	Zr	Bi	Pb	W	Zn	Cu	Ni	Co	Fe	Mn	Cr	V	Ti
1	Bf 141	23	0.00	0.02	ND	0.25	0.09	ND	0.13	ND	0.43	ND	0.51	0.41	5.06
2	Bf 142	35	ND	ND	0.08	0.04	0.02	0.07	0.06	ND	0.66	0.23	0.41	0.27	0.70
3	Bf 143	30	0.01	0.01	0.01	0.38	0.10	0.02	0.10	ND	0.33	0.25	0.55	ND	3.83
4	Bf144	27	0.01	ND	0.01	0.18	0.09	ND	0.21	ND	0.95	ND	0.18	ND	ND
5	Bf 145	28	0.01	0.01	0.01	0.46	0.02	0.02	0.27	ND	0.91	0.46	ND	1.74	ND
6	Bf 146	17	0.01	0.02	0.05	0.28	0.04	0.15	0.08	0.25	0.89	0.23	0.50	ND	2.60
7	Bf 147	35	ND	ND	0.01	0.23	0.10	0.04	ND	0.06	0.47	0.42	0.21	1.57	0.41
8	Bf 148	20	ND	0.02	0.07	0.04	0.01	0.15	ND	0.00	0.63	0.72	ND	0.32	0.59
9	Bf 149	48	ND	0.03	ND	0.19	0.02	0.04	0.03	0.05	0.41	0.63	ND	1.56	1.21
10	Bf1 50	50	0.01	0.05	0.02	0.27	0.05	ND	0.12	0.05	1.41	0.35	0.16	1.02	0.26
11	Af 151	15	0.01	ND	0.02	0.23	0.02	0.01	0.04	ND	0.49	0.34	0.29	0.47	1.96
12	Af 152	12	ND	0.01	ND	0.73	ND	ND	0.01	0.13	0.60	ND	0.08	0.04	1.97
13	Af 153	12	0.01	ND	0.02	0.22	0.07	0.10	0.17	0.35	0.64	0.83	ND	2.20	1.37
14	Af 154	18	ND	ND	ND	0.14	0.13	ND	0.14	0.13	0.64	0.27	0.06	ND	0.28
15	Af 155	18	0.01	0.04	0.05	0.44	0.03	0.07	0.06	0.06	0.91	ND	0.96	0.79	1.13
16	Af 156	17	ND	ND	0.01	0.13	0.05	0.06	0.14	0.22	0.54	ND	ND	0.72	2.40
17	Af 157	16	ND	0.01	0.03	0.49	0.02	0.06	0.05	0.12	0.95	0.23	0.98	0.16	0.32
18	Af 158	14	ND	ND	0.01	0.38	0.04	0.07	0.19	0.05	0.66	0.24	0.47	ND	1.76
19	Af 159	13	0.01	ND	0.03	0.16	0.01	0.10	0.23	0.01	0.52	ND	0.02	1.84	0.09
20	Af 160	11	ND	0.02	0.05	0.05	0.08	0.04	0.05	0.18	0.21	0.21	0.06	0.31	ND

Table (6-2-7): Analysis of Human Nails Samples (Shamal Eldelta locality:Male)

NO	Sample code	Age	Zr	Bi	Pb	W	Zn	Cu	Ni	Co	Fe	Mn	Cr	V	Ti
1	Bm61	30	ND	0.01	ND	0.12	0.09	0.09	ND	ND	0.21	ND	0.32	0.89	ND
2	Bm62	17	0.01	0.01	ND	0.23	0.09	ND	0.02	ND	0.38	ND	0.70	1.04	ND
3	Bm63	16	ND	ND	0.01	0.16	ND	ND	0.14	0.12	0.24	0.22	0.14	ND	1.37
4	Bm64	15	0.01	0.02	ND	0.23	0.06	0.17	0.02	0.07	0.68	ND	0.79	0.85	ND

5	Bm65	13	ND	ND	ND	0.23	ND	ND	0.18	ND	1.12	0.05	0.33	0.68	ND
6	Am66	17	ND	0.02	ND	0.19	0.02	0.24	0.06	ND	0.74	0.29	0.04	0.87	0.53
7	Am67	15	0.01	0.01	0.01	0.10	ND	0.08	0.15	0.16	0.55	0.15	0.78	0.02	4.38
8	Am68	12	ND	ND	0.01	0.15	ND	0.07	ND	ND	1.02	0.04	0.02	0.52	ND
9	Am69	10	ND	0.01	ND	0.11	0.07	ND	ND	ND	0.50	0.29	0.73	0.64	0.38
10	Am70	06	ND	ND	ND	0.11	0.07	0.12	0.05	0.13	0.72	ND	0.20	ND	0.71

Table (6-2-8): Analysis of Human Nails Samples (Shamal Eldelta locality:Female)

NO	Sample code	Age	Zr	Bi	Pb	W	Zn	Cu	Ni	Co	Fe	Mn	Cr	V	Ti
1	Bf1 61	30	ND	ND	ND	0.52	ND	0.14	0.08	ND	0.71	0.28	ND	0.40	ND
2	Bf162	25	0.01	0.02	ND	0.14	0.02	0.05	0.23	0.08	0.23	0.39	0.09	0.15	1.34
3	Bf163	23	ND	ND	0.04	0.44	ND	0.02	0.08	ND	0.60	0.06	0.22	1.39	1.44
4	Bf1 64	30	0.01	0.01	0.06	0.05	0.06	0.11	0.10	0.09	0.26	0.05	0.48	0.74	1.57
5	Bf165	20	ND	ND	0.05	0.17	0.06	ND	0.09	0.09	0.21	0.12	ND	2.41	0.61
6	Af 166	14	0.01	ND	0.03	0.24	ND	0.11	0.16	0.11	0.27	0.91	0.35	1.06	ND
7	Af167	13	0.01	0.02	0.01	0.11	0.08	0.06	0.06	0.02	0.30	0.22	0.49	1.81	0.60
8	Af1 68	15	0.01	0.01	ND	0.20	0.13	0.03	ND	0.26	0.49	0.04	0.43	ND	0.56
9	Af1 69	17	0.01	0.00	0.03	0.26	0.02	0.07	0.12	ND	0.67	ND	ND	0.70	2.76
10	Af170	11	0.01	0.01	0.06	0.32	0.16	0.18	0.22	0.30	1.01	0.52	0.49	0.20	1.84

Table (6-2-9): Analysis of Human Nails Samples (Wad Elhelaw locality:Male)

NO	Sample code	Age	Zr	Bi	Pb	W	Zn	Cu	Ni	Co	Fe	Mn	Cr	V	Ti
1	Bm71	19	0.01	ND	0.01	0.26	0.01	0.06	0.32	ND	1.08	0.04	0.38	0.40	ND
2	Bm72	15	0.01	0.01	0.01	0.41	ND	0.11	ND	0.07	0.31	0.26	0.09	0.28	0.52
3	Bm73	14	0.01	0.02	0.03	0.10	0.08	0.12	0.05	0.11	0.07	0.39	ND	2.11	0.52
4	Bm74	13	ND	ND	0.01	0.29	0.09	0.05	0.03	0.17	0.71	ND	ND	1.15	1.33
5	Bm75	12	ND	ND	ND	0.20	ND	0.07	0.15	ND	0.25	0.10	ND	0.06	2.13
6	Am76	21	ND	0.02	0.01	0.11	0.16	0.10	0.18	0.09	0.26	0.66	0.05	0.69	1.61
7	Am77	20	0.01	ND	0.03	0.19	0.05	ND	0.15	0.16	0.49	ND	0.44	0.45	ND
8	Am78	19	ND	ND	0.01	0.04	0.06	ND	0.16	0.12	0.37	0.09	ND	1.55	1.24
9	Am79	18	0.01	0.06	ND	0.50	ND	0.19	0.04	0.02	0.19	0.21	0.63	0.56	2.33
10	Am80	16	ND	0.02	0.01	0.26	ND	0.03	0.09	ND	0.28	0.30	ND	0.28	0.82

Table (6-2-10): Analysis of Human Nails Samples (Wad Elhelaw locality:Female)

NO	Sample code	Age	Zr	Bi	Pb	W	Zn	Cu	Ni	Co	Fe	Mn	Cr	V	Ti
1	Bf1 71	28	0.01	0.01	0.01	0.31	0.01	0.02	ND	0.12	0.71	0.58	0.61	0.18	0.51
2	Bf 172	80	0.01	ND	0.01	0.20	ND	ND	0.03	0.13	0.26	0.24	0.16	ND	1.61
3	Bf 173	42	0.01	0.02	ND	0.42	ND	0.02	0.06	0.13	0.75	0.24	0.95	0.41	1.84
4	Bf 174	45	0.01	0.00	0.01	0.24	0.02	ND	0.08	ND	0.75	ND	0.35	0.17	0.49

5	Bf 175	38	ND	0.02	ND	0.53	ND	ND	ND	0.01	0.83	0.20	0.55	0.37	2.94
6	Af 176	10	ND	0.02	0.01	0.08	0.06	0.10	0.04	0.19	0.41	ND	0.22	0.07	2.38
7	Af 177	12	ND	ND	0.04	0.07	ND	0.15	0.23	0.20	0.68	0.30	ND	0.32	0.60
8	Af 178	13	0.01	0.03	ND	0.28	ND	0.06	0.04	ND	0.67	0.70	0.19	1.26	ND
9	Af 179	09	0.01	ND	0.03	0.37	ND	ND	ND	ND	0.42	0.58	0.04	0.92	0.82
10	Af 180	08	ND	0.03	ND	0.18	0.06	0.08	0.03	0.11	0.56	0.25	0.02	0.86	ND

Table (6-2-11): Analysis of Human Nails Samples (Telkok locality:Male)

NO	Sample code	Age	Zr	Bi	Pb	W	Zn	Cu	Ni	Co	Fe	Mn	Cr	V	Ti
1	Bm81	16	0.01	ND	0.02	0.17	0.08	ND	ND	0.01	1.25	0.56	0.56	ND	1.90
2	Bm82	15	0.01	ND	0.03	0.26	ND	ND	0.17	0.02	0.83	ND	0.07	0.46	3.15
3	Bm83	12	ND	0.01	0.01	0.20	ND	0.03	0.13	0.11	0.65	ND	0.50	0.16	1.50
4	Bm84	11	0.01	0.02	0.01	0.29	0.06	ND	0.18	ND	0.38	0.41	0.38	0.24	1.49
5	Bm85	17	ND	0.01	0.05	0.13	ND	0.09	0.07	0.16	0.10	0.27	ND	1.41	1.29
6	Am86	15	0.01	ND	0.02	0.24	0.05	0.05	0.13	ND	0.60	0.26	0.04	0.66	1.37
7	Am87	15	ND	0.02	ND	0.25	ND	0.04	0.07	0.02	0.15	0.24	0.31	0.40	2.81
8	Am88	13	0.01	0.01	0.01	0.24	0.19	ND	0.20	ND	0.79	0.13	ND	1.29	ND
9	Am89	10	0.05	0.05	ND	0.37	0.03	0.01	0.02	ND	1.79	0.69	ND	0.81	3.22
10	Am90	08	0.01	0.02	ND	0.01	0.06	0.05	0.10	ND	0.97	0.02	0.66	0.46	1.48

Table (6-2-12): Analysis of Human Nails Samples (Telkok locality:Female)

NO	Sample code	Age	Zn	Bi	Pb	W	Zn	Cu	Ni	Co	Fe	Mn	Cr	V	Ti
1	Bf181	60	0.01	ND	0.02	0.42	0.03	0.09	ND	0.12	0.52	0.23	0.34	0.45	1.39
2	Bf 182	75	ND	ND	ND	0.20	0.05	0.14	0.22	0.04	0.77	0.26	0.30	ND	2.35
3	Bf 183	41	0.01	0.01	0.02	0.04	0.02	0.09	0.04	0.07	0.91	0.38	0.02	0.71	0.40
4	Bf 184	21	0.01	0.01	ND	0.23	0.08	0.09	ND	0.01	0.26	0.36	0.76	1.56	0.40
5	Bf 185	24	ND	0.02	0.05	0.05	0.08	0.04	0.05	0.18	0.21	0.21	0.06	0.31	ND
6	Af 186	16	ND	ND	ND	0.52	ND	0.14	0.08	ND	0.71	0.28	ND	0.40	ND
7	Af 187	14	0.01	0.02	ND	0.14	0.02	0.05	0.23	0.08	0.23	0.39	0.09	0.15	1.34
8	Af 188	13	ND	ND	0.04	0.44	ND	0.02	0.08	ND	0.60	0.06	0.22	1.39	1.44
9	Af 189	10	0.01	0.01	0.06	0.05	0.06	0.11	0.10	0.09	0.26	0.05	0.48	0.74	1.57
10	Af 190	08	ND	ND	0.05	0.17	0.06	ND	0.09	0.09	0.21	0.12	ND	2.41	0.61

Table (6-2-13): Analysis of Human Nails Samples (Hameshkoreb locality:Male)

NO	Sample code	Age	Zr	Bi	Pb	W	Zn	Cu	Ni	Co	Fe	Mn	Cr	V	Ti
1	Bm91	18	0.01	0.01	ND	0.17	0.08	0.10	0.11	0.08	0.10	ND	0.33	0.87	2.35
2	Bm92	15	ND	0.02	ND	0.17	0.03	ND	0.13	0.06	0.80	0.25	ND	0.34	0.19
3	Bm93	14	0.01	0.01	0.04	0.28	0.13	0.10	0.03	0.06	0.35	0.41	0.06	0.35	ND
4	Bm94	13	ND	0.03	ND	0.34	ND	0.05	ND	0.05	0.39	ND	0.50	0.19	0.37

5	Bm95	17	0.01	0.01	ND	0.16	0.11	0.05	0.10	0.17	0.67	0.28	ND	0.07	0.86
6	Am96	07	ND	ND	0.05	0.33	ND	0.14	ND	0.19	0.44	0.20	0.33	0.13	1.31
7	Am97	09	ND	0.02	0.01	0.19	0.08	0.09	0.24	ND	0.69	ND	0.04	1.00	ND
8	Am98	15	0.01	0.02	0.01	0.10	0.04	0.06	0.07	0.09	0.74	ND	0.49	0.09	0.14
9	Am99	15	0.01	ND	0.05	0.14	0.10	0.02	0.15	0.05	0.37	ND	0.66	ND	0.50
10	Am100	11	ND	ND	0.01	0.43	ND	0.01	0.08	ND	0.48	0.26	0.03	0.80	0.48

Table (6-2-14): Analysis of Human Nails Samples(Hameshkoreb locality:Female)

NO	Sample code	Age	Zr	Bi	Pb	W	Zn	Cu	Ni	Co	Fe	MN	Cr	V	Ti
1	Bf 191	30	0.01	ND	0.03	0.24	ND	0.11	0.16	0.11	0.27	0.91	0.35	1.06	ND
2	Bf 192	25	0.01	0.02	0.01	0.11	0.08	0.06	0.06	0.02	0.30	0.22	0.49	1.81	0.60
3	Bf 193	60	0.01	0.01	ND	0.20	0.13	0.03	ND	0.26	0.49	0.04	0.43	ND	0.56
4	Bf 194	70	0.01	ND	0.03	0.26	0.02	0.07	0.12	ND	0.67	ND	ND	0.70	2.76
5	Bf 195	40	0.01	0.01	0.06	0.32	0.16	0.18	0.22	0.30	1.01	0.52	0.49	0.20	1.84
6	Af 196	11	0.01	0.01	0.01	0.31	0.01	0.02	ND	0.12	0.71	0.58	0.61	0.81	0.51
7	Af 197	08	0.01	ND	0.01	0.20	ND	0.00	0.03	0.13	0.26	0.24	0.16	ND	1.61
8	Af 198	06	0.01	0.02	ND	0.42	ND	0.02	0.06	0.13	0.75	0.24	0.95	0.41	1.84
9	Af 199	10	0.01	ND	0.01	0.24	0.02	ND	0.08	ND	0.75	ND	0.35	0.17	0.49
10	Af 200	08	ND	0.02	ND	0.53	ND	ND	ND	0.01	0.83	0.20	0.55	0.37	2.94

Table (6-2-15): Analysis of Human Hair Samples (Kassala town locality:Male)

NO	Sample code	Age	Zr	Bi	Pb	W	Zn	Cu	Ni	Co	Fe	Mn	Cr	V	Ti
1	Bm1	37	ND	ND	0.01	0.14	0.03	ND	ND	0.11	0.13	0.23	ND	0.69	ND
2	Bm2	33	ND	0.02	0.01	ND	0.15	1.5	ND	0.27	0.51	0.27	0.12	0.15	1.72
3	Bm3	32	ND	0.01	0.02	0.23	0.13	ND	ND	0.02	0.12	0.48	0.63	ND	0.50
4	Bm4	30	ND	ND	ND	0.20	ND	0.07	0.05	0.04	0.08	0.25	0.50	ND	1.79
5	Bm5	29	ND	ND	ND	0.27	ND	0.09	ND	ND	ND	0.48	0.24	ND	ND
6	Bm6	27	ND	0.01	0.01	0.22	0.02	0.07	0.09	0.10	0.10	0.12	0.36	0.84	0.75
7	Bm7	26	0.01	ND	0.04	0.09	0.04	0.10	ND	0.14	0.42	0.03	0.59	1.10	0.49
8	Bm8	25	ND	0.02	ND	0.25	0.03	ND	0.01	0.10	0.47	0.27	0.57	ND	2.90
9	Bm9	24	ND	ND	0.06	0.05	0.02	0.02	ND	ND	0.09	0.05	0.44	ND	0.59
10	Bm10	23	ND	ND	0.05	0.32	0.05	0.12	0.13	0.27	ND	0.34	ND	ND	3.84
11	Bm11	22	ND	ND	0.03	0.27	ND	0.05	0.07	0.09	0.04	ND	ND	0.17	1.58
12	Bm12	21	ND	ND	0.04	0.33	ND	ND	0.02	0.23	0.37	ND	1.00	0.71	2.22
13	Bm13	20	0.01	0.57	ND	0.31	0.06	0.40	0.09	ND	ND	0.24	0.12	0.77	0.46
14	Bm14	18	ND	ND	0.03	0.07	ND	0.04	0.01	ND	0.53	0.03	0.57	1.19	0.41
15	Bm15	16	ND	0.02	ND	0.27	0.04	ND	ND	0.31	0.28	0.29	0.19	ND	1.75
16	Bm16	15	ND	0.01	0.02	0.29	0.01	0.02	0.08	0.07	0.37	0.29	ND	2.22	ND
17	Bm17	13	0.01	0.28	0.02	ND	0.12	0.03	0.01	0.13	0.47	0.02	0.58	0.74	0.48
18	Bm18	10	0.01	0.02	0.01	0.43	ND	0.05	0.14	0.09	0.32	0.27	0.50	ND	ND
19	Bm19	10	ND	0.02	ND	0.19	ND	0.02	0.16	ND	0.64	ND	0.79	0.57	1.23
20	Bm20	06	ND	0.01	0.01	ND	0.06	0.06	0.20	0.03	0.66	ND	0.47	0.78	0.49

Table (6-2-16): Analysis of Human Hair Samples (Kassala town locality:Female)

NO	Sample code	Age	Zr	Bi	Pb	W	Zn	Cu	Ni	Co	Fe	Mn	Cr	V	Ti
1	Bf 101	75	ND	ND	0.03	0.04	0.02	0.01	0.18	0.17	0.10	0.08	0.20	ND	1.71
2	Bf 102	20	ND	ND	0.01	0.38	ND	0.04	0.11	0.01	0.17	0.11	ND	0.28	0.50
3	Bf 103	25	ND	ND	0.03	0.10	0.07	0.01	ND	0.07	0.14	0.21	0.07	0.20	0.56
4	Bf 104	40	ND	ND	ND	0.14	ND	0.01	0.04	ND	0.60	0.07	ND	0.75	ND
5	Bf 105	27	ND	0.02	0.01	0.24	ND	0.05	0.09	0.09	0.18	0.28	0.16	ND	ND
6	Bf 106	35	0.01	0.01	0.02	0.18	ND	0.07	0.04	ND	1.60	ND	0.67	ND	3.67
7	Bf 107	13	0.01	ND	0.06	0.24	ND	ND	0.04	ND	0.38	0.15	0.88	0.42	1.37
8	Bf108	60	0.01	ND	0.01	0.27	ND	0.11	0.16	0.03	0.71	ND	0.95	ND	1.40
9	Bf 109	12	ND	ND	0.02	0.23	0.03	ND	0.09	0.06	ND	0.33	0.23	1.26	0.30
10	Bf 110	11	ND	ND	ND	0.16	ND	0.01	0.01	ND	0.71	ND	0.13	0.34	0.67

Table (6-2-17): Analysis of Human Hair Samples (Refi Kassala locality:Male)

NO	Sample code	Age	Zr	Bi	Pb	W	Zn	Cu	Ni	Co	Fe	Mn	Cr	V	Ti
1	Bm21	75	ND	0.03	ND	0.09	0.11	0.02	0.06	0.19	0.51	0.52	ND	0.84	1.78
2	Bm22	50	0.01	ND	0.01	0.16	0.01	ND	0.04	0.04	0.17	ND	0.45	1.07	0.74
3	Bm23	48	ND	0.02	ND	0.02	1.01	ND	0.22	ND	0.42	0.34	0.39	ND	1.32
4	Bm24	45	ND	ND	0.04	0.25	ND	ND	ND	0.12	0.20	0.25	0.25	0.04	1.83
5	Bm25	40	ND	ND	ND	0.31	ND	ND	0.03	0.05	0.35	ND	0.09	0.71	1.90
6	Bm26	37	ND	0.01	0.01	0.37	0.04	0.20	0.05	ND	0.59	0.05	0.49	ND	3.77
7	Bm27	35	0.01	ND	0.01	0.33	ND	0.12	0.29	0.15	0.44	0.26	0.40	0.53	1.26
8	Bm28	32	0.01	ND	0.03	0.11	0.17	0.09	0.13	0.03	0.46	0.57	0.59	0.09	2.18
9	Bm29	30	0.01	0.01	0.01	0.02	0.09	0.08	0.05	ND	0.48	0.25	0.07	0.45	1.42
10	Bm30	28	0.01	ND	0.05	0.36	0.01	0.01	0.05	0.01	0.18	0.08	0.06	0.44	3.03
11	Bm31	27	0.01	0.02	0.01	0.37	ND	0.01	0.13	ND	1.24	ND	0.60	0.24	0.46
12	Bm32	26	0.01	ND	0.03	0.27	ND	0.07	0.09	0.02	0.18	0.13	1.07	0.82	ND
13	Bm33	25	ND	0.01	0.01	0.27	0.02	0.01	0.19	0.08	0.30	0.29	ND	1.12	2.40
14	Bm34	24	ND	0.04	0.01	0.04	0.04	0.06	0.18	0.16	0.43	0.20	0.65	ND	1.32
15	Bm35	20	ND	ND	0.01	0.16	0.07	0.07	0.08	0.13	0.31	0.12	ND	0.65	1.55
16	Bm36	18	0.01	0.01	0.02	0.25	ND	0.11	0.05	0.03	0.06	0.47	0.05	0.72	1.50
17	Bm37	16	ND	ND	ND	0.50	ND	ND	0.11	0.02	0.23	0.49	0.30	ND	2.74
18	Bm38	15	ND	0.02	ND	0.18	0.12	0.06	0.01	ND	0.40	0.72	0.11	0.32	0.65
19	Bm39	13	ND	0.01	0.02	0.27	ND	ND	ND	0.02	0.10	ND	0.15	ND	ND
20	Bm40	10	ND	ND	ND	0.17	0.06	0.07	0.14	0.05	ND	0.81	0.39	0.29	0.59

Table (6-2-18): Analysis of Human Hair Samples (Refi Kassala locality:Female)

NO	Sample code	Age	Zr	Bi	Pb	W	Zn	Cu	Ni	Co	Fe	Mn	Cr	V	Ti
1	Bf 111	60	ND	0.02	ND	0.16	0.05	0.02	0.15	ND	0.84	ND	0.20	0.70	0.97
2	Bf 112	55	0.01	0.01	ND	ND	0.04	0.03	0.17	ND	1.24	ND	ND	ND	2.89
3	Bf 113	32	0.01	0.02	0.03	0.22	0.03	0.08	0.18	0.10	0.58	0.23	0.10	0.04	2.30
4	Bf 114	30	ND	0.02	0.01	0.03	0.10	ND	0.06	0.08	0.31	0.30	0.04	1.02	ND
5	Bf 115	28	0.01	0.01	ND	0.31	0.07	ND	0.12	0.15	0.85	0.63	ND	ND	ND
6	Bf 116	25	0.01	0.01	ND	0.05	0.04	0.04	0.12	ND	0.65	0.10	ND	0.33	2.06
7	Bf 117	24	0.01	0.01	ND	0.09	0.07	0.04	0.03	0.21	0.25	0.47	ND	ND	3.29
8	Bf 118	22	ND	ND	ND	0.34	ND	0.07	0.09	0.27	0.76	0.08	0.41	ND	1.36
9	Bf 119	19	ND	0.01	0.03	0.01	0.05	ND	0.15	0.05	0.70	ND	0.55	0.18	1.66
10	Bf 120	18	ND	0.02	0.03	0.10	0.02	0.13	0.12	ND	0.38	ND	ND	0.06	2.07

Table (6-2-19): Analysis of Human Hair Samples (Aroma locality:Male)

NO	Sample code	Age	Zr	Bi	Pb	W	Zn	Cu	Ni	Co	Fe	Mn	Cr	V	Ti
1	Bm41	50	ND	ND	ND	0.11	0.06	0.07	0.09	0.15	0.90	0.25	0.10	0.28	0.54
2	Bm42	47	0.01	ND	0.01	0.20	0.02	ND	0.11	0.09	0.65	ND	0.55	0.48	2.04
3	Bm43	46	ND	ND	0.01	0.24	ND	0.04	ND	0.07	0.44	0.49	ND	1.26	1.61
4	Bm44	45	0.01	0.03	ND	0.23	0.04	ND	0.29	0.01	0.85	0.380	0.13	ND	0.62
5	Bm45	40	ND	0.01	ND	0.04	0.03	ND	0.01	0.01	0.24	0.15	0.60	ND	0.57
6	Bm46	38	0.01	0.01	ND	0.21	ND	ND	ND	0.04	0.91	ND	1.28	ND	1.78
7	Bm47	37	ND	0.02	ND	0.21	0.09	0.01	0.06	0.24	0.28	0.08	0.02	0.87	ND
8	Bm48	35	0.01	ND	0.05	0.19	ND	0.26	0.09	0.26	0.54	0.09	0.12	0.20	1.60
9	Bm49	29	ND	0.01	0.01	0.27	0.02	ND	ND	0.06	0.29	0.31	0.36	ND	1.94
10	Bm50	28	ND	ND	0.01	0.21	0.06	ND	0.06	ND	0.33	0.17	0.09	ND	1.05
11	Bm51	27	ND	0.01	ND	0.24	0.03	0.08	0.06	0.23	0.57	0.22	0.79	0.06	0.65
12	Bm52	26	ND	0.01	0.01	0.11	0.13	ND	0.05	0.06	0.10	0.09	0.21	ND	2.59
13	Bm53	25	0.01	ND	0.02	0.37	ND	0.05	0.12	0.11	0.22	ND	0.29	0.59	0.30
14	Bm54	22	ND	ND	0.01	0.24	0.01	ND	ND	ND	0.03	0.05	ND	0.75	0.46
15	Bm55	18	ND	0.01	ND	0.24	0.04	ND	0.12	0.03	0.09	1.08	0.05	0.21	0.41
16	Bm56	15	0.01	0.01	0.01	0.17	0.01	ND	0.18	0.23	0.01	0.17	1.08	0.82	ND
17	Bm57	12	ND	0.03	0.03	0.22	0.05	0.14	0.33	0.02	1.32	0.11	0.17	0.26	2.09
18	Bm58	10	ND	ND	0.01	0.08	0.10	ND	0.12	0.03	0.42	0.12	ND	1.32	0.25
19	Bm59	08	ND	0.02	ND	0.19	ND	0.07	ND	ND	0.45	0.35	0.56	0.61	1.30
20	Bm60	07	ND	ND	ND	0.25	0.05	0.06	0.16	ND	0.81	0.18	ND	0.60	ND

Table (6-2-20): Analysis of Human Hair Samples (Aroma locality:Female)

NO	Sample code	Age	Zr	Bi	Pb	W	Zn	Cu	Ni	Co	Fe	Mn	Cr	V	Ti
1	Bf 121	27	0.01	ND	ND	0.26	0.01	0.30	0.10	ND	0.48	0.21	0.48	0.15	1.56
2	Bf 122	25	ND	0.01	ND	0.49	0.11	ND	ND	0.17	0.67	0.34	0.24	ND	2.03
3	Bf 123	35	0.01	ND	ND	0.22	0.03	0.10	0.12	0.01	0.88	ND	0.55	0.71	0.40
4	Bf124	22	ND	0.01	0.02	0.23	0.04	0.03	0.12	ND	0.16	0.07	ND	ND	1.77
5	Bf 125	28	0.01	0.30	ND	0.11	ND	0.13	0.01	0.16	0.69	0.31	ND	0.99	ND
6	Bf 126	39	ND	0.01	0.01	0.06	0.06	ND	0.14	0.11	0.78	ND	ND	2.05	1.58
7	Bf 127	24	ND	0.02	ND	0.35	0.02	0.09	ND	0.12	0.05	0.47	0.05	1.49	ND
8	Bf 128	05	ND	ND	0.01	0.05	ND	ND	0.12	ND	0.30	ND	0.48	0.09	1.02
9	Bf 129	06	ND	ND	0.02	0.04	0.08	0.05	0.16	ND	0.65	ND	0.87	1.06	0.65
10	Bf1 30	45	ND	ND	0.03	0.11	0.05	ND	0.15	0.04	0.12	ND	ND	1.44	0.55

Table (6-2-21): Analysis of Human Hair Samples (Shamal Eldelta

NO	Sample code	Age	Zr	Bi	Pb	W	Zn	Cu	Ni	Co	Fe	Mn	Cr	V	Ti
1	Bm61	65	0.01	0.01	0.03	ND	0.02	0.13	0.08	0.61	0.73	ND	0.16	0.23	1.83
2	Bm62	55	ND	ND	0.07	0.29	ND	0.01	ND	0.01	0.10	0.10	0.08	0.62	2.53
3	Bm63	52	ND	0.01	0.03	0.18	0.04	ND	0.20	0.01	0.33	0.09	0.18	ND	3.54
4	Bm64	50	ND	0.01	0.01	0.06	0.07	0.01	ND	ND	0.73	ND	ND	0.21	1.65
5	Bm65	47	ND	0.01	0.02	0.07	0.08	0.01	0.04	0.09	0.69	0.74	ND	0.13	1.20
6	Bm66	45	ND	ND	0.03	0.02	0.09	0.04	ND	0.10	0.83	0.26	0.19	ND	1.60
7	Bm67	40	ND	ND	0.01	0.16	0.02	0.01	ND	0.05	0.30	0.25	0.01	0.75	ND
8	Bm68	38	ND	ND	0.01	0.24	0.01	ND	ND	ND	0.41	ND	0.20	ND	ND
9	Bm69	35	ND	ND	ND	0.13	0.07	ND	ND	0.09	0.54	0.05	0.07	0.17	0.61
10	Bm70	25	ND	ND	0.03	0.12	0.03	0.05	0.02	ND	0.54	ND	0.39	0.39	ND

Table (6-2-22): Analysis of Human Hair Samples (Shamal Eldelta locality:Female)

NO	Sample code	Age	Zr	Bi	Pb	W	Zn	Cu	Ni	Co	Fe	Mn	Cr	V	Ti
1	Bf1 31	02	0.01	0.01	ND	0.12	0.08	0.07	0.03	0.08	0.17	0.07	0.13	ND	0.48
2	Bf132	40	ND	ND	ND	0.09	ND	0.02	0.02	ND	0.89	0.06	0.04	0.60	1.25
3	Bf133	45	0.01	0.02	0.03	0.27	0.05	0.13	0.10	0.11	1.08	1.12	0.15	ND	0.65
4	Bf1 34	35	ND	0.02	ND	0.23	ND	0.04	0.04	0.05	0.48	ND	ND	ND	1.40
5	Bf135	01	ND	0.03	ND	0.20	0.06	0.04	ND	0.22	0.30	0.11	ND	1.81	ND

Table (6-2-23): Analysis of Human Hair Samples (Wad Elhelaw locality:Male)

NO	Sample code	Age	Zr	Bi	Pb	W	Zn	Cu	Ni	Co	Fe	Mn	Cr	V	Ti
1	Bm71	50	ND	ND	0.03	0.04	0.03	0.05	0.02	0.09	0.39	0.31	0.22	ND	0.78
2	Bm72	45	ND	ND	0.03	0.34	0.09	0.01	ND	0.24	0.49	0.11	0.13	0.48	ND
3	Bm73	44	0.01	0.03	ND	ND	0.08	0.15	ND	ND	0.28	0.46	ND	1.35	ND
4	Bm74	42	0.01	0.01	ND	0.22	0.07	0.03	0.02	0.13	0.14	0.08	0.51	0.52	ND
5	Bm75	37	ND	0.04	ND	0.37	ND	0.05	ND	0.08	0.21	0.25	0.14	0.53	0.65
6	Bm76	34	ND	ND	0.01	0.31	ND	0.07	0.18	0.04	0.81	ND	ND	ND	2.67
7	Bm77	32	ND	ND	0.01	0.09	0.13	ND	0.25	0.06	0.46	0.24	0.15	ND	0.56
8	Bm78	26	0.01	ND	0.03	0.54	ND	ND	ND	ND	0.44	0.62	ND	ND	ND
9	Bm79	18	0.01	0.01	0.07	0.19	0.20	0.19	0.47	ND	0.82	0.22	0.48	ND	3.46
10	Bm80	16	ND	0.01	0.08	0.16	0.21	0.07	0.07	ND	1.14	ND	ND	0.37	2.70

Table (6-2-24): Analysis of Human Hair Samples (Wad Elhelaw locality:Female)

NO	Sample code	Age	Zr	Bi	Pb	W	Zn	Cu	Ni	Co	Fe	Mn	Cr	V	Ti
1	Bf1 36	15	ND	0.01	ND	0.16	0.07	0.05	0.07	ND	0.91	0.21	ND	0.96	1.08
2	Bf 137	08	0.01	ND	ND	0.38	ND	0.13	0.20	ND	1.29	0.32	ND	1.50	ND
3	Bf 138	02	ND	0.01	0.01	0.21	0.05	0.12	0.41	0.01	0.93	0.22	0.37	0.38	ND
4	Bf 139	04	0.01	0.02	0.01	0.34	ND	ND	0.28	0.04	0.76	ND	ND	ND	0.68
5	Bf 140	22	ND	ND	0.01	0.16	0.02	0.09	0.11	0.14	ND	ND	0.85	0.35	0.74

Table (6-2-25): Analysis of Human Hair Samples (Telkok locality:Male)

NO	Sample code	Age	Zr	Bi	Pb	W	Zn	Cu	Ni	Co	Fe	Mn	Cr	V	Ti
1	Bm81	70	ND	ND	0.01	0.08	ND	0.05	0.10	0.12	0.22	0.30	0.56	0.03	1.94
2	Bm82	50	ND	ND	0.01	0.23	0.05	0.08	0.04	ND	0.22	0.38	ND	ND	ND
3	Bm83	31	ND	0.03	ND	0.10	ND	ND	0.06	0.03	0.07	0.47	0.14	0.08	2.48
4	Bm84	30	ND	ND	ND	0.28	ND	0.04	0.05	0.16	0.21	0.14	ND	0.79	ND
5	Bm85	29	ND	ND	0.02	0.07	0.14	0.10	0.14	0.05	0.32	0.21	0.15	ND	2.79
6	Bm86	21	ND	ND	0.03	0.17	0.03	0.03	0.06	0.03	0.17	0.05	0.60	0.25	0.13
7	Bm87	20	ND	ND	ND	0.44	ND	ND	ND	0.13	0.89	0.16	ND	0.36	0.95
8	Bm88	17	ND	ND	0.01	0.16	0.12	0.08	0.06	ND	0.34	ND	0.17	ND	1.57
9	Bm89	13	ND	ND	ND	0.12	0.01	ND	0.06	0.11	ND	0.20	0.79	ND	2.50
10	Bm90	07	ND	ND	ND	0.27	0.03	ND	0.07	ND	ND	0.42	ND	0.93	0.39

Table (6-2-26): Analysis of Human Hair Samples (Telkok locality:Female)

NO	Sample code	Age	Zr	Bi	Pb	W	Zn	Cu	Ni	Co	Fe	Mn	Cr	V	Ti

1	Bf141	03	ND	0.01	0.01	ND	0.12	0.15	0.08	0.02	0.31	0.28	0.20	ND	1.71
2	Bf 142	50	0.01	0.01	0.01	0.28	0.01	0.08	0.01	0.15	0.61	0.11	0.10	0.57	1.76
3	Bf 143	35	ND	0.01	0.01	ND	0.14	0.06	0.10	0.23	1.07	0.51	ND	0.87	0.57
4	Bf 144	02	0.01	ND	ND	0.29	0.02	0.01	ND	0.40	0.40	0.10	0.14	0.21	1.78
5	Bf 145	01	ND	0.02	ND	0.16	0.04	0.08	0.03	0.17	0.46	0.11	ND	0.98	2.07

Table (6-2-27): Analysis of Human Hair Samples(Hameshkoreb locality:Male)

NO	Sample code	Age	Zr	Bi	Pb	W	Zn	Cu	Ni	Co	Fe	Mn	Cr	V	Ti
1	Bm91	37	ND	0.03	ND	0.02	0.03	0.07	0.05	0.14	0.35	ND	1.29	0.14	1.51
2	Bm92	35	0.03	0.01	ND	0.04	0.17	0.02	0.14	0.07	0.66	ND	ND	1.16	ND
3	Bm93	32	ND	0.01	ND	0.10	0.13	0.10	0.26	0.27	0.31	0.22	ND	1.19	ND
4	Bm94	30	ND	ND	ND	0.11	0.05	ND	ND	ND	0.80	0.27	0.07	0.69	1.48
5	Bm95	28	0.01	ND	0.01	0.28	ND	0.02	ND	0.13	0.81	0.49	0.40	0.67	0.63
6	Bm96	27	ND	0.01	0.03	0.13	ND	0.11	0.03	ND	0.08	ND	0.22	0.84	1.78
7	Bm97	25	ND	0.03	ND	0.06	0.07	0.04	0.28	0.10	0.57	0.44	ND	ND	ND
8	Bm98	20	0.01	ND	0.02	0.09	0.08	0.01	0.11	0.23	0.86	0.44	0.47	2.09	0.90
9	Bm99	15	ND	ND	0.06	0.29	0.12	ND	0.05	0.07	ND	0.45	0.12	1.25	0.93
10	Bm100	12	ND	0.01	ND	0.26	ND	ND	0.07	0.09	0.45	0.65	0.82	0.08	2.78

Table (6-2-28): Analysis of Human Hair Samples (Hameshkoreb locality:Female)

NO	Sample code	Age	Zr	Bi	Pb	W	Zn	Cu	Ni	Co	Fe	Mn	Cr	V	Ti
1	Bf 146	03	ND	0.01	0.08	0.21	0.02	0.13	0.10	0.20	0.53	0.23	0.48	ND	1.60
2	Bf 147	44	0.01	ND	0.01	0.24	ND	0.02	0.18	0.10	0.50	0.39	0.03	0.60	1.24
3	Bf 148	01	0.01	ND	0.01	0.36	ND	0.15	ND	ND	0.36	0.54	ND	1.11	0.64
4	Bf 149	01	0.01	0.03	ND	0.19	0.04	0.08	0.04	0.04	0.57	0.72	ND	0.28	0.52
5	Bf 150	40	ND	ND	0.04	0.17	0.07	ND	0.11	0.27	0.29	0.02	0.57	0.87	ND

Table (6-2-29): Physical properties of elements presents in the sample

No	Element	Atomic Number	Atomic Weight	Densityg/cm^3	SpectralLines Kα/Lα (Kev)
1	Ti	22	47.87	4.54	4.512 / 0.452
2	Cr	24	52.00	7.15	5.415 / 0.572
3	Mn	25	54.94	7.44	5.900 / 0.637
4	Fe	26	55.85	7.87	6.405 / 0.705
5	Co	27	58.93	8.86	6.931 / 0.775
6	Ni	28	58.96	8.91	7.480 / 0.849
7	Cu	29	63.55	8.93	8.046 / 0.929
8	Zn	30	65.38	7.13	8.637 / 1.012
9	Zr	40	91.22	6.51	15.775 / 2.044
10	Bi	83	208.98	9.81	Lα=10.551,Mα=2.273
11	Pb	82	207.20	11.34	Lα=10.269,Mα=2.195
12	W	74	183.84	19.25	Lα=8.146,Mα=1.775
13	V	23	50.94	6.11	4.953 / 0.510

Nails:

Table (6-2-30):(Mean±SD) Concentration(%), Male

Area	Zn	Cu	Fe	Mn
Kassala Town	0.0646 ± 0.05	0.0667 ± 0.05	0.6485 ± 0.39	0.3706 ± 0.27
Refi Kassala	0.0600 ± 0.05	0.1013 ± 0.06	0.6010 ± 0.22	0.3293 ± 0.41
Aroma	0.0608 ± 0.03	0.0593 ± 0.03	0.5795 ± 0.36	0.3300 ± 0.24
Shamal eldelta	0.0667 ± 0.03	0.1283 ± 0.07	0.6160 ± 0.30	0.1733 ± 0.11
Wad elhelaw	0.0750 ± 0.05	0.0913 ±0.05	0.4010 ± 0.30	0.2563 ± 0.20
Telkok	0.0783 ± 0.06	0.0450 ± 0.03	0.7510 ± 0.51	0.3225 ± 0.22
Hameshkoreb	0.0814 ± 0.04	0.0689 ± 0.04	0.5030 ± 0.22	0.2800 ± 0.08

Table (6-2-31):(Mean±SD) Concentration(%) ,Female

Area	Zn	Cu	Fe	Mn
Kassala Town	0.1036 ± 0.13	0.1027 ± 0.06	0.5494 ± 0.31	0.3424 ± 0.23
Refi Kassala	0.0654 ± 0.05	0.0779 ± 0.05	0.4516 ± 0.23	0.2965 ± 0.20
Aroma	0.0521 ± 0.04	0.0667 ± 0.04	0.6625 ± 0.28	0.3864 ± 0.20
Shamal eldelta	0.0757 ± 0.05	0.0856 ± 0.05	0.4750 ± 0.27	0.2878 ± 0.29
Wad elhelaw	0.0375 ± 0.03	0.0717 ± 0.05	0.6040 ± 0.18	0.3863 ± 0.20
Telkok	0.0500 ± 0.02	0.0856 ± 0.04	0.4680 ± 0.27	0.2340 ± 0.13
Hameshkoreb	0.0700 ± 0.06	0.0613 ± 0.06	0.6040 ± 0.26	0.3687 ± 0.28

Table (6-2-32):(Mean±SD) Concentration(%), Male

Area	Bi	Pb	Ni	Ti
Kassala Town	0.225 ± 0.02	0.0346 ± 0.03	0.1210 ± 0.08	1.9493 ± 1.21
Refi Kassala	0.0156 ± 0.01	0.0325 ± 0.02	0.8900 ± 2.96	1.6238 ± 1.16
Aroma	0.0186 ± 0.02	0.0200 ± 0.01	0.1456 ± 0.10	1.9350 ± 1.61
Shamal eldelta	0.0133 ± 0.01	0.0100 ± 0.00	0.0886 ± 0.07	1.4740 ± 1.67
Wad elhelaw	0.0260 ± 0.02	0.0150 ± 0.01	0.1300 ± 0.09	1.3125 ± 0.69
Telkok	0.0200 ± 0.01	0.0214 ± 0.01	0.1189 ± 0.06	2.0233 ± 0.80
Hameshkoreb	0.0171 ± 0.01	0.0283 ± 0.02	0.1138 ± 0.06	0.7750 ± 0.74

Table (6-2-33):(Mean±SD) Concentration(%), Female

Area	Bi	Pb	Ni	Ti
Kassala Town	0.0167 ± 0.01	0.0307 ± 0.02	0.1050 ± 0.06	1.6233 ± 1.29
Refi Kassala	0.0200 ± 0.01	0.0207 ± 0.01	0.1084 ± 0.08	1.1818 ± 0.85
Aroma	0.0218 ± 0.01	0.0300 ± 0.02	0.1156 ± 0.08	1.5259 ± 1.37
Shamal eldelta	0.0117 ± 0.01	0.0400 ± 0.02	0.1267 ± 0.06	1.3400 ± 0.76
Wad elhelaw	0.0186 ± 0.01	0.0183 ± 0.01	0.0729 ± 0.07	1.3988 ± 0.99
Telkok	0.0140 ± 0.01	0.0400 ± 0.02	0.1113 ± 0.07	1.1875 ± 0.68
Hameshkoreb	0.0150 ± 0.01	0.0229 ± 0.02	0.1043 ± 0.07	1.4611 ± 0.97

Table (6-2-34):(Mean±SD) Concentration(%), Male

Area	Zr	Co	Cr	V
Kassala Town	0.0110 ± 0.03	0.1285 ± 0.15	0.5015 ± 0.47	0.5546 ± 0.57
Refi Kassala	0.0100 ± 0.00	0.1288 ± 0.11	0.4256 ± 0.44	0.7792 ± 0.67
Aroma	0.0107 ± 0.03	0.1579 ± 0.08	0.6247 ± 0.46	0.5793 ± 0.44
Shamal eldelta	0.0100 ± 0.00	0.1200 ± 0.04	0.4050 ± 0.31	0.6888 ± 0.32
Wad elhelaw	0.0100 ± 0.00	0.1057 ± 0.05	0.3180 ± 0.24	0.7530 ± 0.65

Telkok	0.0157 ± 0.02	0.0640 ± 0.07	0.3600 ± 0.24	0.6544 ± 0.44
Hameshkoreb	0.0100 ± 0.00	0.0938 ± 0.06	0.3050 ± 0.24	0.4267 ± 0.36

Table (6-2-35):(Mean±SD) Concentration(%),Female

Area	Zr	Co	Cr	V
Kassala Town	0.0100 ± 0.00	0.1585 ± 0.13	0.3214 ± 0.20	0.6685 ± 0.47
Refi Kassala	0.0211 ± 0.03	0.1543 ± 0.12	0.4119 ± 0.30	0.9479 ± 0.61
Aroma	0.0090 ± 0.00	0.1186 ± 0.10	0.3627 ± 0.31	0.8947 ± 0.71
Shamal eldelta	0.0100 ± 0.00	0.1357 ± 0.10	0.3643 ± 0.16	0.9844 ± 0.76
Wad elhelaw	0.0100 ± 0.00	0.1271 ± 0.06	0.3433 ± 0.31	0.5067 ± 0.41
Telkok	0.0100 ± 0.00	0.0850 ± 0.05	0.2838 ± 0.25	0.9022 ± 0.74
Hameshkoreb	0.0100 ± 0.00	0.1350 ± 0.10	0.4867 ± 0.22	0.6912 ± 0.55

Table (6-2-36):(Max&Mini) Concentration(%) ,Male

Area	Zn		Cu		Fe		Mn	
	Max	Mini	Max	Mini	Max	Mini	Max	Mini
Kassala Town	0.17	0.02	0.18	0.02	1.73	0.08	0.99	0.01
Refi Kassala	0.17	0.01	0.21	0.02	0.90	0.24	1.57	0.01
Aroma	0.12	0.02	0.11	0.01	1.80	0.17	0.71	0.05
Shamal eldelta	0.09	0.02	0.24	0.07	1.12	0.21	0.29	0.04
Wad elhelaw	0.16	0.01	0.19	0.03	1.08	0.07	0.66	0.04
Telkok	0.19	0.03	0.09	0.01	1.79	0.10	0.69	0.02
Hameshkoreb	0.13	0.03	0.14	0.01	0.80	0.10	0.41	0.20

Table (6-2-37):(Max&Mini) Concentration(%) ,Female

Area	Zn		Cu		Fe		Mn	
	Max	Mini	Max	Mini	Max	Mini	Max	Mini
Kassala Town	0.47	0.01	0.21	0.04	1.21	0.09	0.78	0.04
Refi Kassala	0.15	0.01	0.15	0.01	0.93	0.09	0.79	0.01
Aroma	0.13	0.01	0.15	0.01	1.41	0.21	0.83	0.21
Shamal eldelta	0.16	0.02	0.18	0.02	1.01	0.21	0.91	0.04
Wad elhelaw	0.06	0.01	0.15	0.02	0.83	0.26	0.70	0.20
Telkok	0.08	0.02	0.14	0.02	0.91	0.21	0.39	0.05
Hameshkoreb	0.16	0.01	0.18	0.00	1.01	0.26	0.91	0.04

Table (6-2-38):(Max&Mini) Concentration(%), Male

Area	Bi		Pb		Ni		Ti	
	Max	Mini	Max	Mini	Max	Mini	Max	Mini
Kassala Town	0.05	0.01	0.11	0.01	0.26	0.01	4.49	0.45
Refi Kassala	0.04	0.01	0.08	0.01	12.00	0.01	5.25	0.45

Aroma	0.06	0.01	0.05	0.01	0.36	0.01	5.53	0.40
Shamal eldelta	0.02	0.01	0.01	0.01	0.18	0.02	4.38	0.38
Wad elhelaw	0.06	0.01	0.03	0.01	0.32	0.03	2.33	0.52
Telkok	0.05	0.01	0.05	0.01	0.20	0.02	2.22	1.29
Hameshkoreb	0.03	0.01	0.05	0.01	0.24	0.03	2,35	0.14

Table (6-2-39):(Max&Mini) Concentration(%) ,Female

Area	Bi		Pb		Ni		Ti	
	Max	Mini	Max	Mini	Max	Mini	Max	Mini
Kassala Town	0.03	0.01	0.07	0.01	0.18	0.03	3.93	0.42
Refi Kassala	0.04	0.01	0.05	0.01	0.30	0.00	3.71	0.30
Aroma	0.05	0.01	0.08	0.01	0.27	0.01	5.06	0.09
Shamal eldelta	0.02	0.00	0.06	0.01	0.23	0.06	2,76	0.50
Wad elhelaw	0.03	0.00	0.04	0.01	0.23	0.03	2.94	0.49
Telkok	0.02	0.01	0.06	0.02	0.23	0.04	2.35	0.40
Hameshkoreb	0.02	0.01	0.06	0.01	0.22	0.03	2.94	0.49

Table (6-2-40):(Max&Mini) Concentration(%) ,Male

Area	Zr		Co		Cr		V	
	Max	Mini	Max	Mini	Max	Mini	Max	Mini
Kassala Town	0.02	0.01	0.50	0.01	1.63	0.07	1.95	0.08
Refi Kassala	0.01	0.01	0.48	0.02	1.64	0.04	2.23	0.04
Aroma	0.02	0.01	0.28	0.03	1.41	0.05	1.41	0.04
Shamal eldelta	0.01	0.01	0.16	0.07	0.79	0.02	1.04	0.02
Wad elhelaw	0.01	0.01	0.17	0.02	0.63	0.05	2.11	0.06
Telkok	0.05	0.01	0.16	0.01	0.66	0.04	1.41	0.16
Hameshkoreb	0.01	0.01	0.19	0.05	0.66	0.03	1.00	0.07

Table (6-2-41):(Max&Mini) Concentration(%),Female

Area	Zr		Co		Cr		V	
	Max	Mini	Max	Mini	Max	Mini	Max	Mini
Kassala Town	0.01	0.01	0.51	0.02	0.65	0.08	1.55	0.18
Refi Kassala	0.10	0.01	0.52	0.06	0.97	0.03	2.21	0.14
Aroma	0.01	0.00	0.35	0.00	0.98	0.02	2.20	0.04
Shamal eldelta	0.01	0.01	0.30	0.02	0.49	0.09	2.41	0.15
Wad elhelaw	0.01	0.01	0.20	0.01	0.95	0.02	1.26	0.07
Telkok	0.01	0.01	0.18	0.01	0.76	0.02	2.41	0.16
Hameshkoreb	0.01	0.01	0.30	0.01	0.95	0.16	1.81	0.17

Hair

Table (6-2-42):(Mean±SD) Concentration(%) ,Male.

Area	Zn	Cu	Fe	Mn
Kassala Town	0.0585 ± 0.05	0.1760 ± 0.40	0.0815 ± 0.20	0.2288 ± 0.15
Refi Kassala	0.1458 ± 0.30	0.0700 ± 0.05	0.1056 ± 0.25	0.3469 ± 0.22
Aroma	0.0493 ± 0.03	0.0867 ± 0.07	0.1233 ± 0.35	0.2524 ± 0.24
Shamal eldelta	0.0478 ± 0.03	0.0371 ± 0.04	0.0850 ± 0.23	0.2483 ± 0.25
Wad elhelaw	0.1157 ± 0.07	0.0775 ± 0.06	0.1683 ± 0.31	0.2863 ± 0.18
Telkok	0.0633 ± 0.05	0.0633 ± 0.03	0.0711 ± 0.25	0.2589 ± 0.14
Hameshkoreb	0.0929 ± 0.05	0.0529 ± 0.04	0.1238 ± 0.27	0.4050 ± 0.14

Table (6-2-43):(Mean±SD) Concentration(%) ,Female.

Area	Zn	Cu	Fe	Mn
Kassala Town	0.0400 ± 0.03	0.0388 ± 0.04	0.0844 ± 0.48	0.1757 ± 0.10
Refi Kassala	0.0522 ± 0.02	0.0586 ± 0.04	0.1190 ± 0.30	0.3017 ± 0.21
Aroma	0.0500 ± 0.03	0.1167 ± 0.10	0.1150 ± 0.30	0.2800 ± 0.15
Shamal eldelta	0.0633 ± 0.02	0.0600 ± 0.04	0.0475 ± 0.39	0.3400 ± 0.52
Wad elhelaw	0.0467 ± 0.05	0.0975 ± 0.04	0.2140 ± 0.22	0.2500 ± 0.06
Telkok	0.0660 ± 0.06	0.0760 ± 0.05	0.0550 ± 0.30	0.2220 ± 0.18
Hameshkoreb	0.0433 ± 0.03	0.0950 ± 0.06	0.1075 ± 0.12	0.2857 ± 0.27

Table (6-2-44):(Mean±SD) Concentration(%) ,Male.

Area	Bi	Pb	Ni	Ti
Kassala Town	0.0900 ± 0.18	0.0257 ± 0.02	0.0815 ± 0.06	1.3250 ± 1.02
Refi Kassala	0.0180 ± 0.01	0.0193 ± 0.01	0.1056 ± 0.08	1.6911 ± 0.89
Aroma	0.0155 ± 0.01	0.0164 ± 0.01	0.1233 ± 0.09	1.1647 ± 0.75
Shamal eldelta	0.0100 ± 0.00	0.0267 ± 0.02	0.0850 ± 0.08	1.8514 ± 0.95
Wad elhelaw	0.0200 ± 0.01	0.0371 ± 0.03	0.1683 ± 0.17	1.8033 ± 1.28
Telkok	0.0300 ± 0.00	0.0160 ± 0.01	0.0711 ± 0.03	1.5938 ± 1.01
Hameshkoreb	0.0167 ± 0.01	0.0300 ± 0.02	0.1238 ± 0.10	1.4300 ± 1.43

Table (6-2-45):(Mean±SD) Concentration(%) ,Female.

Area	Bi	Pb	Ni	Ti
Kassala Town	0.0150 ± 0.01	0.0238 ± 0.02	0.0844 ± 0.06	1.2725 ± 1.09
Refi Kassala	0.0144 ± 0.01	0.0250 ± 0.01	0.1190 ± 0.05	2.0750 ± 0.76
Aroma	0.0700 ± 0.12	0.0180 ± 0.01	0.1150 ± 0.05	1.1950 ± 0.62

Shamal eldelta	0.0200 ± 0.01	0.0300 ± 0.00	0.0475 ± 0.04	0.9450 ± 0.45
Wad elhelaw	0.0133 ± 0.01	0.0100 ± 0.00	0.2140 ± 0.14	0.8333 ± 0.22
Telkok	0.0125 ± 0.01	0.0100 ± 0.00	0.0550 ± 0.04	1.5877 ± 0.58
Hameshkoreb	0.0200 ± 0.01	0.0350 ± 0.03	0.1075 ± 0.06	1.0000 ± 1.00

Table (6-2-46):(Mean±SD) Concentration(%), Male.

Area	Zr	Co	Cr	V
Kassala Town	0.0100 ± 0.00	0.1333 ± 0.09	0.4794 ± 0.24	0.8275 ± 0.54
Refi Kassala	0.0100 ± 0.00	0.0733 ± 0.06	0.3594 ± 0.27	0.5553 ± 0.33
Aroma	0.0100 ± 0.00	0.1025 ± 0.09	0.4000 ± 0.38	0.5936 ± 0.39
Shamal eldelta	0.0100 ± 0.00	0.1371 ± 0.21	0.1600 ± 0.12	0.3571 ± 0.24
Wad elhelaw	0.0100 ± 0.00	0.1067 ± 0.07	0.2717 ± 0.17	0.6500 ± 0.40
Telkok	0.0100 ± 0.00	0.0900 ± 0.05	0.4017 ± 0.28	0.4067 ± 0.37
Hameshkoreb	0.0167 ± 0.01	0.1375 ± 0.07	0.4843 ± 0.44	0.9011 ± 0.62

Table (6-2-47):(Mean±SD) Concentration(%),Female.

Area	Zr	Co	Cr	V
Kassala Town	0.0100 ± 0.00	0.0717 ± 0.06	0.4113 ± 0.36	0.5417 ± 0.40
Refi Kassala	0.0100 ± 0.00	0.1433 ± 0.08	0.2600 ± 0.21	0.3883 ± 0.39
Aroma	0.0100 ± 0.00	0.1017 ± 0.06	0.4450 ± 0.28	0.9975 ± 0.67
Shamal eldelta	0.0100 ± 0.00	0.1150 ± 0.07	0.1067 ± 0.06	1.2050 ± 0.85
Wad elhelaw	0.0100 ± 0.00	0.0633 ± 0.07	0.6100 ± 0.34	0.7975 ± 0.55
Telkok	0.0100 ± 0.00	0.1940 ± 0.13	0.1467 ± 0.05	0.6575 ± 0.35
Hameshkoreb	0.0100 ± 0.00	0.1525 ± 0.10	0.3600 ± 0.29	0.8438 ± 0.36

Table (6-2-48):(Max&Mini) Concentration(%), Male.

Area	Zn		Cu		Fe		Mn	
	Max	Mini	Max	Mini	Max	Mini	Max	Mini
Kassala Town	0.15	0.01	1.50	0.02	0.66	0.04	0.48	0.02
Refi Kassala	1.01	0.01	0.20	0.01	1.24	0.06	0.81	0.05
Aroma	0.13	0.01	0.26	0.01	1.32	0.01	1.08	0.05
Shamal eldelta	0.09	0.01	0.13	0.01	0.83	0.10	0.74	0.05
Wad elhelaw	0.21	0.03	0.19	0.01	1.14	0.14	0.62	0.08
Telkok	0.14	0.01	0.10	0.03	0.89	0.07	0.47	0.05
Hameshkoreb	0.17	0.03	0.11	0.01	0.86	0.08	0.65	0.22

Table (6-2-49):(Max&Mini) Concentration(%) ,Female.

Area	Zn		Cu		Fe		Mn	
	Max	Mini	Max	Mini	Max	Mini	Max	Mini
Kassala Town	0.07	0.02	0.11	0.01	1.60	0.10	0.33	0.07
Refi Kassala	0.10	0.02	0.13	0.02	1.24	0.25	0.63	0.08

Aroma	0.11	0.01	0.30	0.03	0.88	0.05	0.47	0.07
Shamal eldelta	0.08	0.05	0.13	0.02	1.08	0.17	1.12	0.06
Wad elhelaw	0.07	0.02	0.13	0.05	1.29	0.76	0.32	0.21
Telkok	0.14	0.01	0.15	0.01	1.07	0.31	0.51	0.10
Hameshkoreb	0.17	0.02	0.15	0.02	1.32	0.01	0.72	0.02

Table (6-2-50):(Max&Mini) Concentration(%) ,Male.

Area	Bi		Pb		Ni		Ti	
	Max	Mini	Max	Mini	Max	Mini	Max	Mini
Kassala Town	0.57	0.01	0.06	0.01	0.20	0.01	3.84	0.41
Refi Kassala	0.04	0.01	0.05	0.01	0.29	0.01	3.77	0.46
Aroma	0.03	0.01	0.05	0.01	0.33	0.01	2.59	0.25
Shamal eldelta	0.01	0.01	0.07	0.01	0.20	0.02	3.54	0.61
Wad elhelaw	0.04	0.01	0.08	0.01	0.47	0.02	3.46	0.56
Telkok	0.03	0.03	0.03	0.01	0.14	0.04	2.79	0.13
Hameshkoreb	0.03	0.01	0.06	0.01	0.28	0.03	2.78	0.63

Table (6-2-51):(Max&Mini) Concentration(%) ,Female.

Area	Bi		Pb		Ni		Ti	
	Max	Mini	Max	Mini	Max	Mini	Max	Mini
Kassala Town	0.02	0.01	0.06	0.01	0.18	0.01	3.67	0.30
Refi Kassala	0.02	0.01	0.03	0.01	0.18	0.03	3.29	0.97
Aroma	0.30	0.01	0.03	0.01	0.16	0.01	2.03	0.40
Shamal eldelta	0.03	0.01	0.03	0.01	0.10	0.02	1.40	0.48
Wad elhelaw	0.02	0.01	0.01	0.01	0.41	0.07	1.08	0.68
Telkok	0.02	0.01	0.01	0.01	0.10	0.01	2.07	0.57
Hameshkoreb	0.03	0.01	0.08	0.01	0.18	0.04	1.60	0.52

Table (6-2-52):(Max&Mini) Concentration(%) ,Male.

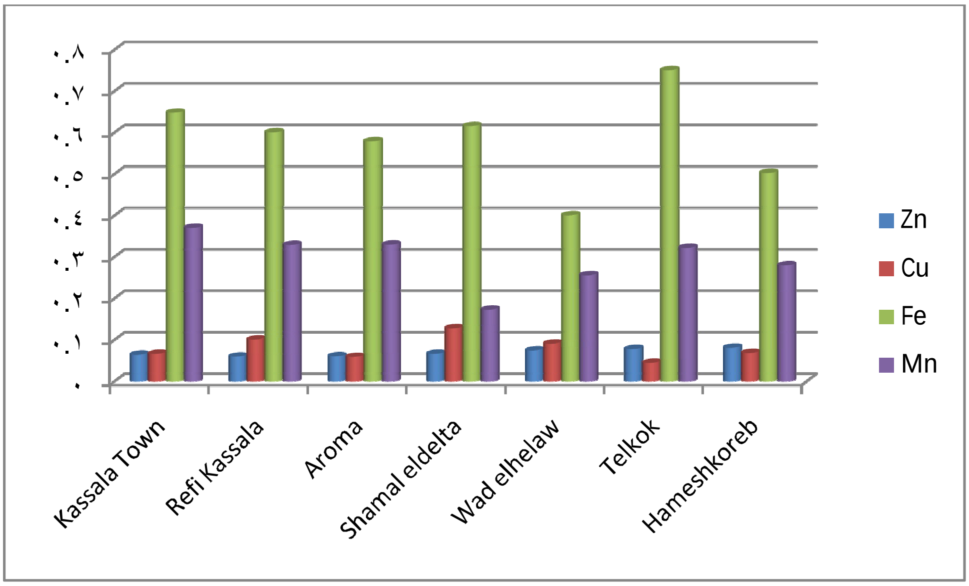
Area	Zr		Co		Cr		V	
	Max	Mini	Max	Mini	Max	Mini	Max	Mini
Kassala Town	0.01	0.01	0.31	0.02	1.00	0.12	2.22	0.15
Refi Kassala	0.01	0.01	0.19	0.01	1.07	0.05	1.12	0.04
Aroma	0.01	0.01	0.26	0.01	1.28	0.02	1.32	0.06
Shamal eldelta	0.01	0.01	0.61	0.01	0.39	0.01	0.75	0.13
Wad elhelaw	0.01	0.01	0.24	0.04	0.51	0.13	1.35	0.37
Telkok	0.01	0.01	0.16	0.03	0.79	0.14	0.93	0.03
Hameshkoreb	0.03	0.01	0.27	0.07	1.29	0.07	2.09	0.08

Table (6-2-53):(Max&Mini) Concentration(%),Female.

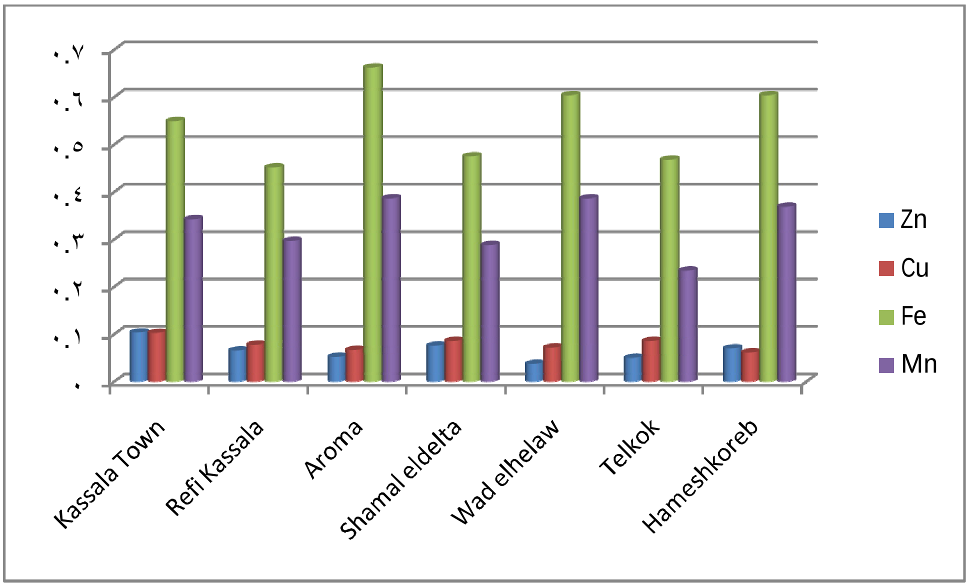
Area	Zr	Co	Cr	V

	Max	Mini	Max	Mini	Max	Mini	Max	Mini
Kassala Town	0.01	0.01	0.17	0.01	0.95	0.07	1.26	0.20
Refi Kassala	0.01	0.01	0.27	0.05	0.55	0.04	1.02	0.04
Aroma	0.01	0.01	0.17	0.01	0.87	0.05	2.05	0.09
Shamal eldelta	0.01	0.01	0.22	0.05	0.15	0.04	1.81	0.60
Wad elhelaw	0.01	0.01	0.14	0.01	0.85	0.37	1.50	0.35
Telkok	0.01	0.01	0.40	0.02	0.20	0.10	0.98	0.21
Hameshkoreb	0.01	0.01	0.27	0.04	0.57	0.03	2.22	0.03

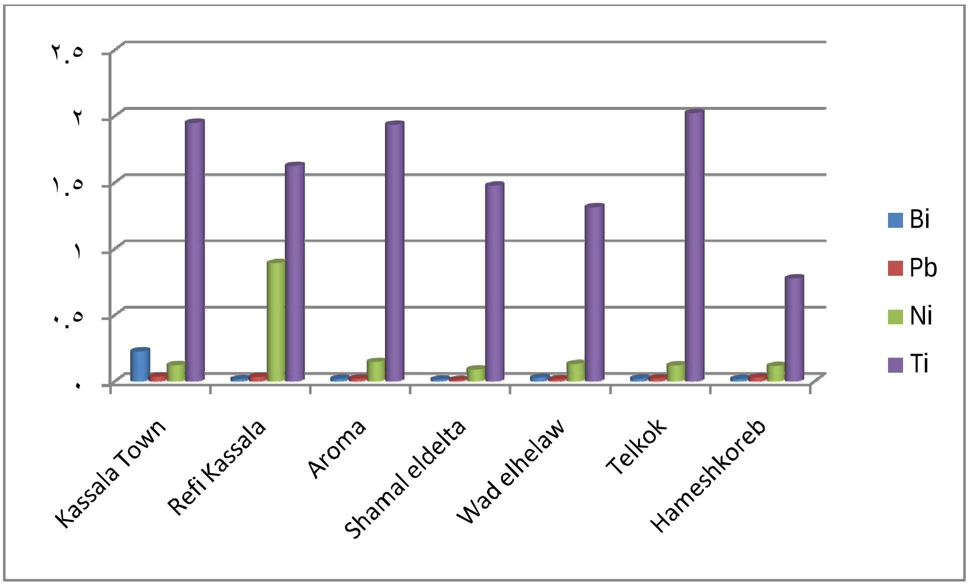
Nails:



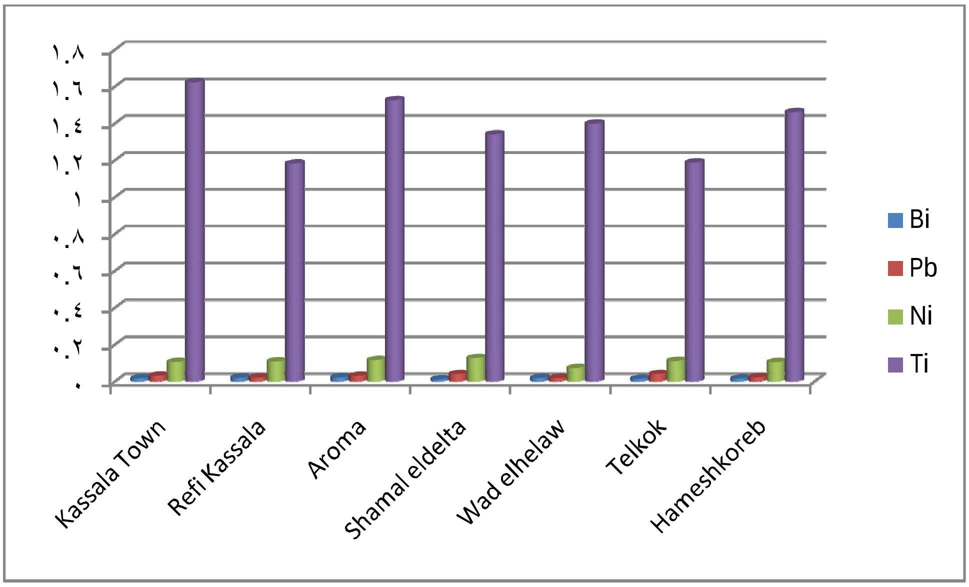
Graph (6-2-1):Mean Concentration(%) ,Male.



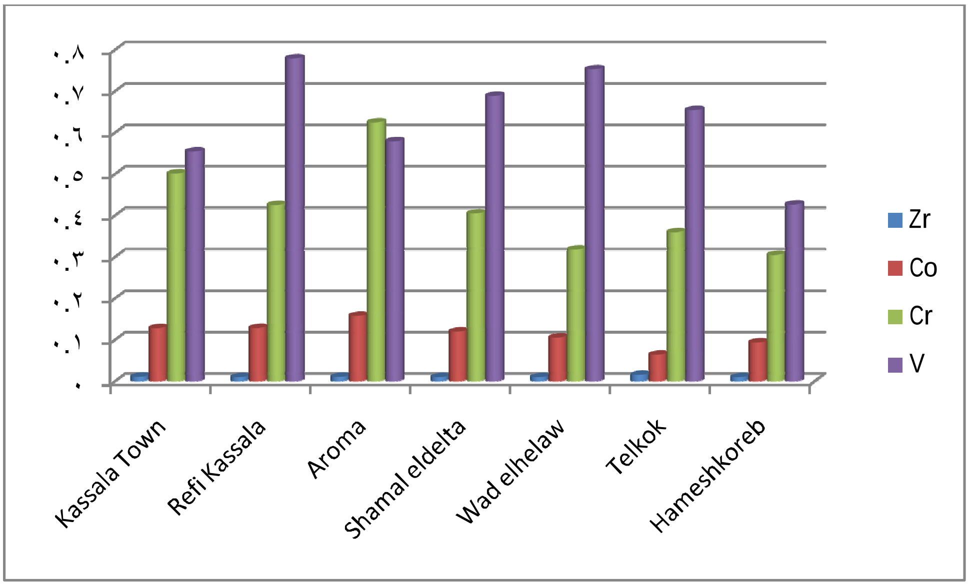
Graph (6-2-2):Mean Concentration(%), Female.



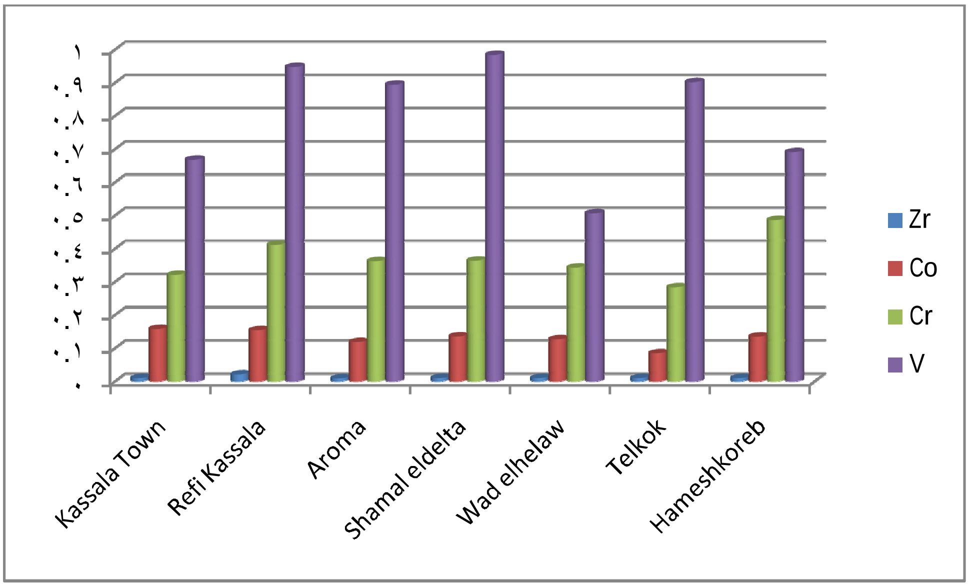
Graph (6-2-3):Mean Concentration(%) ,Male.



Graph (6-2-4):Mean Concentration(%) ,Female.

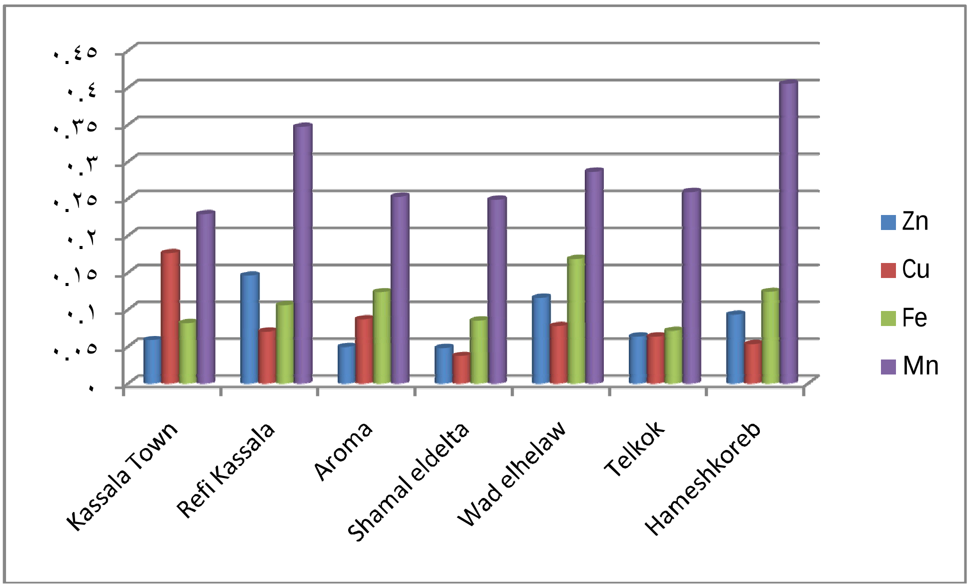


Graph (6-2-5):Mean Concentration(%), Male.

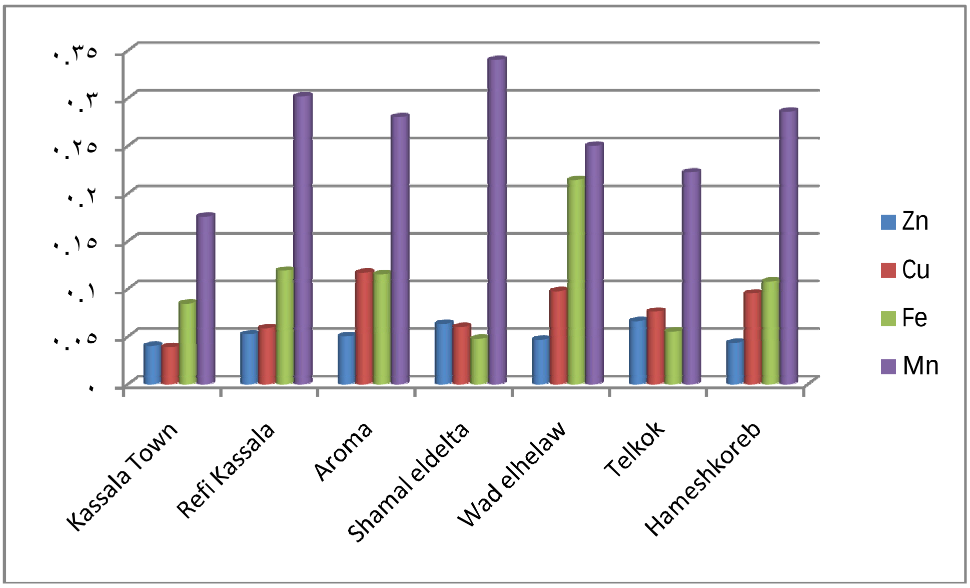


Graph (6-2-6):Mean Concentration(%) ,Female.

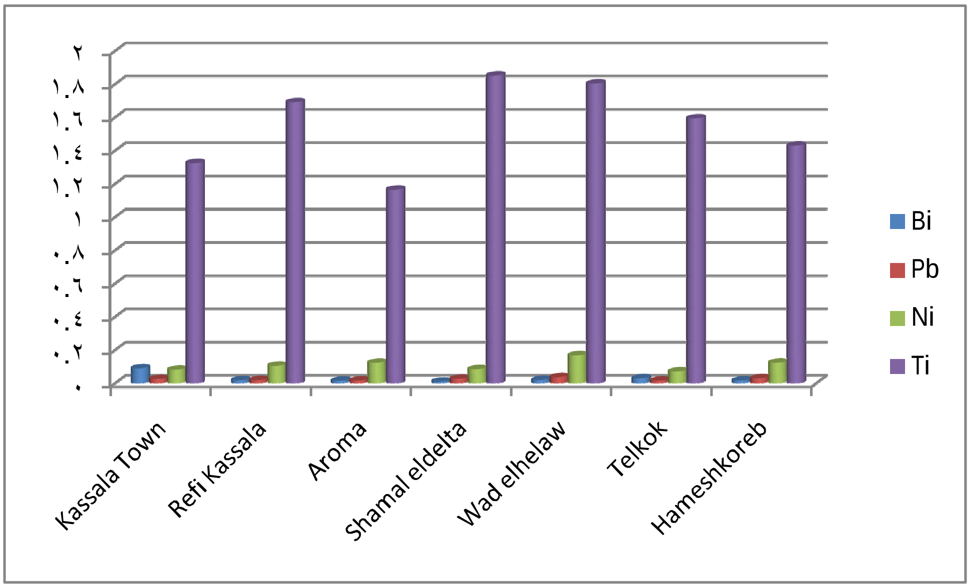
Hair:



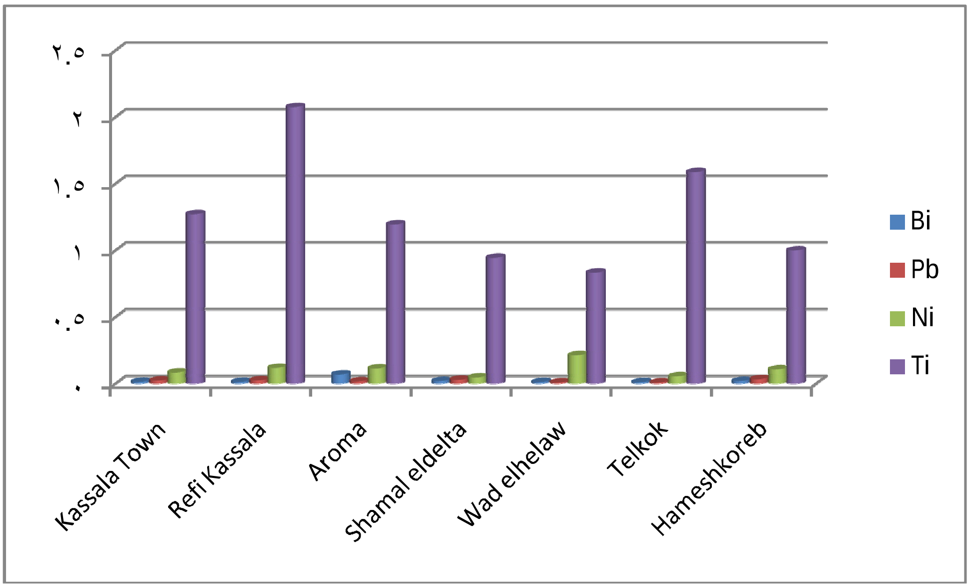
Graph (6-2-7):Mean Concentration(%) ,Male.



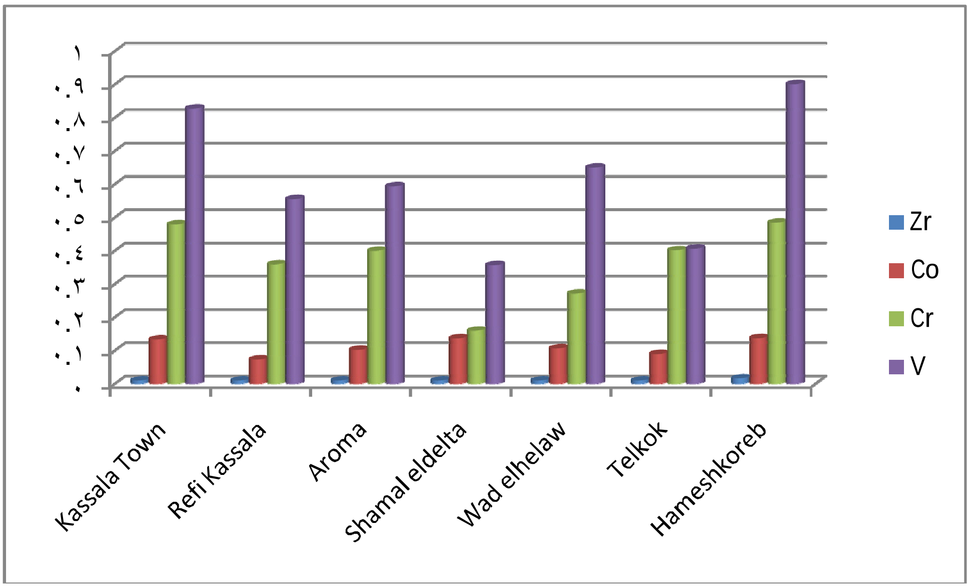
Graph (6-2-8):Mean Concentration(%) ,Female.



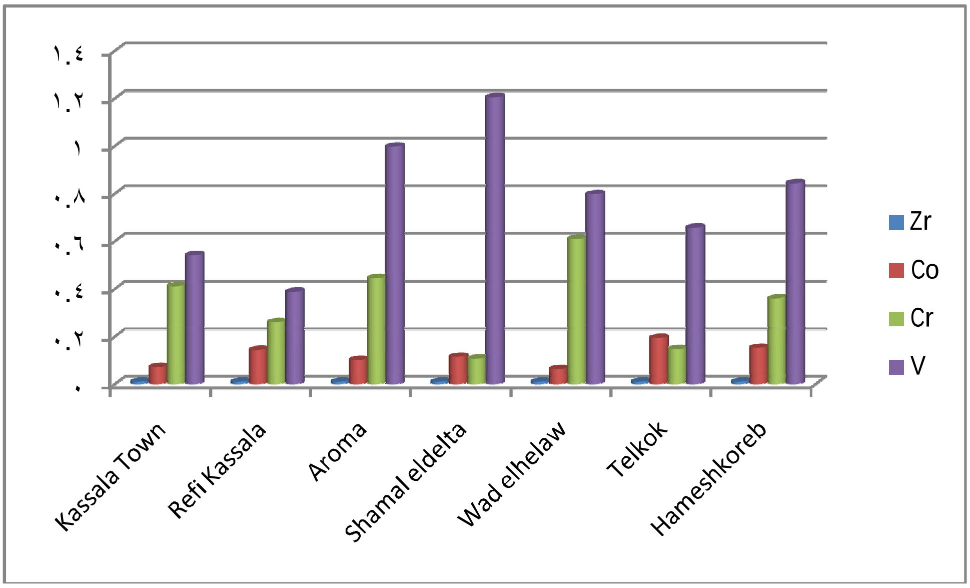
Graph (6-2-9):Mean Concentration(%) ,Male.



Graph (6-2-10):Mean Concentration(%) ,Female.



Graph (6-2-11):Mean Concentration(%) ,Male.



Graph (6-2-12):Mean Concentration(%) ,Female.

6-3 Discusion:

The human nail and hair are two of the interfaces between the body and the environment, and it plays an important role in the defense of the organism.

In 2013 and 2014 hair and fingernails samples collected from inhabitants of Kassala state eastern-Suadn,our study proved that hair and nail can be a ccumulating indicator of occupational and/or environmental exposure.

The samples have been analyzed via X-Ray Fluorescence spectroscopy(XRF) analysis to determine the trace element,the results obtained are presented in tables from (6-2-1) to(6-2-14) for nails according to inhabitants location and tables from (6-2-15) to (6-2-28) for hair samples.

The main descriptive statistics of element concentration in hair and nails are presented from table (6-2-30) to table (6-2-53) presents mean values± standard deviation ,max and mini values according to locations of the study,graph (6-2-1) and graph (6-2-2) presents concentration of (Zn,Cu,Fe,Mn) in nails male and female respectively , graph (6-2-3) and graph (6-2-4) presents concentration of (Bi,Pb,Ni,Ti) in nails male and female respectively, graph (6-2-5) and graph (6-2-6) presents concentration of (Zr,Co,Cr,V) in nails male and female respectively, graph (6-2-7) and graph (6-2-8) presents concentration of (Zn,Cu,Fe,Mn) in hair male and female respectively , graph (6-2-9) and graph (6-2-10) presents concentration of (Bi,Pb,Ni,Ti) in hair male and female respectively, graph (6-2-11) and graph (6-2-12) presents concentration of (Zr,Co,Cr,V) in hair male and female respectively, The concentration of Cu,Zn,Fe and Mn are low value in male than female in all sample,the lowst level of Fe in all samples showed in female hair than male,the concentration of Fe,Zn,Mn and Cu were affected by age. In hair samples Cr,Ni and Co were different in males and females but higher levels in females.The Fe level in nail samples were affected by all three factors[location,sex,age],Cobalt level varied with residence in hair isamples and showed maximum concentration in females followed by Cr. Fe,Mn and Zn .

The data presented here clearly demonstrated the suitability of XRF for the quantitative analysis of Fe, Zn,Co,Cu,Ni,Cr,Mn ,Zr,V,Bi,Pb and Ti.

CHAPTER (VI)

Conculsion and Future Work

7-1 Conculsion:

In this work it we conclude that:

- The investigation of elements concentration in hair and nails in the population of study area are at a possible ris due to exposures to surface soil,drinking water,types of food and other environmental soure.
- Hair analysis might soon become a powerful diagnostic tool in monitoring of environmental exposure and studying the nutritional status of individuals.
- The body store of minerals may be estimated from hair and nails analysis ,the concentration of elements in hair and nails are the best method of evaluating the mineral status of the body.
- Hair is an indicator of heavy metals status in human body.
- Hair is widely accepted for assessing toxic elements exposures.
- Element contents in hair and nails of a given person showed that the level changed significantly with changes of living habits or environmental exposure.
- The effect of living habits on the level of given elements was found to be stronger than the influence of either sex and age.
- The application of hair minerals analysis is suitable for the assessment of human exposure to metals from various sources.
- Nails and hair of human being elements concentration percentage in Eastern Sudan,Kassala State relative to the long term source exposure have not been stablished yet.

7-2 **Future Work and Recommendations:**

(1) Anmuber of research works have been carried out with the aim of correlating the levels of metals in human hair as diagnosis of various diseases.

(2) In this framework it is recommended that mineral analysis of hair and nails may be useful in knowing elemental concentration in body tissues.

Recommendations:

(1) The use of hair analysis by spectroscopy techniques to estimate the elements radiation in the area.

(2) To compare the results of the analysis of water in Kassala state with that of hair and nails in other area.

(3) Analysis of water ,hair and nails in Kassala state by using other spectroscopy techniques(ICP-MS,NAA,AAS and LIBS).

(4) This research work which is mainly concerned with the area of Kassala State, in Eastern Sudan, as proposed project which can be further extended to other areas in Sudan.

(5) To propose a study of hair analysis for human habits for example (smokers and non smokers people).

(6) To study the correlation of concentration of elements in hair and nails with dietary intake.

(7) To study the correlation respective concentration of elements in hair and nails with avairety diseases in areas.

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Appendix

Statistical Analysis of Nails Samples data:

Zr

Sex	Area	Mean	N	Std. Deviation	Minimum	Maximum
Male	Kassala	0.0110	10	0.00316	0.01	0.02
	Refi Kassala	0.0100	9	0.00000	0.01	0.01
	Aroma	0.0107	14	0.00267	0.01	0.02
	Eldelta	0.0100	3	0.00000	0.01	0.01
	Wad eLhelaw	0.0100	5	0.00000	0.01	0.01
	Telkok	0.0157	7	0.01512	0.01	0.05
	Hameshkoreb	0.0100	5	0.00000	0.01	0.01
	Total	0.0111	53	0.00577	0.01	0.05
Female	Kassala	0.0100	8	0.00000	0.01	0.01
	Refi Kassala	0.0211	9	0.02977	0.01	0.10
	Aroma	0.0090	10	0.00316	0.00	0.01
	Eldelta	0.0100	7	0.00000	0.01	0.01
	Wad eLhelaw	0.0100	6	0.00000	0.01	0.01
	Telkok	0.0100	5	0.00000	0.01	0.01
	Hameshkoreb	0.0100	9	0.00000	0.01	0.01
	Total	0.0117	54	0.01240	0.00	0.10
Total	Kassala	0.0106	18	0.00236	0.01	0.02
	Refi Kassala	0.0156	18	0.02121	0.01	0.10
	Aroma	0.0100	24	0.00295	0.00	0.02
	Eldelta	0.0100	10	0.00000	0.01	0.01
	Wad eLhelaw	0.0100	11	0.00000	0.01	0.01
	Telkok	0.0133	12	0.01155	0.01	0.05
	Hameshkoreb	0.0100	14	0.00000	0.01	0.01
	Total	0.0114	107	0.00966	0.00	0.10

Bi

Sex	Area	Mean	N	Std. Deviation	Minimum	Maximum
Male	Kassala	0.0225	12	0.01603	0.01	0.05
	Refi Kassala	0.0156	9	0.01130	0.01	0.04
	Aroma	0.0186	14	0.01657	0.01	0.06
	Eldelta	0.0133	6	0.00516	0.01	0.02
	Wad eLhelaw	0.0260	5	0.01949	0.01	0.06
	Telkok	0.0200	7	0.01414	0.01	0.05
	Hameshkoreb	0.0171	7	0.00756	0.01	0.03
	Total	0.0190	60	0.01386	0.01	0.06
Female	Kassala	0.0167	6	0.00816	0.01	0.03
	Refi Kassala	0.0200	10	0.00943	0.01	0.04
	Aroma	0.0218	11	0.01328	0.01	0.05
	Eldelta	0.0117	6	0.00753	0.00	0.02
	Wad eLhelaw	0.0186	7	0.01069	0.00	0.03
	Telkok	0.0140	5	0.00548	0.01	0.02
	Hameshkoreb	0.0150	6	0.00548	0.01	0.02
	Total	0.0176	51	0.00971	0.00	0.05
Total	Kassala	0.0206	18	0.01392	0.01	0.05
	Refi Kassala	0.0179	19	0.01032	0.01	0.04
	Aroma	0.0200	25	0.01500	0.01	0.06
	Eldelta	0.0125	12	0.00622	0.00	0.02
	Wad eLhelaw	0.0217	12	0.01467	0.00	0.06
	Telkok	0.0175	12	0.01138	0.01	0.05
	Hameshkoreb	0.0162	13	0.00650	0.01	0.03
	Total	0.0184	111	0.01210	0.00	0.06

Pb

Sex	Area	Mean	N	Std. Deviation	Minimum	Maximum
Male	Kassala	0.0346	13	0.02787	0.01	0.11
	Refi Kassala	0.0325	12	0.02179	0.01	0.08
	Aroma	0.0200	11	0.01483	0.01	0.05
	Eldelta	0.0100	3	0.00000	0.01	0.01
	Wad eLhelaw	0.0150	8	0.00926	0.01	0.03
	Telkok	0.0214	7	0.01464	0.01	0.05
	Hameshkoreb	0.0283	6	0.02041	0.01	0.05
	Total	0.0255	60	0.02037	0.01	0.11
Female	Kassala	0.0307	14	0.02336	0.01	0.07
	Refi Kassala	0.0207	14	0.01328	0.00	0.05
	Aroma	0.0300	16	0.02309	0.01	0.08
	Eldelta	0.0400	7	0.01826	0.01	0.06
	Wad eLhelaw	0.0183	6	0.01329	0.01	0.04
	Telkok	0.0400	6	0.01673	0.02	0.06
	Hameshkoreb	0.0229	7	0.01890	0.01	0.06
	Total	0.0284	70	0.01990	0.00	0.08
Total	Kassala	0.0326	27	0.02521	0.01	0.11
	Refi Kassala	0.0262	26	0.01835	0.00	0.08
	Aroma	0.0259	27	0.02043	0.01	0.08
	Eldelta	0.0310	10	0.02079	0.01	0.06
	Wad eLhelaw	0.0164	14	0.01082	0.01	0.04
	Telkok	0.0300	13	0.01780	0.01	0.06
	Hameshkoreb	0.0254	13	0.01898	0.01	0.06
	Total	0.0271	130	0.02009	0.00	0.11

W

Sex	Area	Mean	N	Std. Deviation	Minimum	Maximum
Male	Kassala	0.3389	19	0.15051	0.13	0.67
	Refi Kassala	0.2105	20	0.08204	0.08	0.39
	Aroma	0.2645	20	0.13359	0.05	0.58
	Eldelta	0.1630	10	0.05355	0.10	0.23
	Wad eLhelaw	0.2360	10	0.14152	0.04	0.50
	Telkok	0.2160	10	0.09755	0.01	0.37
	Hameshkoreb	0.2310	10	0.10713	0.10	0.43
	Total	0.2465	99	0.12564	0.01	0.67
Female	Kassala	0.2395	19	0.10809	0.03	0.46
	Refi Kassala	0.2455	20	0.14838	0.02	0.60
	Aroma	0.2645	20	0.17352	0.04	0.73
	Eldelta	0.2450	10	0.14699	0.05	0.52
	Wad eLhelaw	0.2680	10	0.14597	0.07	0.53
	Telkok	0.2260	10	0.17564	0.04	0.52
	Hameshkoreb	0.2830	10	0.12010	0.11	0.53
	Total	0.2522	99	0.14359	0.02	0.73
Total	Kassala	0.2892	38	0.13873	0.03	0.67
	Refi Kassala	0.2280	40	0.11966	0.02	0.60
	Aroma	0.2645	40	0.15285	0.04	0.73
	Eldelta	0.2040	20	0.11559	0.05	0.52
	Wad eLhelaw	0.2520	20	0.14088	0.04	0.53
	Telkok	0.2210	20	0.13837	0.01	0.52
	Hameshkoreb	0.2570	20	0.11393	0.10	0.53
	Total	0.2493	198	0.13461	0.01	0.73

Zn

Sex	Area	Mean	N	Std. Deviation	Minimum	Maximum
Male	Kassala	0.0646	13	0.04576	0.02	0.17
	Refi Kassala	0.0600	14	0.04658	0.01	0.17
	Aroma	0.0608	13	0.03252	0.02	0.12
	Eldelta	0.0667	6	0.02582	0.02	0.09
	Wad eLhelaw	0.0750	6	0.05010	0.01	0.16
	Telkok	0.0783	6	0.05707	0.03	0.19
	Hameshkoreb	0.0814	7	0.03625	0.03	0.13
	Total	0.0671	65	0.04145	0.01	0.19
Female	Kassala	0.1036	11	0.12871	0.01	0.47
	Refi Kassala	0.0654	13	0.05076	0.01	0.15
	Aroma	0.0521	19	0.03660	0.01	0.13
	Eldelta	0.0757	7	0.05287	0.02	0.16
	Wad eLhelaw	0.0375	4	0.02630	0.01	0.06
	Telkok	0.0500	8	0.02449	0.02	0.08
	Hameshkoreb	0.0700	6	0.06387	0.01	0.16
	Total	0.0659	68	0.06573	0.01	0.47
Total	Kassala	0.0825	24	0.09322	0.01	0.47
	Refi Kassala	0.0626	27	0.04776	0.01	0.17
	Aroma	0.0556	32	0.03473	0.01	0.13
	Eldelta	0.0715	13	0.04120	0.02	0.16
	Wad eLhelaw	0.0600	10	0.04472	0.01	0.16
	Telkok	0.0621	14	0.04228	0.02	0.19
	Hameshkoreb	0.0762	13	0.04891	0.01	0.16
	Total	0.0665	133	0.05501	0.01	0.47

Cu

Sex	Area	Mean	N	Std. Deviation	Minimum	Maximum
Male	Kassala	0.0667	15	0.04546	0.02	0.18
	Refi Kassala	0.1013	15	0.05986	0.02	0.21
	Aroma	0.0593	14	0.03496	0.01	0.11
	Eldelta	0.1283	6	0.06555	0.07	0.24
	Wad eLhelaw	0.0913	8	0.05055	0.03	0.19
	Telkok	0.0450	6	0.02665	0.01	0.09
	Hameshkoreb	0.0689	9	0.04197	0.01	0.14
	Total	0.0786	73	0.05149	0.01	0.24
Female	Kassala	0.1027	15	0.05958	0.04	0.21
	Refi Kassala	0.0779	14	0.04949	0.01	0.15
	Aroma	0.0667	15	0.04304	0.01	0.15
	Eldelta	0.0856	9	0.05318	0.02	0.18
	Wad eLhelaw	0.0717	6	0.04997	0.02	0.15
	Telkok	0.0856	9	0.04216	0.02	0.14
	Hameshkoreb	0.0613	8	0.05939	0.00	0.18
	Total	0.0801	76	0.05108	0.00	0.21
Total	Kassala	0.0847	30	0.05519	0.02	0.21
	Refi Kassala	0.0900	29	0.05542	0.01	0.21
	Aroma	0.0631	29	0.03883	0.01	0.15
	Eldelta	0.1027	15	0.06017	0.02	0.24
	Wad eLhelaw	0.0829	14	0.04937	0.02	0.19
	Telkok	0.0693	15	0.04114	0.01	0.14
	Hameshkoreb	0.0653	17	0.04939	0.00	0.18
	Total	0.0794	149	0.05111	0.00	0.24

Ni

Sex	Area	Mean	N	Std. Deviation	Minimum	Maximum
Male	Kassala	0.1210	10	0.08117	0.01	0.26
	Refi Kassala	0.8900	16	02.96427	0.01	12.00
	Aroma	0.1456	16	0.10152	0.01	0.36
	Eldelta	0.0886	7	0.06644	0.02	0.18
	Wad eLhelaw	0.1300	9	0.09110	0.03	0.32
	Telkok	0.1189	9	0.05925	0.02	0.20
	Hameshkoreb	0.1138	8	0.06301	0.03	0.24
	Total	0.2873	75	1.37335	0.01	12.00
Female	Kassala	0.1050	16	0.05502	0.03	0.18
	Refi Kassala	0.1084	19	0.08441	0.00	0.30
	Aroma	0.1156	18	0.07524	0.01	0.27
	Eldelta	0.1267	9	0.06265	0.06	0.23
	Wad eLhelaw	0.0729	7	0.07158	0.03	0.23
	Telkok	0.1113	8	0.07298	0.04	0.23
	Hameshkoreb	0.1043	7	0.06680	0.03	0.22
	Total	0.1082	84	0.07022	0.00	0.30
Total	Kassala	0.1112	26	0.06520	0.01	0.26
	Refi Kassala	0.4657	35	2.00908	0.00	12.00
	Aroma	0.1297	34	0.08851	0.01	0.36
	Eldelta	0.1100	16	0.06512	0.02	0.23
	Wad eLhelaw	0.1050	16	0.08563	0.03	0.32
	Telkok	0.1153	17	0.06404	0.02	0.23
	Hameshkoreb	0.1093	15	0.06262	0.03	0.24
	Total	0.1927	159	0.94551	0.00	12.00

Co

Sex	Area	Mean	N	Std. Deviation	Minimum	Maximum
Male	Kassala	0.1285	13	0.14611	0.01	0.50
	Refi Kassala	0.1288	16	0.10582	0.02	0.48
	Aroma	0.1579	14	0.08126	0.03	0.28
	Eldelta	0.1200	4	0.03742	0.07	0.16
	Wad eLhelaw	0.1057	7	0.05192	0.02	0.17
	Telkok	0.0640	5	0.06731	0.01	0.16
	Hameshkoreb	0.0938	8	0.05528	0.05	0.19
	Total	0.1228	67	0.09646	0.01	0.50
Female	Kassala	0.1585	13	0.13069	0.02	0.51
	Refi Kassala	0.1543	14	0.12024	0.06	0.52
	Aroma	0.1186	14	0.10076	0.00	0.35
	Eldelta	0.1357	7	0.10309	0.02	0.30
	Wad eLhelaw	0.1271	7	0.06237	0.01	0.20
	Telkok	0.0850	8	0.05099	0.01	0.18
	Hameshkoreb	0.1350	8	0.10184	0.01	0.30
	Total	0.1335	71	0.10276	0.00	0.52
Total	Kassala	0.1435	26	0.13667	0.01	0.51
	Refi Kassala	0.1407	30	0.11154	0.02	0.52
	Aroma	0.1382	28	0.09202	0.00	0.35
	Eldelta	0.1300	11	0.08283	0.02	0.30
	Wad eLhelaw	0.1164	14	0.05624	0.01	0.20
	Telkok	0.0769	13	0.05603	0.01	0.18
	Hameshkoreb	0.1144	16	0.08197	0.01	0.30
	Total	0.1283	138	0.09954	0.00	0.52

Fe

Sex	Area	Mean	N	Std. Deviation	Minimum	Maximum
Male	Kassala	0.6485	20	0.38606	0.08	1.73
	Refi Kassala	0.6010	20	0.22433	0.24	0.90
	Aroma	0.5795	20	0.36026	0.17	1.80
	Eldelta	0.6160	10	0.30318	0.21	1.12
	Wad eLhelaw	0.4010	10	0.29535	0.07	1.08
	Telkok	0.7510	10	0.50989	0.10	1.79
	Hameshkoreb	0.5030	10	0.21807	0.10	0.80
	Total	0.5929	100	0.33942	0.07	1.80
Female	Kassala	0.5494	18	0.30794	0.09	1.21
	Refi Kassala	0.4516	19	0.23315	0.09	0.93
	Aroma	0.6625	20	0.27526	0.21	1.41
	Eldelta	0.4750	10	0.26759	0.21	1.01
	Wad eLhelaw	0.6040	10	0.18464	0.26	0.83
	Telkok	0.4680	10	0.26699	0.21	0.91
	Hameshkoreb	0.6040	10	0.26022	0.26	1.01
	Total	0.5488	97	0.26715	0.09	1.41
Total	Kassala	0.6016	38	0.35017	0.08	1.73
	Refi Kassala	0.5282	39	0.23798	0.09	0.93
	Aroma	0.6210	40	0.31923	0.17	1.80
	Edelta	0.5455	20	0.28756	0.21	1.12
	Wad eLhelaw	0.5025	20	0.26137	0.07	1.08
	Telkok	0.6095	20	0.42189	0.10	1.79
	Hameshkoreb	0.5535	20	0.23935	0.10	1.01
	Total	0.5712	197	0.30600	0.07	1.80

Mn

Sex	Area	Mean	N	Std. Deviation	Minimum	Maximum
Male	Kassala	0.3706	17	0.26799	0.01	0.99
	Refi Kassala	0.3293	15	0.40775	0.01	1.57
	Aroma	0.3300	14	0.24019	0.05	0.71
	Eldelta	0.1733	6	0.11219	0.04	0.29
	Wad eLhelaw	0.2563	8	0.20135	0.04	0.66
	Telkok	0.3225	8	0.22076	0.02	0.69
	Hameshkoreb	0.2800	5	0.07842	0.20	0.41
	Total	0.3141	73	0.26751	0.01	1.57
Female	Kassala	0.3424	17	0.22645	0.04	0.78
	Refi Kassala	0.2965	17	0.20347	0.01	0.79
	Aroma	0.3864	14	0.20296	0.21	0.83
	Eldelta	0.2878	9	0.28595	0.04	0.91
	Wad eLhelaw	0.3863	8	0.19892	0.20	0.70
	Telkok	0.2340	10	0.12563	0.05	0.39
	Hameshkoreb	0.3687	8	0.28089	0.04	0.91
	Total	0.3282	83	0.21684	0.01	0.91
Total	Kassala	0.3565	34	0.24472	0.01	0.99
	Refi Kassala	0.3119	32	0.31102	0.01	1.57
	Aroma	0.3582	28	0.22009	0.05	0.83
	Eldelta	0.2420	15	0.23364	0.04	0.91
	Wad eLhelaw	0.3213	16	0.20467	0.04	0.70
	Telkok	0.2733	18	0.17456	0.02	0.69
	Hameshkoreb	0.3346	13	0.22382	0.04	0.91
	Total	0.3216	156	0.24118	0.01	1.57

Cr

Sex	Area	Mean	N	Std. Deviation	Minimum	Maximum
Male	Kassala	0.5015	13	0.47353	0.07	1.63
	Refi Kassala	0.4256	16	0.43673	0.04	1.64
	Aroma	0.6247	15	0.46340	0.05	1.41
	Eldelta	0.4050	10	0.31412	0.02	0.79
	Wad eLhelaw	0.3180	5	0.24489	0.05	0.63
	Telkok	0.3600	7	0.23770	0.04	0.66
	Hameshkoreb	0.3050	8	0.24065	0.03	0.66
	Total	0.4500	74	0.39282	0.02	1.64
Female	Kassala	0.3214	14	0.19868	0.08	0.65
	Refi Kassala	0.4119	16	0.30781	0.03	0.97
	Aroma	0.3627	15	0.30600	0.02	0.98
	Eldelta	0.3643	7	0.15576	.009	0.49
	Wad eLhelaw	0.3433	9	0.30635	0.02	0.95
	Telkok	0.2838	8	0.24784	0.02	0.76
	Hameshkoreb	0.4867	9	0.21829	0.16	0.95
	Total	0.3695	78	0.25995	0.02	0.98
Total	Kassala	0.4081	27	0.36282	0.07	1.63
	Refi Kassala	0.4188	32	0.37173	0.03	1.64
	Aroma	0.4937	30	0.40820	0.02	1.41
	Eldelta	0.3882	17	0.25501	0.02	0.79
	Wad eLhelaw	0.3343	14	0.27634	0.02	0.95
	Telkok	0.3193	15	0.23765	0.02	0.76
	Hameshkoreb	0.4012	17	0.24062	0.03	0.95
	Total	0.4087	152	0.33270	0.02	1.64

V

Sex	Area	Mean	N	Std. Deviation	Minimum	Maximum
Male	Kassala	0.5546	13	0.56549	0.08	1.95
	Refi Kassala	0.7792	12	0.67283	0.04	2.23
	Aroma	0.5793	15	0.44286	0.04	1.41
	Eldelta	0.6888	8	0.31643	0.02	1.04
	Wad eLhelaw	0.7530	10	0.65146	0.06	2.11
	Telkok	0.6544	9	0.44097	0.16	1.41
	Hameshkoreb	0.4267	9	0.36445	0.07	1.00
	Total	0.6318	76	0.51169	0.02	2.23
Female	Kassala	0.6685	13	0.46681	0.18	1.55
	Refi Kassala	0.9479	14	0.61153	0.14	2.21
	Aroma	0.8947	15	0.70790	0.04	2.20
	Eldelta	0.9844	9	0.76467	0.15	2.41
	Wad eLhelaw	0.5067	9	0.40878	0.07	1.26
	Telkok	0.9022	9	0.73998	0.15	2.41
	Hameshkoreb	0.6912	8	0.54734	0.17	1.81
	Total	0.8110	77	0.61676	0.04	2.41
Total	Kassala	0.6115	26	0.51133	0.08	1.95
	Refi Kassala	0.8700	26	0.63325	0.04	2.23
	Aroma	0.7370	30	0.60193	0.04	2.20
	Eldelta	0.8453	17	0.59943	0.02	2.41
	Wad eLhelaw	0.6363	19	0.54994	0.06	2.11
	Telkok	0.7783	18	0.60451	0.15	2.41
	Hameshkoreb	0.5512	17	0.46477	0.07	1.81
	Total	0.7220	153	0.57225	0.02	2.41

Ti

Sex	Area	Mean	N	Std. Deviation	Minimum	Maximum
Male	Kassala	1.9493	15	1.21109	0.45	4.49
	Refi Kassala	1.6238	16	1.15580	0.45	5.25
	Aroma	1.9350	14	1.60718	0.40	5.53
	Eldelta	1.4740	5	1.66788	0.38	4.38
	Wad eLhelaw	1.3125	8	0.68623	0.52	2.33
	Telkok	2.0233	9	0.80262	1.29	3.22
	Hameshkoreb	0.7750	8	0.74125	0.14	2.35
	Total	1.6612	75	1.21089	0.14	5.53
Female	Kassala	1.6233	15	1.28725	0.42	3.93
	Refi Kassala	1.1818	17	0.85451	0.30	3.71
	Aroma	1.5259	17	1.36729	0.09	5.06
	Eldelta	1.3400	8	0.75765	0.56	2.76
	Wad eLhelaw	1.3988	8	0.93856	0.49	2.94
	Telkok	1.1875	8	0.67608	0.40	2.35
	Hameshkoreb	1.4611	9	0.97370	0.49	2.94
	Total	1.4017	82	1.04239	0.09	5.06
Total	Kassala	1.7863	30	1.23916	0.42	4.49
	Refi Kassala	1.3961	33	1.02059	0.30	5.25
	Aroma	1.7106	31	1.46943	0.09	5.53
	Eldelta	1.3915	13	1.12549	0.38	4.38
	Wad eLhelaw	1.3556	16	0.79550	0.49	2.94
	Telkok	1.6300	17	0.84083	0.40	3.22
	Hameshkoreb	1.1382	17	0.91599	0.14	2.94
	Total	1.5257	157	1.12988	0.09	5.53

Zr

Area	Age	Mean	N	Std. Deviation	Minimum	Maximum
Kassala Town	1-20	0.0100	11	0.00000	0.01	0.01
	20-40	0.0117	6	0.00408	0.01	0.02
	60-80	0.0100	1	0.0000	0.01	0.01
	Total	0.0106	18	0.00236	0.01	0.02
R. Kassala	1-20	0.0108	13	0.00277	0.01	0.02
	20-40	0.0100	4	0.00000	0.01	0.01
	40-60	0.1000	1	0.0000	0.10	0.10
	Total	0.0156	18	0.02121	0.01	0.10
Aroma	1-20	0.0106	18	0.00236	0.01	0.02
	20-40	0.0080	5	0.00447	0.00	0.01
	40-60	0.0100	1	0.0000	0.01	0.01
	Total	0.0100	24	0.00295	0.00	0.02
Eldelta	1-20	0.0100	8	0.00000	0.01	0.01
	20-40	0.0100	2	0.00000	0.01	0.01
	Total	0.0100	10	0.00000	0.01	0.01
W.ELhelaw	1-20	0.0100	7	0.00000	0.01	0.01
	20-40	0.0100	1	0.0000	0.01	0.01
	40-60	0.0100	2	0.00000	0.01	0.01
	60-80	0.0100	1	0.0000	0.01	0.01
	Total	0.0100	11	0.00000	0.01	0.01
Telkok	1-20	0.0144	9	0.01333	0.01	0.05
	20-40	0.0100	1	0.00000	0.01	0.01
	40-60	0.0100	2	0.00000	0.01	0.01
	Total	0.0133	12	0.01155	0.01	0.05
Hameshkoreb	1-20	0.0100	5	0.00000	0.01	0.01
	Total	0.0100	5	0.00000	0.01	0.01
7.00	1-20	0.0100	4	0.00000	0.01	0.01
	20-40	0.0100	3	0.00000	0.01	0.01
	40-60	0.0100	1	0.0000	0.01	0.01
	60-80	0.0100	1	0.0000	0.01	0.01
	Total	0.0100	9	0.00000	0.01	0.01
Total	1-20	0.0108	75	0.00487	0.01	0.05
	20-40	0.0100	22	0.00309	0.00	0.02
	40-60	0.0229	7	0.03402	0.01	0.10
	60-80	0.0100	3	0.00000	0.01	0.01
	Total	0.0114	107	0.00966	0.00	0.10

Bi

Area	Age	Mean	N	Std. Deviation	Minimum	Maximum
Kassala Town	1-20	0.0200	14	0.01301	0.01	0.04
	20-40	0.0267	3	0.02082	0.01	0.05
	60-80	0.0100	1	0.0000	0.01	0.01
	Total	0.0206	18	0.01392	0.01	0.05
R.Kassala	1-20	0.0181	16	0.01109	0.01	0.04
	20-40	0.0167	3	0.00577	0.01	0.02
	Total	0.0179	19	0.01032	0.01	0.04
Aroma	1-20	0.0189	18	0.01530	0.01	0.06
	20-40	0.0160	5	0.00894	0.01	0.03
	40-60	0.0400	2	0.01414	0.03	0.05
	Total	0.0200	25	0.01500	0.01	0.06
Eldelta	1-20	0.0122	9	0.00667	0.00	0.02
	20-40	0.0133	3	0.00577	0.01	0.02
	Total	0.0125	12	0.00622	0.00	0.02
ELhelaw	1-20	0.0271	7	0.01604	0.01	0.06
	20-40	0.0167	3	0.00577	0.01	0.02
	40-60	0.0100	2	0.01414	0.00	0.02
	Total	0.0217	12	0.01467	0.00	0.06
Telkok	1-20	0.0189	9	0.01269	0.01	0.05
	20-40	0.0150	2	0.00707	0.01	0.02
	40-60	0.0100	1	0.0000	0.01	0.01
	Total	0.0175	12	0.01138	0.01	0.05
Hameshkoreb	1-20	0.0171	7	0.00756	0.01	0.03
	Total	0.0171	7	0.00756	0.01	0.03
7.00	1-20	0.0167	3	0.00577	0.01	0.02
	20-40	0.0150	2	0.00707	0.01	0.02
	40-60	0.0100	1	0.0000	0.01	0.01
	Total	0.0150	6	0.00548	0.01	0.02
Total	1-20	0.0187	83	0.01237	0.00	0.06
	20-40	0.0171	21	0.00956	0.01	0.05
	40-60	0.0200	6	0.01789	0.00	0.05
	60-80	0.0100	1	0.0000	0.01	0.01
	Total	0.0184	111	0.01210	0.00	0.06

Pb

Area	Age	Mean	N	Std. Deviation	Minimum	Maximum
Kassala	1-20	0.0364	14	0.03128	0.01	0.11
	20-40	0.0282	11	0.01834	0.01	0.07
	60-80	0.0300	2	0.00000	0.03	0.03
	Total	0.0326	27	0.02521	0.01	0.11
R. Kassala	1-20	0.0272	18	0.01965	0.00	0.08
	20-40	0.0240	5	0.01342	0.01	0.04
	40-60	0.0100	2	0.00000	0.01	0.01
	60-80	0.0500	1	0.0000	0.05	0.05
	Total	0.0262	26	0.01835	0.00	0.08
Aroma	1-20	0.0267	21	0.01853	0.01	0.07
	20-40	0.0240	5	0.03130	0.01	0.08
	40-60	0.0200	1	0.0000	0.02	0.02
	Total	0.0259	27	0.02043	0.01	0.08
Eldelta	1-20	0.0263	8	0.01996	0.01	0.06
	20-40	0.0500	2	0.01414	0.04	0.06
	Total	0.0310	10	0.02079	0.01	0.06
W.ELhelaw	1-20	0.0190	10	0.01197	0.01	0.04
	20-40	0.0100	2	0.00000	0.01	0.01
	40-60	0.0100	1	0.0000	0.01	0.01
	60-80	0.0100	1	0.0000	0.01	0.01
	Total	0.0164	14	0.01082	0.01	0.04
Telkok	1-20	0.0300	10	0.01886	0.01	0.06
	20-40	0.0500	1	0.0000	0.05	0.05
	40-60	0.0200	2	0.00000	0.02	0.02
	Total	0.0300	13	0.01780	0.01	0.06
Hameshkoreb	1-20	0.0283	6	0.02041	0.01	0.05
	Total	0.0283	6	0.02041	0.01	0.05
7.00	1-20	0.0100	3	0.00000	0.01	0.01
	20-40	0.0333	3	0.02517	0.01	0.06
	60-80	0.0300	1	0.0000	0.03	0.03
	Total	0.0229	7	0.01890	0.01	0.06
Total	1-20	0.0273	90	0.02076	0.00	0.11
	20-40	0.0283	29	0.02054	0.01	0.08
	40-60	0.0150	6	0.00548	0.01	0.02
	60-80	0.0300	5	0.01414	0.01	0.05
	Total	0.0271	130	0.02009	0.00	0.11

W

Area	Age	Mean	N	Std. Deviation	Minimum	Maximum
Kassala Town	1-20	.2904	25	0.14004	0.03	0.67
	20-40	.2509	11	0.10830	0.03	0.46
	60-80	.4850	2	0.17678	0.36	0.61
	Total	.2892	38	0.13873	0.03	0.67
R.Kassala	1-20	.2345	31	0.12803	0.02	0.60
	20-40	.2400	5	0.06892	0.16	0.33
	40-60	.2033	3	0.06506	0.14	0.27
	60-80	.0400	1	0.0000	0.04	0.04
	Total	.2280	40	0.11966	0.02	0.60
Aroma	1-20	.2683	30	0.16402	0.04	0.73
	20-40	.2588	8	0.13346	0.04	0.46
	40-60	.2300	2	0.05657	0.19	0.27
	Total	.2645	40	0.15285	0.04	0.73
Eldelta	1-20	.1873	15	0.06508	0.10	0.32
	20-40	.2540	5	0.21090	0.05	0.52
	Total	.2040	20	0.11559	0.05	0.52
W.ELhelaw	1-20	.2307	14	0.13556	0.04	0.50
	20-40	.3167	3	0.21008	0.11	0.53
	40-60	.3300	2	0.12728	0.24	0.42
	60-80	.2000	1	0.0000	0.20	0.20
	Total	.2520	20	0.14088	0.04	0.53
Telkok	1-20	.2320	15	0.13624	0.01	0.52
	20-40	.1400	2	0.12728	0.05	0.23
	40-60	.2300	2	0.26870	0.04	0.42
	60-80	.2000	1	0.0000	0.20	0.20
	Total	.2210	20	0.13837	0.01	0.52
Hameshkoreb	1-20	.2310	10	0.10713	0.10	0.43
	Total	.2310	10	0.10713	0.10	0.43
7.00	1-20	.3400	5	0.13509	0.20	0.53
	20-40	.2233	3	0.10599	0.11	0.32
	40-60	.2000	1	0.0000	0.20	0.20
	60-80	.2600	1	0.0000	0.26	0.26
	Total	.2830	10	0.12010	0.11	0.53
Total	1-20	.2490	145	0.13561	0.01	0.73
	20-40	.2486	37	0.12981	0.03	0.53
	40-60	.2390	10	0.11657	0.04	0.42
	60-80	.2783	6	0.19292	0.04	0.61
	Total	.2493	198	0.13461	0.01	0.73

Zn

Area	Age rane	Mean	N	Std. Deviation	Minimum	Maximum
Kassala Town	1-20	0.0673	15	0.04367	0.01	0.15
	20-40	0.1188	8	0.14894	0.03	0.47
	60-80	0.0200	1	0.0000	0.02	0.02
	Total	0.0825	24	0.09322	0.01	0.47
R.Kassala	1-20	0.0667	21	0.04757	0.01	0.17
	20-40	0.0133	3	0.00577	0.01	0.02
	40-60	0.0600	2	0.04243	0.03	0.09
	60-80	0.1300	1	0.0000	0.13	0.13
	Total	0.0626	27	0.04776	0.01	0.17
Aroma	1-20	0.0532	22	0.03537	0.01	0.13
	20-40	0.0675	8	0.03495	0.02	0.10
	40-60	0.0350	2	0.02121	0.02	0.05
	Total	0.0556	32	0.03473	0.01	0.13
Eldelta	1-20	0.0760	10	0.04351	0.02	0.16
	20-40	0.0567	3	0.03512	0.02	0.09
	Total	0.0715	13	0.04120	0.02	0.16
W. ELhelaw	1-20	0.0586	7	0.02545	0.01	0.09
	20-40	0.0850	2	0.10607	0.01	0.16
	40-60	0.0200	1	0.0000	0.02	0.02
	Total	0.0600	10	0.04472	0.01	0.16
Telkok	1-20	0.0678	9	0.04919	0.02	0.19
	20-40	0.0800	2	0.00000	0.08	0.08
	40-60	0.0250	2	0.00707	0.02	0.03
	60-80	0.0500	1	0.0000	0.05	0.05
	Total	0.0621	14	0.04228	0.02	0.19
Hameshkoreb	1-20	0.0814	7	0.03625	0.03	0.13
	Total	0.0814	7	0.03625	0.03	0.13
7.00	1-20	0.0150	2	0.00707	0.01	0.02
	20-40	0.1200	2	0.05657	0.08	0.16
	40-60	0.1300	1	0.0000	0.13	0.13
	60-80	0.0200	1	0.0000	0.02	0.02
	Total	0.0700	6	0.06387	0.01	0.16
Total	1-20	0.0641	93	0.04145	0.01	0.19
	20-40	0.0811	28	0.08867	0.01	0.47
	40-60	0.0488	8	0.04051	0.02	0.13
	60-80	0.0550	4	0.05196	0.02	0.13
	Total	0.0665	133	0.05501	0.01	0.47

Cu

Area	Age	Mean	N	Std. Deviation	Minimum	Maximum
Kassala Town	1-20	0.0771	21	0.05283	0.02	0.20
	20-40	0.1100	8	0.05880	0.04	0.21
	60-80	0.0400	1	0.0000	0.04	0.04
	Total	0.0847	30	0.05519	0.02	0.21
R. Kassala	1-20	0.0973	22	0.05487	0.02	0.21
	20-40	0.1025	4	0.04500	0.05	0.14
	40-60	0.0200	2	0.01414	0.01	0.03
	60-80	0.0200	1	0.0000	0.02	0.02
	Total	0.0900	29	0.05542	0.01	0.21
Aroma	1-20	0.0691	23	0.04067	0.01	0.15
	20-40	0.0400	5	0.02121	0.02	0.07
	40-60	0.0400	1	0.0000	0.04	0.04
	Total	0.0631	29	0.03883	0.01	0.15
Eldelta	1-20	0.1130	10	0.06533	0.03	0.24
	20-40	0.0820	5	0.04764	0.02	0.14
	Total	0.1027	15	0.06017	0.02	0.24
Wad eLhelaw	1-20	0.0927	11	0.04735	0.03	0.19
	20-40	0.0600	2	0.05657	0.02	0.10
	40-60	0.0200	1	0.0000	0.02	0.02
	Total	0.0829	14	0.04937	0.02	0.19
Telkok	1-20	0.0590	10	0.04149	0.01	0.14
	20-40	0.0650	2	0.03536	0.04	0.09
	40-60	0.0900	2	0.00000	0.09	0.09
	60-80	0.1400	1	0.0000	0.14	0.14
	Total	0.0693	15	0.04114	0.01	0.14
Hameshkoreb	1-20	0.0689	9	0.04197	0.01	0.14
	Total	0.0689	9	0.04197	0.01	0.14
7.00	1-20	0.0133	3	0.01155	0.00	0.02
	20-40	0.1167	3	0.06028	0.06	0.18
	40-60	0.0300	1	0.0000	0.03	0.03
	60-80	0.0700	1	0.0000	0.07	0.07
	Total	0.0613	8	0.05939	0.00	0.18
Total	1-20	0.0803	109	0.05156	0.00	0.24
	20-40	0.0862	29	0.05151	0.02	0.21
	40-60	0.0443	7	0.03259	0.01	0.09
	60-80	0.0675	4	0.05252	0.02	0.14
	Total	0.0794	149	0.05111	0.00	0.24

Ni

Area	Age	Mean	N	Std. Deviation	Minimum	Maximum
Kassala Town	1-20	0.1200	15	0.06481	0.01	0.26
	20-40	0.0860	10	0.05358	0.03	0.18
	60-80	0.2300	1	0.0000	0.23	0.23
	Total	0.1112	26	0.06520	0.01	0.26
R. Kassala	1-20	0.5644	27	2.28759	0.00	12.00
	20-40	0.1550	4	0.07371	0.06	0.24
	40-60	0.1267	3	0.03786	0.10	0.17
	60-80	0.0600	1	0.0000	0.06	0.06
	Total	0.4657	35	2.00908	0.00	12.00
Aroma	1-20	0.1144	25	0.07583	0.01	0.30
	20-40	0.2000	7	0.10801	0.06	0.36
	40-60	0.0750	2	0.06364	0.03	0.12
	Total	0.1297	34	0.08851	0.01	0.36
Eldelta	1-20	0.1058	12	0.06543	0.02	0.22
	20-40	0.1225	4	0.07228	0.08	0.23
	Total	0.1100	16	0.06512	0.02	0.23
Wad eLhelaw	1-20	0.1108	12	0.09327	0.03	0.32
	20-40	0.1800	1	0.0000	0.18	0.18
	40-60	0.0700	2	0.01414	0.06	0.08
	60-80	0.0300	1	0.0000	0.03	0.03
	Total	0.1050	16	0.08563	0.03	0.32
Telkok	1-20	0.1179	14	0.05860	0.02	0.23
	20-40	0.0500	1	0.0000	0.05	0.05
	40-60	0.0400	1	0.0000	0.04	0.04
	60-80	0.2200	1	0.0000	0.22	0.22
	Total	0.1153	17	0.06404	0.02	0.23
Hameshkoreb	1-20	0.1138	8	0.06301	0.03	0.24
	Total	0.1138	8	0.06301	0.03	0.24
7.00	1-20	0.0567	3	0.02517	0.03	0.08
	20-40	0.1467	3	0.08083	0.06	0.22
	60-80	0.1200	1	0.0000	0.12	0.12
	Total	0.1043	7	0.06680	0.03	0.22
Total	1-20	0.2175	116	1.10619	0.00	12.00
	20-40	0.1347	30	0.08435	0.03	0.36
	40-60	0.0888	8	0.04612	0.03	0.17
	60-80	0.1320	5	0.09094	0.03	0.23
	Total	0.1927	159	0.94551	0.00	12.00

Co

Area	Age	Mean	N	Std. Deviation	Minimum	Maximum
Kassala Town	1-20	0.1450	16	0.13466	0.01	0.50
	20-40	0.1522	9	0.15147	0.02	0.51
	60-80	0.0400	1	0.0000	0.04	0.04
	Total	0.1435	26	0.13667	0.01	0.51
R.Kassala	1-20	0.1477	22	0.12705	0.02	0.52
	20-40	0.1075	4	0.03202	0.06	0.13
	40-60	0.1500	3	0.07211	0.07	0.21
	60-80	0.0900	1	0.0000	0.09	0.09
	Total	0.1407	30	0.11154	0.02	0.52
Aroma	1-20	0.1484	25	0.09227	0.00	0.35
	20-40	0.0600	1	0.0000	0.06	0.06
	40-60	0.0500	2	0.0000	0.05	0.05
	Total	0.1382	28	0.09202	0.00	0.35
Eldelta	1-20	0.1400	9	0.08916	0.02	0.30
	20-40	0.0850	2	0.00707	0.08	0.09
	Total	0.1300	11	0.08283	0.02	0.30
Wad eLhelaw	1-20	0.1278	9	0.05869	0.02	0.20
	20-40	0.0733	3	0.05686	0.01	0.12
	40-60	0.1300	1	0.0000	0.13	0.13
	60-80	0.1300	1	0.0000	0.13	0.13
	Total	0.1164	14	0.05624	0.01	0.20
Telkok	1-20	0.0725	8	0.05230	0.01	0.16
	20-40	0.0950	2	0.12021	0.01	0.18
	40-60	0.0950	2	0.03536	0.07	0.12
	60-80	0.0400	1	0.0000	0.04	0.04
	Total	0.0769	13	0.05603	0.01	0.18
Hameshkoreb	1-20	0.0938	8	0.05528	0.05	0.19
	Total	0.0938	8	0.05528	0.05	0.19
7.00	1-20	0.0975	4	0.05852	0.01	0.13
	20-40	0.1433	3	0.14295	0.02	0.30
	40-60	0.2600	1	0.0000	0.26	0.26
	Total	0.1350	8	0.10184	0.01	0.30
Total	1-20	0.1328	101	0.10088	0.00	0.52
	20-40	0.1196	24	0.10913	0.01	0.51
	40-60	0.1256	9	0.07485	0.05	0.26
	60-80	0.0750	4	0.04359	0.04	0.13
	Total	0.1283	138	0.09954	0.00	0.52

Fe

Area	Age	Mean	N	Std. Deviation	Minimum	Maximum
Kassala Town	1-20	0.6446	24	0.38728	0.08	1.73
	20-40	0.5392	12	0.29405	0.09	0.93
	60-80	0.4600	2	0.07071	0.41	0.51
	Total	0.6016	38	0.35017	0.08	1.73
R.Kassala	1-20	0.5719	31	0.22096	0.24	0.93
	20-40	0.4000	4	0.23238	0.21	0.73
	40-60	0.3167	3	0.33382	0.09	0.70
	60-80	0.3200	1	0.0000	0.32	0.32
	Total	0.5282	39	0.23798	0.09	0.93
Aroma	1-20	0.5960	30	0.31012	0.17	1.80
	20-40	0.6425	8	0.26612	0.33	0.97
	40-60	0.9100	2	0.70711	0.41	1.41
	Total	0.6210	40	0.31923	0.17	1.80
Eldelta	1-20	0.5933	15	0.29437	0.21	1.12
	20-40	0.4020	5	0.23488	0.21	0.71
	Total	0.5455	20	0.28756	0.21	1.12
Wad Lhelaw	1-20	0.4636	14	0.26111	0.07	1.08
	20-40	0.6000	3	0.30050	0.26	0.83
	40-60	0.7500	2	0.00000	0.75	0.75
	60-80	0.2600	1	0.0000	0.26	0.26
	Total	0.5025	20	0.26137	0.07	1.08
Telkok	1-20	0.6347	15	0.46032	0.10	1.79
	20-40	0.2350	2	0.03536	0.21	0.26
	40-60	0.7150	2	0.27577	0.52	0.91
	60-80	0.7700	1	0.0000	0.77	0.77
	Total	0.6095	20	0.42189	0.10	1.79
Hameshkoreb	1-20	0.5030	10	0.21807	0.10	0.80
	Total	0.5030	10	0.21807	0.10	0.80
7.00	1-20	0.6600	5	0.22782	0.26	0.83
	20-40	0.5267	3	0.41885	0.27	1.01
	40-60	0.4900	1	0.0000	0.49	0.49
	60-80	0.6700	1	0.0000	0.67	0.67
	Total	0.6040	10	0.26022	0.26	1.01
Total	1-20	0.5856	144	0.31109	0.07	1.80
	20-40	0.5154	37	0.27863	0.09	1.01
	40-60	0.6190	10	0.38179	0.09	1.41
	60-80	0.4900	6	0.19970	0.26	0.77
	Total	0.5712	197	0.30600	0.07	1.80

Mn

Area	Age	Mean	N	Std. Deviation	Minimum	Maximum
Kassala Town	1-20	0.3748	23	0.26817	0.03	0.99
	20-40	0.2978	9	0.20903	0.01	0.64
	60-80	0.4100	2	0.01414	0.40	0.42
	Total	0.3565	34	0.24472	0.01	0.99
R.Kassala	1-20	0.3371	24	0.35208	0.01	1.57
	20-40	0.1880	5	0.10474	0.08	0.31
	40-60	0.3250	2	0.10607	0.25	0.40
	60-80	0.3000	1	0.0000	0.30	0.30
	Total	0.3119	32	0.31102	0.01	1.57
Aroma	1-20	0.3410	21	0.24039	0.05	0.83
	20-40	0.3780	5	0.13217	0.23	0.53
	40-60	0.4900	2	0.19799	0.35	0.63
	Total	0.3582	28	0.22009	0.05	0.83
Eldelta	1-20	0.2591	11	0.25840	0.04	0.91
	20-40	0.1950	4	0.16783	0.05	0.39
	Total	0.2420	15	0.23364	0.04	0.91
Wad eLhelaw	1-20	0.2927	11	0.20244	0.04	0.70
	20-40	0.4800	3	0.24576	0.20	0.66
	40-60	0.2400	1	0.0000	0.24	0.24
	60-80	0.2400	1	0.0000	0.24	0.24
	Total	0.3213	16	0.20467	0.04	0.70
Telkok	1-20	0.2677	13	0.20261	0.02	0.69
	20-40	0.2850	2	0.10607	0.21	0.36
	40-60	0.3050	2	0.10607	0.23	0.38
	60-80	0.2600	1	0.0000	0.26	0.26
	Total	0.2733	18	0.17456	0.02	0.69
Hameshkoreb	1-20	0.2800	5	0.07842	0.20	0.41
	Total	0.2800	5	0.07842	0.20	0.41
7.00	1-20	0.3150	4	0.17767	0.20	0.58
	20-40	0.5500	3	0.34598	0.22	0.91
	40-60	0.0400	1	0.0000	0.04	0.04
	Total	0.3687	8	0.28089	0.04	0.91
Total	1-20	0.3221	112	0.25917	0.01	1.57
	20-40	0.3210	31	0.21040	0.01	0.91
	40-60	0.3150	8	0.17096	0.04	0.63
	60-80	0.3240	5	0.08173	0.24	0.42
	Total	0.3216	156	0.24118	0.01	1.57

Cr

Area	Age	Mean	N	Std. Deviation	Minimum	Maximum
Kassala Town	1-20	0.4006	17	0.41484	0.07	1.63
	20-40	0.4210	10	0.27213	0.11	0.89
	Total	0.4081	27	0.36282	0.07	1.63
R.Kassala	1-20	0.4529	24	0.39758	0.03	1.64
	20-40	0.2200	5	0.18868	0.03	0.43
	40-60	0.5950	2	0.43134	0.29	0.90
	60-80	0.2400	1	0.0000	0.24	0.24
	Total	0.4188	32	0.37173	0.03	1.64
Aroma	1-20	0.5059	22	0.44428	0.02	1.41
	20-40	0.5029	7	0.30869	0.18	1.11
	40-60	0.1600	1	0.0000	0.16	0.16
	Total	0.4937	30	0.40820	0.02	1.41
Eldelta	1-20	0.4223	13	0.27310	0.02	0.79
	20-40	0.2775	4	0.16460	0.09	0.48
	Total	0.3882	17	0.25501	0.02	0.79
Wad eLhelaw	1-20	0.2512	8	0.21530	0.02	0.63
	20-40	0.4033	3	0.30746	0.05	0.61
	40-60	0.6500	2	0.42426	0.35	0.95
	60-80	0.1600	1	0.0000	0.16	0.16
	Total	0.3343	14	0.27634	0.02	0.95
Telkok	1-20	0.3310	10	0.22048	0.04	0.66
	20-40	0.4100	2	0.49497	0.06	0.76
	40-60	0.1800	2	0.22627	0.02	0.34
	60-80	0.3000	1	0.0000	0.30	0.30
	Total	0.3193	15	0.23765	0.02	0.76
Hameshkoreb	1-20	0.3050	8	0.24065	0.03	0.66
	Total	0.3050	8	0.24065	0.03	0.66
7.00	1-20	0.5240	5	0.29678	0.16	0.95
	20-40	0.4433	3	0.08083	0.35	0.49
	40-60	0.4300	1	0.0000	0.43	0.43
	Total	0.4867	9	0.21829	0.16	0.95
Total	1-20	0.4176	107	0.35833	0.02	1.64
	20-40	0.3912	34	0.25895	0.03	1.11
	40-60	0.4300	8	0.33089	0.02	0.95
	60-80	0.2333	3	0.07024	0.16	0.30
	Total	0.4087	152	0.33270	0.02	1.64

V

Area	Age	Mean	N	Std. Deviation	Minimum	Maximum
Kassala	1-20	0.5388	17	0.37480	0.18	1.44
	20-40	0.6329	7	0.62465	0.08	1.55
	60-80	1.1550	2	1.12430	0.36	1.95
	Total	0.6115	26	0.51133	0.08	1.95
R.Kassala	1-20	0.9805	19	0.70260	0.04	2.23
	20-40	0.6533	3	0.23692	0.38	0.80
	40-60	0.6100	3	0.03606	0.58	0.65
	60-80	0.2000	1	0.0000	0.20	0.20
	Total	0.8700	26	0.63325	0.04	2.23
Aroma	1-20	0.6441	22	0.59635	0.04	2.20
	20-40	0.8933	6	0.62369	0.27	1.74
	40-60	1.2900	2	0.38184	1.02	1.56
	Total	0.7370	30	0.60193	0.04	2.20
Delta	1-20	0.9000	12	0.65516	0.02	2.41
	20-40	0.7140	5	0.47574	0.15	1.39
	Total	0.8453	17	0.59943	0.02	2.41
Wad eLhelaw	1-20	0.7336	14	0.60515	0.06	2.11
	20-40	0.4133	3	0.25775	0.18	0.69
	40-60	0.2900	2	0.16971	0.17	0.41
	Total	0.6363	19	0.54994	0.06	2.11
Telkok	1-20	0.7843	14	0.63665	0.15	2.41
	20-40	0.9350	2	0.88388	0.31	1.56
	40-60	0.5800	2	0.18385	0.45	0.71
	Total	0.7783	18	0.60451	0.15	2.41
Hameshkoreb	1-20	0.4267	9	0.36445	0.07	1.00
	Total	0.4267	9	0.36445	0.07	1.00
7.00	1-20	0.4400	4	0.26808	0.17	0.81
	20-40	1.0233	3	0.80563	0.20	1.81
	60-80	0.7000	1	0.0000	0.70	0.70
	Total	0.6912	8	0.54734	0.17	1.81
Total	1-20	0.7172	111	0.58885	0.02	2.41
	20-40	0.7414	29	0.54773	0.08	1.81
	40-60	0.6833	9	0.40218	0.17	1.56
	60-80	0.8025	4	0.79290	0.20	1.95
	Total	0.7220	153	0.57225	0.02	2.41

Ti

Area	Age	Mean	N	Std. Deviation	Minimum	Maximum
Kassala Town	1-20	1.7021	19	1.20678	0.42	4.49
	20-40	2.0800	10	1.31373	0.52	4.41
	60-80	0.4500	1	0.0000	0.45	0.45
	Total	1.7863	30	1.23916	0.42	4.49
R.Kassala	1-20	1.3988	25	1.02030	0.44	5.25
	20-40	1.6150	4	1.50547	0.48	3.71
	40-60	0.9700	3	0.59152	0.30	1.42
	60-80	1.7300	1	0.0000	1.73	1.73
	Total	1.3961	33	1.02059	0.30	5.25
Aroma	1-20	1.6546	24	1.38161	0.09	5.53
	20-40	2.3700	5	2.01672	0.41	5.06
	40-60	0.7350	2	0.67175	0.26	1.21
	Total	1.7106	31	1.46943	0.09	5.53
Eldelta	1-20	1.3740	10	1.29790	0.38	4.38
	20-40	1.4500	3	0.11533	1.34	1.57
	Total	1.3915	13	1.12549	0.38	4.38
Wad eLhelaw	1-20	1.2690	10	0.75120	0.52	2.38
	20-40	1.6867	3	1.21681	0.51	2.94
	40-60	1.1650	2	0.95459	0.49	1.84
	60-80	1.6100	1	0.0000	1.61	1.61
	Total	1.3556	16	0.79550	0.49	2.94
Telkok	1-20	1.7823	13	0.78574	0.61	3.22
	20-40	0.4000	1	0.0000	0.40	0.40
	40-60	0.8950	2	0.70004	0.40	1.39
	60-80	2.3500	1	0.0000	2.35	2.35
	Total	1.6300	17	0.84083	0.40	3.22
Hameshkoreb	1-20	0.7750	8	0.74125	0.14	2.35
	Total	0.7750	8	0.74125	0.14	2.35
7.00	1-20	1.4780	5	1.02458	0.49	2.94
	20-40	1.2200	2	0.87681	0.60	1.84
	40-60	0.5600	1	0.0000	0.56	0.56
	60-80	2.7600	1	0.0000	2.76	2.76
	Total	1.4611	9	0.97370	0.49	2.94
Total	1-20	1.4931	114	1.10642	0.09	5.53
	20-40	1.8343	28	1.33207	0.40	5.06
	40-60	0.9060	10	0.56541	0.26	1.84
	60-80	1.7800	5	0.87829	0.45	2.76
	Total	1.5257	157	1.12988	0.09	5.53

Statistical Analysis of Hair Samples data:

Zr

Area	Sex	Mean	N	Std. Deviation	Minimum	Maximum
Kassala Town	Male	0.0100	4	0.00000	0.01	0.01
	Female	0.0100	3	0.00000	0.01	0.01
	Total	0.0100	7	0.00000	0.01	0.01
Refi Kassala	Male	0.0100	8	0.00000	0.01	0.01
	Female	0.0100	5	0.00000	0.01	0.01
	Total	0.0100	13	0.00000	0.01	0.01
Aroma	Male	0.0100	6	0.00000	0.01	0.01
	Female	0.0100	3	0.00000	0.01	0.01
	Total	0.0100	9	0.00000	0.01	0.01
Eldelta	Male	0.0100	1	0.00000	0.01	0.01
	Female	0.0100	2	0.00000	0.01	0.01
	Total	0.0100	3	0.00000	0.01	0.01
Wad eLhelaw	Male	0.0100	4	0.00000	0.01	0.01
	Female	0.0100	2	0.00000	0.01	0.01
	Total	0.0100	6	0.00000	0.01	0.01
Telkok	Female	0.0100	2	0.00000	0.01	0.01
	Total	0.0100	2	0.00000	0.01	0.01
Hameshkoreb	Male	0.0167	3	0.01155	0.01	0.03
	Female	0.0100	3	0.00000	0.01	0.01
	Total	0.0133	6	0.00816	0.01	0.03
Total	Male	0.0108	26	0.00392	0.01	0.03
	Female	0.0100	20	0.00000	0.01	0.01
	Total	0.0104	46	0.00295	0.01	0.03

Bi

Area	Sex	Mean	N	Std. Deviation	Minimum	Maximum
Kassala Town	Male	0.0900	11	0.17793	0.01	0.57
	Female	0.0150	2	0.00707	0.01	0.02
	Total	0.0785	13	0.16487	0.01	0.57
Refi Kassala	Male	0.0180	10	0.01033	0.01	0.04
	Female	0.0144	9	0.00527	0.01	0.02
	Total	0.0163	19	0.00831	0.01	0.04
Aroma	Male	0.0155	11	0.00820	0.01	0.03
	Female	0.0700	5	0.12865	0.01	0.30
	Total	0.0325	16	0.07169	0.01	0.30
Edelta	Male	0.0100	4	0.00000	0.01	0.01
	Female	0.0200	4	0.00816	0.01	0.03
	Total	0.0150	8	0.00756	0.01	0.03
Wad eLhelaw	Male	0.0200	5	0.01414	0.01	0.04
	Female	0.0133	3	0.00577	0.01	0.02
	Total	0.0175	8	0.01165	0.01	0.04
Telkok	Male	0.0300	1	0.00000	0.03	0.03
	Female	0.0125	4	0.00500	0.01	0.02
	Total	0.0160	5	0.00894	0.01	0.03
Hameshkoreb	Male	0.0167	6	0.01033	0.01	0.03
	Female	0.0200	2	0.01414	0.01	0.03
	Total	0.0175	8	0.01035	0.01	0.03
Total	Male	0.0335	48	0.08818	0.01	0.57
	Female	0.0248	29	0.05329	0.01	0.30
	Total	0.0303	77	0.07664	0.01	0.57

Pb

Area	Sex	Mean	N	Std. Deviation	Minimum	Maximum
Kassala Town	Male	0.0257	14	0.01651	0.01	0.06
	Female	0.0238	8	0.01685	0.01	0.06
	Total	0.0250	22	0.01626	0.01	0.06
Refi Kassala	Male	0.0193	14	0.01328	0.01	0.05
	Female	0.0250	4	0.01000	0.01	0.03
	Total	0.0206	18	0.01259	0.01	0.05
Aroma	Male	0.0164	11	0.01286	0.01	0.05
	Female	0.0180	5	0.00837	0.01	0.03
	Total	0.0169	16	0.01138	0.01	0.05
Eldelta	Male	0.0267	9	0.01871	0.01	0.07
	Female	0.0300	1	0.00000	0.03	0.03
	Total	0.0270	10	0.01767	0.01	0.07
Wad eLhelaw	Male	0.0371	7	0.02752	0.01	0.08
	Female	0.0100	3	0.00000	0.01	0.01
	Total	0.0290	10	0.02601	0.01	0.08
Telkok	Male	0.0160	5	0.00894	0.01	0.03
	Female	0.0100	3	0.00000	0.01	0.01
	Total	0.0138	8	0.00744	0.01	0.03
Hameshkoreb	Male	0.0300	4	0.02160	0.01	0.06
	Female	0.0350	4	0.03317	0.01	0.08
	Total	0.0325	8	0.02605	0.01	0.08
Total	Male	0.0236	64	0.01749	0.01	0.08
	Female	0.0218	28	0.01679	0.01	0.08
	Total	0.0230	92	0.01721	0.01	0.08

W

Area	Sex	Mean	N	Std. Deviation	Minimum	Maximum
Kassala Town	Male	0.2312	17	0.10049	0.05	0.43
	Female	0.1980	10	0.09578	0.04	0.38
	Total	0.2189	27	0.09827	0.04	0.43
Refi Kassala	Male	0.2250	20	0.13073	0.02	0.50
	Female	0.1456	9	0.12074	0.01	0.34
	Total	0.2003	29	0.13100	0.01	0.50
Aroma	Male	0.2010	20	0.07312	0.04	0.37
	Female	0.1920	10	0.14711	0.04	0.49
	Total	0.1980	30	0.10118	0.04	0.49
Eldeltal	Male	0.1411	9	0.08710	0.02	0.29
	Female	0.1820	5	0.07530	0.09	0.27
	Total	0.1557	14	0.08262	0.02	0.29
Wad eLhelaw	Male	0.2511	9	0.15512	0.04	0.54
	Female	0.2500	5	0.10344	0.16	0.38
	Total	0.2507	14	0.13453	0.04	0.54
Telkok	Male	0.1920	10	0.11516	0.07	0.44
	Female	0.2433	3	0.07234	0.16	0.29
	Total	0.2038	13	0.10642	0.07	0.44
Hameshkoreb	Male	0.1380	10	0.10130	0.02	0.29
	Female	0.2340	5	0.07503	0.17	0.36
	Total	0.1700	15	0.10198	0.02	0.36
Total	Male	0.2029	95	0.11179	0.02	0.54
	Female	0.1972	47	0.10884	0.01	0.49
	Total	0.2011	142	0.11047	0.01	0.54

Zn

Area	Sex	Mean	N	Std. Deviation	Minimum	Maximum
Kassala Town	Male	0.0585	13	0.04562	0.01	0.15
	Female	0.0400	3	0.02646	0.02	0.07
	Total	0.0550	16	0.04258	0.01	0.15
Refi Kassala	Male	0.1458	12	0.27645	0.01	1.01
	Female	0.0522	9	0.02438	0.02	0.10
	Total	0.1057	21	0.21101	0.01	1.01
Aroma	Male	0.0493	15	0.03453	0.01	0.13
	Female	0.0500	8	0.03295	0.01	0.11
	Total	0.0496	23	0.03323	0.01	0.13
Eldelta	Male	0.0478	9	0.02991	0.01	0.09
	Female	0.0633	3	0.01528	0.05	0.08
	Total	0.0517	12	0.02725	0.01	0.09
Wad eLhelaw	Male	0.1157	7	0.06779	0.03	0.21
	Female	0.0467	3	0.02517	0.02	0.07
	Total	0.0950	10	0.06570	0.02	0.21
Telkok	Male	0.0633	6	0.05354	0.01	0.14
	Female	0.0660	5	0.05983	0.01	0.14
	Total	0.0645	11	0.05355	0.01	0.14
Hameshkoreb	Male	0.0929	7	0.04923	0.03	0.17
	Female	0.0433	3	0.02517	0.02	0.07
	Total	0.0780	10	0.04826	0.02	0.17
Total	Male	0.0800	69	0.12362	0.01	1.01
	Female	0.0524	34	0.03172	0.01	0.14
	Total	0.0709	103	0.10337	0.01	1.01

Cu

Area	sex	Mean	N	Std. Deviation	Minimum	Maximum
Kassala Town	Male	0.1760	15	0.37796	0.02	1.50
	Female	0.0388	8	0.03682	0.01	0.11
	Total	0.1283	23	0.30953	0.01	1.50
Refi Kassala	Male	0.0700	14	0.05189	0.01	0.20
	Female	0.0586	7	0.03805	0.02	0.13
	Total	0.0662	21	0.04706	0.01	0.20
Aroma	Male	0.0867	9	0.07382	0.01	0.26
	Female	0.1167	6	0.09668	0.03	0.30
	Total	0.0987	15	0.08175	0.01	0.30
Eldelta	Male	0.0371	7	0.04424	0.01	0.13
	Female	0.0600	5	0.04301	0.02	0.13
	Total	0.0467	12	0.04334	0.01	0.13
Wad eLhelaw	Male	0.0775	8	0.06135	0.01	0.19
	Female	0.0975	4	0.03594	0.05	0.13
	Total	0.0842	12	0.05334	0.01	0.19
Telkok	Male	0.0633	6	0.02733	0.03	0.10
	Female	0.0760	5	0.05030	0.01	0.15
	Total	0.0691	11	0.03780	0.01	0.15
Hameshkoreb	Male	0.0529	7	0.04071	0.01	0.11
	Female	0.0950	4	0.05802	0.02	0.15
	Total	0.0682	11	0.04956	0.01	0.15
Total	Male	0.0914	66	0.18735	0.01	1.50
	Female	0.0736	39	0.05710	0.01	0.30
	Total	0.0848	105	0.15233	0.01	1.50

Ni

Area	Sex	Mean	N	Std. Deviation	Minimum	Maximum
Kassala Town	Male	0.0815	13	0.06216	0.01	0.20
	Female	0.0844	9	0.05812	0.01	0.18
	Total	0.0827	22	0.05914	0.01	0.20
Refi Kassala	Male	0.1056	18	0.07540	0.01	0.29
	Female	0.1190	10	0.04771	0.03	0.18
	Total	0.1104	28	0.06619	0.01	0.29
Aroma	Male	0.1233	15	0.08772	0.01	0.33
	Female	0.1150	8	0.04660	0.01	0.16
	Total	0.1204	23	0.07486	0.01	0.33
Eldelta	Male	0.0850	4	0.08062	0.02	0.20
	Female	0.0475	4	0.03594	0.02	0.10
	Total	0.0663	8	0.06116	0.02	0.20
Wad eLhelaw	Male	0.1683	6	0.17406	0.02	0.47
	Female	0.2140	5	0.13649	0.07	0.41
	Total	0.1891	11	0.15221	0.02	0.47
Telkok	Male	0.0711	9	0.03060	0.04	0.14
	Female	0.0550	4	0.04203	0.01	0.10
	Total	0.0662	13	0.03355	0.01	0.14
Hameshkoreb	Male	0.1238	8	0.09709	0.03	0.28
	Female	0.1075	4	0.05737	0.04	0.18
	Total	0.1183	12	0.08343	0.03	0.28
Total	Male	0.1067	73	0.08708	0.01	0.47
	Female	0.1086	44	0.07547	0.01	0.41
	Total	0.1074	117	0.08258	0.01	0.47

Co

Area	sex	Mean	N	Std. Deviation	Minimum	Maximum
Kassala Town	Male	0.1333	15	0.09286	0.02	0.31
	Female	0.0717	6	0.05601	0.01	0.17
	Total	0.1157	21	0.08738	0.01	0.31
Refi Kassala	Male	0.0733	15	0.06032	0.01	0.19
	Female	0.1433	6	0.08383	0.05	0.27
	Total	0.0933	21	0.07317	0.01	0.27
Aroma	Male	0.1025	16	0.09007	0.01	0.26
	Female	0.1017	6	0.06432	0.01	0.17
	Total	0.1023	22	0.08234	0.01	0.26
Eldelta	Male	0.1371	7	0.21187	0.01	0.61
	Female	0.1150	4	0.07416	0.05	0.22
	Total	0.1291	11	0.16944	0.01	0.61
Wad eLhelaw	Male	0.1067	6	0.07202	0.04	0.24
	Female	0.0633	3	0.06807	0.01	0.14
	Total	0.0922	9	0.06978	0.01	0.24
Telkok	Male	0.0900	7	0.05260	0.03	0.16
	Female	0.1940	5	0.13831	0.02	0.40
	Total	0.1333	12	0.10646	0.02	0.40
Hameshkoreb	Male	0.1375	8	0.07459	0.07	0.27
	Female	0.1525	4	0.10243	0.04	0.27
	Total	0.1425	12	0.08035	0.04	0.27
Total	Male	0.1091	74	0.09704	0.01	0.61
	Female	0.1215	34	0.08975	0.01	0.40
	Total	0.1130	108	0.09457	0.01	0.61

Fe

Area	Sex	Mean	N	Std. Deviation	Minimum	Maximum
Kassala Town	Male	0.3294	17	0.20489	0.04	0.66
	Female	0.5100	9	0.47731	0.10	1.60
	Total	0.3919	26	0.32779	0.04	1.60
Refi Kassala	Male	0.3711	19	0.25772	0.06	1.24
	Female	0.6560	10	0.29662	0.25	1.24
	Total	0.4693	29	0.29996	0.06	1.24
Aroma	Male	0.4725	20	0.34808	0.01	1.32
	Female	0.4780	10	0.29970	0.05	0.88
	Total	0.4743	30	0.32751	0.01	1.32
Eldelta	Male	0.5200	10	0.23262	0.10	0.83
	Female	0.5840	5	0.38811	0.17	1.08
	Total	0.5413	15	0.28071	0.10	1.08
Wad eLhelaw	Male	0.5180	10	0.31347	0.14	1.14
	Female	0.9725	4	0.22485	0.76	1.29
	Total	0.6479	14	0.35369	0.14	1.29
Telkok	Male	0.3050	8	0.25088	0.07	0.89
	Female	0.5700	5	0.30008	0.31	1.07
	Total	0.4069	13	0.29110	0.07	1.07
Hameshkoreb	Male	0.5433	9	0.26618	0.08	0.86
	Female	0.4500	5	0.11937	0.29	0.57
	Total	0.5100	14	0.22392	0.08	0.86
Total	Male	0.4281	93	0.28016	0.01	1.32
	Female	0.5800	48	0.34213	0.05	1.60
	Total	0.4798	141	0.30999	0.01	1.60

Mn

Area	Sex	Mean	N	Std. Deviation	Minimum	Maximum
Kassala Town	Male	0.2288	16	0.14564	0.02	0.48
	Female	0.1757	7	0.10097	0.07	0.33
	Total	0.2126	23	0.13366	0.02	0.48
Refi Kassala	Male	0.3469	16	0.22776	0.05	0.81
	Female	0.3017	6	0.21498	0.08	0.63
	Total	0.3345	22	0.22019	0.05	0.81
Aroma	Male	0.2524	17	0.24522	0.05	1.08
	Female	0.2800	5	0.14967	0.07	0.47
	Total	0.2586	22	0.22410	0.05	1.08
Eldelta	Male	0.2483	6	0.25624	0.05	0.74
	Female	0.3400	4	0.52045	0.06	1.12
	Total	0.2850	10	0.35917	0.05	1.12
Wad eLhelaw	Male	0.2863	8	0.17872	0.08	0.62
	Female	0.2500	3	0.06083	0.21	0.32
	Total	0.2764	11	0.15292	0.08	0.62
Telkok	Male	0.2589	9	0.14155	0.05	0.47
	Female	0.2220	5	0.17768	0.10	0.51
	Total	0.2457	14	0.14960	0.05	0.51
Hameshkoreb	Male	0.4229	7	0.14256	0.22	0.65
	Female	0.3800	5	0.27083	0.02	0.72
	Total	0.4050	12	0.19556	0.02	0.72
Total	Male	0.2857	79	0.20159	0.02	1.08
	Female	0.2731	35	0.22898	0.02	1.12
	Total	0.2818	114	0.20943	0.02	1.12

Cr

Area	Sex	Mean	N	Std. Deviation	Minimum	Maximum
Kassala Town	Male	0.4794	16	0.23736	0.12	1.00
	Female	0.4113	8	0.36117	0.07	0.95
	Total	0.4567	24	0.27842	0.07	1.00
Refi Kassala	Male	0.3594	17	0.27300	0.05	1.07
	Female	0.2600	5	0.21459	0.04	0.55
	Total	0.3368	22	0.25957	0.04	1.07
Aroma	Male	0.4000	16	0.38158	0.02	1.28
	Female	0.4450	6	0.28005	0.05	0.87
	Total	0.4123	22	0.35085	0.02	1.28
Eldelta	Male	0.1600	8	0.11514	0.01	0.39
	Female	0.1067	3	0.05859	0.04	0.15
	Total	0.1455	11	0.10289	0.01	0.39
Wad eLhelaw	Male	0.2717	6	0.17612	0.13	0.51
	Female	0.6100	2	0.33941	0.37	0.85
	Total	0.3562	8	0.25128	0.13	0.85
Telkok	Male	0.4017	6	0.28308	0.14	0.79
	Female	0.1467	3	0.05033	0.10	0.20
	Total	0.3167	9	0.25880	0.10	0.79
Hameshkoreb	Male	0.4843	7	0.43653	0.07	1.29
	Female	0.3600	3	0.28931	0.03	0.57
	Total	0.4470	10	0.38632	0.03	1.29
Total	Male	0.3801	76	0.29937	0.01	1.29
	Female	0.3440	30	0.28435	0.03	0.95
	Total	0.3699	106	0.29430	0.01	1.29

V

Area	Sex	Mean	N	Std. Deviation	Minimum	Maximum
Kassala Town	Male	0.8275	12	0.53500	0.15	2.22
	Female	0.5417	6	0.40002	0.20	1.26
	Total	0.7322	18	0.50149	0.15	2.22
Refi Kassala	Male	0.5553	15	0.33028	0.04	1.12
	Female	0.3883	6	0.39296	0.04	1.02
	Total	0.5076	21	0.34776	0.04	1.12
Aroma	Male	0.5936	14	0.38566	0.06	1.32
	Female	0.9975	8	0.67343	0.09	2.05
	Total	0.7405	22	0.53178	0.06	2.05
Eldelta	Male	0.3571	7	0.24116	0.13	0.75
	Female	1.2050	2	0.85560	0.60	1.81
	Total	0.5456	9	0.52431	0.13	1.81
Wad eLhelaw	Male	0.6500	5	0.39642	0.37	1.35
	Female	0.7975	4	0.54604	0.35	1.50
	Total	0.7156	9	0.44320	0.35	1.50
Telkok	Male	0.4067	6	0.37313	0.03	0.93
	Female	0.6575	4	0.34500	0.21	0.98
	Total	0.5070	10	0.36579	0.03	0.98
Hameshkoreb	Male	0.9011	9	0.61653	0.08	2.09
	Female	0.7150	4	0.35707	0.28	1.11
	Total	0.8438	13	0.54155	0.08	2.09
Total	Male	0.6304	68	0.44684	0.03	2.22
	Female	0.7250	34	0.52481	0.04	2.05
	Total	0.6620	102	0.47376	0.03	2.22

Ti

Area	Sex	Mean	N	Std. Deviation	Minimum	Maximum
Kassala Town	Male	1.3250	16	1.01585	0.41	3.84
	Female	1.2725	8	1.09403	0.30	3.67
	Total	1.3075	24	1.01879	0.30	3.84
Refi Kassala	Male	1.6911	18	0.88566	0.46	3.77
	Female	2.0750	8	0.76493	0.97	3.29
	Total	1.8092	26	0.85433	0.46	3.77
Aroma	Male	1.1647	17	0.75037	0.25	2.59
	Female	1.1950	8	0.61933	0.40	2.03
	Total	1.1744	25	0.69818	0.25	2.59
Eldelta	Male	1.8514	7	0.94706	0.61	3.54
	Female	0.9450	4	0.44844	0.48	1.40
	Total	1.5218	11	0.89867	0.48	3.54
Wad eLhelaw	Male	1.8033	6	1.28241	0.56	3.46
	Female	0.8333	3	0.21572	0.68	1.08
	Total	1.4800	9	1.12904	0.56	3.46
Telkok	Male	1.5938	8	1.01166	0.13	2.79
	Female	1.5780	5	0.58084	0.57	2.07
	Total	1.5877	13	0.84234	0.13	2.79
Hameshkoreb	Male	1.4300	7	0.72166	0.63	2.78
	Female	1.0000	4	0.50912	0.52	1.60
	Total	1.2736	11	0.66129	0.52	2.78
Total	Male	1.4934	79	0.92190	0.13	3.84
	Female	1.3627	40	0.79466	0.30	3.67
	Total	1.4495	119	0.87998	0.13	3.84

Zr

Area	Age	Mean	N	Std. Deviation	Minimum	Maximum
Kassala Town	1-20	0.0100	4	0.00000	0.01	0.01
	20-40	0.0100	2	0.00000	0.01	0.01
	40-60	0.0100	1	0.00000	0.01	0.01
	Total	0.0100	7	0.00000	0.01	0.01
R. Kassala	1-20	0.0100	1	0.00000	0.01	0.01
	20-40	0.0100	10	0.00000	0.01	0.01
	40-60	0.0100	2	0.00000	0.01	0.01
	Total	0.0100	13	0.00000	0.01	0.01
Aroma	1-20	0.0100	1	0.00000	0.01	0.01
	20-40	0.0100	6	0.00000	0.01	0.01
	40-60	0.0100	2	0.00000	0.01	0.01
	Total	0.0100	9	0.00000	0.01	0.01
Eldelta	1-20	0.0100	1	0.00000	0.01	0.01
	40-60	0.0100	1	0.00000	0.01	0.01
	60+	0.0100	1	0.00000	0.01	0.01
	Total	0.0100	3	0.00000	0.01	0.01
Wad eLhelaw	1-20	0.0100	3	0.00000	0.01	0.01
	20-40	0.0100	1	0.00000	0.01	0.01
	40-60	0.0100	2	0.00000	0.01	0.01
	Total	0.0100	6	0.00000	0.01	0.01
Telkok	1-20	0.0100	1	0.00000	0.01	0.01
	40-60	0.0100	1	0.00000	0.01	0.01
	Total	0.0100	2	0.00000	0.01	0.01
Hameshkoreb	1-20	0.0100	3	0.00000	0.01	0.01
	20-40	0.0200	2	0.01414	0.01	0.03
	40-60	0.0100	1	0.00000	0.01	0.01
	Total	0.0133	6	0.00816	0.01	0.03
Total	1-20	0.0100	14	0.00000	0.01	0.01
	20-40	0.0110	21	0.00436	0.01	0.03
	40-60	0.0100	10	0.00000	0.01	0.01
	60+	0.0100	1	0.00000	0.01	0.01
	Total	0.0104	46	0.00295	0.01	0.03

Bi

Area	Age	Mean	N	Std. Deviation	Minimum	Maximum
Kassala Town	1-20	0.1329	7	0.21647	0.01	0.57
	20-40	0.0150	6	0.00548	0.01	0.02
	Total	0.0785	13	0.16487	0.01	0.57
R. Kassala	1-20	0.0140	5	0.00548	0.01	0.02
	20-40	0.0160	10	0.00966	0.01	0.04
	40-60	0.0167	3	0.00577	0.01	0.02
	60+	0.0300	1	0.00000	0.03	0.03
	Total	0.0163	19	0.00831	0.01	0.04
Aroma	1-20	0.0175	4	0.00957	0.01	0.03
	20-40	0.0382	11	0.08693	0.01	0.30
	40-60	0.0300	1	0.00000	0.03	0.03
	Total	0.0325	16	0.07169	0.01	0.30
Eldelta	1-20	0.0200	2	0.01414	0.01	0.03
	20-40	0.0200	1	0.00000	0.02	0.02
	40-60	0.0125	4	0.00500	0.01	0.02
	60+	0.0100	1	0.00000	0.01	0.01
	Total	0.0150	8	0.00756	0.01	0.03
Wad eLhelaw	1-20	0.0120	5	0.00447	0.01	0.02
	20-40	0.0400	1	0.00000	0.04	0.04
	40-60	0.0200	2	0.01414	0.01	0.03
	Total	0.0175	8	0.01165	0.01	0.04
Telkok	1-20	0.0150	2	0.00707	0.01	0.02
	20-40	0.0200	2	0.01414	0.01	0.03
	40-60	0.0100	1	0.00000	0.01	0.01
	Total	0.0160	5	0.00894	0.01	0.03
Hameshkoreb	1-20	0.0167	3	0.01155	0.01	0.03
	20-40	0.0180	5	0.01095	0.01	0.03
	Total	0.0175	8	0.01035	0.01	0.03
Total	1-20	0.0446	28	0.11465	0.01	0.57
	20-40	0.0239	36	0.04812	0.01	0.30
	40-60	0.0164	11	0.00809	0.01	0.03
	60+	0.0200	2	0.01414	0.01	0.03
	Total	0.0303	77	0.07664	0.01	0.57

Pb

Area	Age	Mean	N	Std. Deviation	Minimum	Maximum
Kassala Town	1-20	0.0225	8	0.01669	0.01	0.06
	20-40	0.0275	12	0.01712	0.01	0.06
	40-60	0.0100	1	0.00000	0.01	0.01
	60+	0.0300	1	0.00000	0.03	0.03
	Total	0.0250	22	0.01626	0.01	0.06
R. Kassala	1-20	0.0220	5	0.00837	0.01	0.03
	20-40	0.0191	11	0.01375	0.01	0.05
	40-60	0.0250	2	0.02121	0.01	0.04
	Total	0.0206	18	0.01259	0.01	0.05
Aroma	1-20	0.0160	5	0.00894	0.01	0.03
	20-40	0.0175	8	0.01389	0.01	0.05
	40-60	0.0167	3	0.01155	0.01	0.03
	Total	0.0169	16	0.01138	0.01	0.05
Elelta	20-40	0.0167	3	0.01155	0.01	0.03
	40-60	0.0317	6	0.02041	0.01	0.07
	60+	0.0300	1	0.00000	0.03	0.03
	Total	0.0270	10	0.01767	0.01	0.07
Wad eLhelaw	1-20	0.0425	4	0.03775	0.01	0.08
	20-40	0.0150	4	0.01000	0.01	0.03
	40-60	0.0300	2	0.00000	0.03	0.03
	Total	0.0290	10	0.02601	0.01	0.08
Telkok	1-20	0.0100	2	0.00000	0.01	0.01
	20-40	0.0200	3	0.01000	0.01	0.03
	40-60	0.0100	2	0.00000	0.01	0.01
	60+	0.0100	1	0.00000	0.01	0.01
	Total	0.0138	8	0.00744	0.01	0.03
Hameshkoreb	1-20	0.0425	4	0.03304	0.01	0.08
	20-40	0.0267	3	0.01528	0.01	0.04
	40-60	0.0100	1	0.00000	0.01	0.01
	Total	0.0325	8	0.02605	0.01	0.08
Total	1-20	0.0261	28	0.02233	0.01	0.08
	20-40	0.0211	44	0.01418	0.01	0.06
	40-60	0.0229	17	0.01611	0.01	0.07
	60+	0.0233	3	0.01155	0.01	0.03
	Total	0.0230	92	0.01721	0.01	0.08

W

Area	Age	Mean	N	Std. Deviation	Minimum	Maximum
Kassala Town	1-20	0.2570	10	0.10489	0.07	0.43
	20-40	0.2020	15	0.08394	0.05	0.33
	40-60	0.2700	1	0.00000	0.27	0.27
	60+	0.0400	1	0.00000	0.04	0.04
	Total	0.2189	27	0.09827	0.04	0.43
R. Kassala	1-20	0.2050	8	0.14452	0.01	0.50
	20-40	0.2181	16	0.13629	0.02	0.37
	40-60	0.1475	4	0.09500	0.02	0.25
	60+	0.0900	1	0.00000	0.09	0.09
	Total	0.2003	29	0.13100	0.01	0.50
Aroma	1-20	0.1550	8	0.08602	0.04	0.25
	20-40	0.2241	17	0.11192	0.04	0.49
	40-60	0.1780	5	0.06380	0.11	0.24
	Total	0.1980	30	0.10118	0.04	0.49
Eldelta	1-20	0.1600	2	0.05657	0.12	0.20
	20-40	0.1617	6	0.06113	0.09	0.24
	40-60	0.1483	6	0.11514	0.02	0.29
	Total	0.1557	14	0.08262	0.02	0.29
Wad eLhelaw	1-20	0.2400	6	0.09571	0.16	0.38
	20-40	0.2940	5	0.17757	0.09	0.54
	40-60	0.2000	3	0.15100	0.04	0.34
	Total	0.2507	14	0.13453	0.04	0.54
Telkok	1-20	0.2400	6	0.11883	0.12	0.44
	20-40	0.1550	4	0.09327	0.07	0.28
	40-60	0.2550	2	0.03536	0.23	0.28
	60+	0.0800	1	0.00000	0.08	0.08
	Total	0.2038	13	0.10642	0.07	0.44
Hameshkoreb	1-20	0.2333	6	0.09266	0.09	0.36
	20-40	0.1138	8	0.08314	0.02	0.28
	40-60	0.2400	1	0.00000	0.24	0.24
	Total	0.1700	15	0.10198	0.02	0.36
Total	1-20	0.2185	46	0.10768	0.01	0.50
	20-40	0.2014	71	0.11543	0.02	0.54
	40-60	0.1814	22	0.09533	0.02	0.34
	60+	0.0700	3	0.02646	0.04	0.09
	Total	0.2011	142	0.11047	0.01	0.54

Zn

Area	Age	Mean	N	Std. Deviation	Minimum	Maximum
Kassala Town	1-20	0.0533	6	0.03777	0.01	0.12
	20-40	0.0600	9	0.04822	0.02	0.15
	60+	0.0200	1	0.00000	0.02	0.02
	Total	0.0550	16	0.04258	0.01	0.15
R. Kassala	1-20	0.0640	5	0.03647	0.02	0.12
	20-40	0.0618	11	0.04579	0.01	0.17
	40-60	0.2775	4	0.48863	0.01	1.01
	60+	0.1100	1	0.00000	0.11	0.11
	Total	0.1057	21	0.21101	0.01	1.01
Aroma	1-20	0.0550	6	0.03146	0.01	0.10
	20-40	0.0492	13	0.03883	0.01	0.13
	40-60	0.0425	4	0.01708	0.02	0.06
	Total	0.0496	23	0.03323	0.01	0.13
Eldelta	1-20	0.0700	2	0.01414	0.06	0.08
	20-40	0.0325	4	0.02630	0.01	0.07
	40-60	0.0660	5	0.02074	0.04	0.09
	60+	0.0200	1	0.00000	0.02	0.02
	Total	0.0517	12	0.02725	0.01	0.09
Wad eLhelaw	1-20	0.1325	4	0.08421	0.05	0.21
	20-40	0.0750	2	0.07778	0.02	0.13
	40-60	0.0675	4	0.02630	0.03	0.09
	Total	0.0950	10	0.06570	0.02	0.21
Telkok	1-20	0.0567	6	0.05007	0.01	0.12
	20-40	0.1033	3	0.06351	0.03	0.14
	40-60	0.0300	2	0.02828	0.01	0.05
	Total	0.0645	11	0.05355	0.01	0.14
Hameshkoreb	1-20	0.0650	4	0.04435	0.02	0.12
	20-40	0.0867	6	0.05279	0.03	0.17
	Total	0.0780	10	0.04826	0.02	0.17
Total	1-20	0.0679	33	0.04910	0.01	0.21
	20-40	0.0619	48	0.04671	0.01	0.17
	40-60	0.1021	19	0.22120	0.01	1.01
	60+	0.0500	3	0.05196	0.02	0.11
	Total	0.0709	103	0.10337	0.01	1.01

Cu

Area	Age	Mean	N	Std. Deviation	Minimum	Maximum
Kassala Town	1-20	0.0744	9	0.12310	0.01	0.40
	20-40	0.1800	12	0.41713	0.01	1.50
	40-60	0.1100	1	0.00000	0.11	0.11
	60+	0.0100	1	0.00000	0.01	0.01
	Total	0.1283	23	0.30953	0.01	1.50
R. Kassala	1-20	0.0880	5	0.03033	0.06	0.13
	20-40	0.0677	13	0.05215	0.01	0.20
	40-60	0.0250	2	0.00707	0.02	0.03
	60+	0.0200	1	0.00000	0.02	0.02
	Total	0.0662	21	0.04706	0.01	0.20
Aroma	1-20	0.0800	4	0.04082	0.05	0.14
	20-40	0.1167	9	0.10000	0.01	0.30
	40-60	0.0550	2	0.02121	0.04	0.07
	Total	0.0987	15	0.08175	0.01	0.30
Eldelta	1-20	0.0550	2	0.02121	0.04	0.07
	20-40	0.0300	4	0.01826	0.01	0.05
	40-60	0.0400	5	0.05196	0.01	0.13
	60+	0.1300	1	0.00000	0.13	0.13
	Total	0.0467	12	0.04334	0.01	0.13
Wad eLhelaw	1-20	0.1120	5	0.05495	0.05	0.19
	20-40	0.0700	3	0.02000	0.05	0.09
	40-60	0.0600	4	0.06218	0.01	0.15
	Total	0.0842	12	0.05334	0.01	0.19
Telkok	1-20	0.0800	4	0.05715	0.01	0.15
	20-40	0.0575	4	0.03096	0.03	0.10
	40-60	0.0800	2	0.00000	0.08	0.08
	60+	0.0500	1	0.00000	0.05	0.05
	Total	0.0691	11	0.03780	0.01	0.15
Hameshkoreb	1-20	0.0925	4	0.06238	0.01	0.15
	20-40	0.0600	6	0.03950	0.02	0.11
	40-60	0.0200	1	0.00000	0.02	0.02
	Total	0.0682	11	0.04956	0.01	0.15
Total	1-20	0.0845	33	0.07306	0.01	0.40
	20-40	0.0982	51	0.20837	0.01	1.50
	40-60	0.0524	17	0.04423	0.01	0.15
	60+	0.0525	4	0.05439	0.01	0.13
	Total	0.0848	105	0.15233	0.01	1.50

Ni

Area	Age	Mean	N	Std. Deviation	Minimum	Maximum
Kassala Town	1-20	0.0855	11	0.06440	0.01	0.20
	20-40	0.0600	9	0.03841	0.01	0.13
	40-60	0.1600	1	0.00000	0.16	0.16
	60+	0.1800	1	0.00000	0.18	0.18
	Total	0.0827	22	0.05914	0.01	0.20
R. Kassala	1-20	0.0943	7	0.05062	0.01	0.15
	20-40	0.1119	16	0.07139	0.03	0.29
	40-60	0.1450	4	0.07594	0.04	0.22
	60+	0.0600	1	0.00000	0.06	0.06
	Total	0.1104	28	0.06619	0.01	0.29
Aroma	1-20	0.1700	7	0.07461	0.12	0.33
	20-40	0.0783	12	0.04345	0.01	0.14
	40-60	0.1600	4	0.09018	0.09	0.29
	Total	0.1204	23	0.07486	0.01	0.33
Edelta	1-20	0.0300	1	0.00000	0.03	0.03
	20-40	0.0267	3	0.01155	0.02	0.04
	40-60	0.1133	3	0.08083	0.04	0.20
	60+	0.0800	1	0.00000	0.08	0.08
	Total	0.0663	8	0.06116	0.02	0.20
Wad eLhelaw	1-20	0.2500	6	0.16864	0.07	0.47
	20-40	0.1800	3	0.07000	0.11	0.25
	40-60	0.0200	2	0.00000	0.02	0.02
	Total	0.1891	11	0.15221	0.02	0.47
Telkok	1-20	0.0600	5	0.01871	0.03	0.08
	20-40	0.0820	5	0.03768	0.05	0.14
	40-60	0.0250	2	0.02121	0.01	0.04
	60+	0.1000	1	0.00000	0.10	0.10
	Total	0.0662	13	0.03355	0.01	0.14
Hameshkoreb	1-20	0.0740	5	0.03050	0.04	0.11
	20-40	0.1450	6	0.10483	0.03	0.28
	40-60	0.1800	1	0.00000	0.18	0.18
	Total	0.1183	12	0.08343	0.03	0.28
Total	1-20	0.1188	42	0.10010	0.01	0.47
	20-40	0.0957	54	0.06870	0.01	0.29
	40-60	0.1171	17	0.08191	0.01	0.29
	60+	0.1050	4	0.05260	0.06	0.18
	Total	0.1074	117	0.08258	0.01	0.47

Co

Area	Age	Mean	N	Std. Deviation	Minimum	Maximum
Kassala Town	1-20	0.1000	7	0.10050	0.01	0.31
	20-40	0.1275	12	0.08444	0.02	0.27
	40-60	0.0300	1	0.00000	0.03	0.03
	60+	0.1700	1	0.00000	0.17	0.17
	Total	0.1157	21	0.08738	0.01	0.31
R. Kassala	1-20	0.0500	6	0.04147	0.02	0.13
	20-40	0.1092	12	0.08051	0.01	0.27
	40-60	0.0800	2	0.05657	0.04	0.12
	60+	0.1900	1	0.00000	0.19	0.19
	Total	0.0933	21	0.07317	0.01	0.27
Aroma	1-20	0.0775	4	0.10178	0.02	0.23
	20-40	0.1215	13	0.08572	0.01	0.26
	40-60	0.0720	5	0.05310	0.01	0.15
	Total	0.1023	22	0.08234	0.01	0.26
Eldelta	1-20	0.1500	2	0.09899	0.08	0.22
	20-40	0.0633	3	0.02309	0.05	0.09
	40-60	0.0640	5	0.04980	0.01	0.11
	60+	0.6100	1	0.00000	0.61	0.61
	Total	0.1291	11	0.16944	0.01	0.61
Wad eLhelaw	1-20	0.0250	2	0.02121	0.01	0.04
	20-40	0.0800	4	0.04320	0.04	0.14
	40-60	0.1533	3	0.07767	0.09	0.24
	Total	0.0922	9	0.06978	0.01	0.24
Telkok	1-20	0.1660	5	0.14188	0.02	0.40
	20-40	0.1000	5	0.09055	0.03	0.23
	40-60	0.1500	1	0.00000	0.15	0.15
	60+	0.1200	1	0.00000	0.12	0.12
	Total	0.1333	12	0.10646	0.02	0.40
Hameshkoreb	1-20	0.1260	5	0.08385	0.04	0.23
	20-40	0.1633	6	0.08618	0.07	0.27
	40-60	0.1000	1	0.00000	0.10	0.10
	Total	0.1425	12	0.08035	0.04	0.27
Total	1-20	0.1006	31	0.09619	0.01	0.40
	20-40	0.1165	55	0.07996	0.01	0.27
	40-60	0.0878	18	0.05986	0.01	0.24
	60+	0.2725	4	0.22692	0.12	0.61
	Total	0.1130	108	0.09457	0.01	0.61

Fe

Area	Age	Mean	N	Std. Deviation	Minimum	Maximum
Kassala Town	1-20	0.4530	10	0.17951	0.17	0.71
	20-40	0.3464	14	0.40606	0.04	1.60
	40-60	0.7100	1	0.00000	0.71	0.71
	60+	0.1000	1	0.00000	0.10	0.10
	Total	0.3919	26	0.32779	0.04	1.60
R. Kassala	1-20	0.3114	7	0.21528	0.06	0.70
	20-40	0.5031	16	0.27700	0.18	1.24
	40-60	0.5740	5	0.45856	0.17	1.24
	60+	0.5100	1	0.00000	0.51	0.51
	Total	0.4693	29	0.29996	0.06	1.24
Aroma	1-20	0.5063	8	0.42220	0.01	1.32
	20-40	0.4247	17	0.28862	0.03	0.91
	40-60	0.5920	5	0.32042	0.12	0.90
	Total	0.4743	30	0.32751	0.01	1.32
Eldelta	1-20	0.2350	2	0.09192	0.17	0.30
	20-40	0.5267	6	0.19977	0.30	0.89
	40-60	0.6267	6	0.35410	0.10	1.08
	60+	0.7300	1	0.00000	0.73	0.73
	Total	0.5413	15	0.28071	0.10	1.08
Wad eLhelaw	1-20	0.9750	6	0.20147	0.76	1.29
	20-40	0.4800	4	0.24752	0.21	0.81
	40-60	0.3250	4	0.15022	0.14	0.49
	Total	0.6479	14	0.35369	0.14	1.29
Telkok	1-20	0.4800	5	0.23633	0.31	0.89
	20-40	0.3680	5	0.40252	0.07	1.07
	40-60	0.4150	2	0.27577	0.22	0.61
	60+	0.2200	1	0.00000	0.22	0.22
	Total	0.4069	13	0.29110	0.07	1.07
Hameshkoreb	1-20	0.5540	5	0.18902	0.36	0.86
	20-40	0.4838	8	0.26554	0.08	0.81
	40-60	0.5000	1	0.00000	0.50	0.50
	Total	0.5100	14	0.22392	0.08	0.86
Total	1-20	0.5174	43	0.31482	0.01	1.32
	20-40	0.4416	70	0.30539	0.03	1.60
	40-60	0.5387	24	0.31852	0.10	1.24
	60+	0.3900	4	0.28460	0.10	0.73
	Total	0.4798	141	0.30999	0.01	1.60

Mn

Area	Age	Mean	N	Std. Deviation	Minimum	Maximum
Kassala Town	1-20	0.1922	9	0.11777	0.02	0.33
	20-40	0.2369	13	0.14522	0.03	0.48
	60+	0.0800	1	0.00000	0.08	0.08
	Total	0.2126	23	0.13366	0.02	0.48
R. Kassala	1-20	0.5220	5	0.26809	0.12	0.81
	20-40	0.2600	14	0.18305	0.05	0.63
	40-60	0.2950	2	0.06364	0.25	0.34
	60+	0.5200	1	0.00000	0.52	0.52
	Total	0.3345	22	0.22019	0.05	0.81
Aroma	1-20	0.3350	6	0.37506	0.11	1.08
	20-40	0.1969	13	0.12861	0.05	0.47
	40-60	0.3733	3	0.12014	0.25	0.49
	Total	0.2586	22	0.22410	0.05	1.08
Eldelta	1-20	0.0900	2	0.02828	0.07	0.11
	20-40	0.1200	3	0.11269	0.05	0.25
	40-60	0.4620	5	0.45290	0.09	1.12
	Total	0.2850	10	0.35917	0.05	1.12
Wad eLhelaw	1-20	0.2425	4	0.05188	0.21	0.32
	20-40	0.3700	3	0.21656	0.24	0.62
	40-60	0.2400	4	0.17870	0.08	0.46
	Total	0.2764	11	0.15292	0.08	0.62
Telkok	1-20	0.2117	6	0.12139	0.10	0.42
	20-40	0.2760	5	0.20391	0.05	0.51
	40-60	0.2450	2	0.19092	0.11	0.38
	60+	0.3000	1	0.00000	0.30	0.30
	Total	0.2457	14	0.14960	0.05	0.51
Hameshkoreb	1-20	0.5050	6	0.17398	0.23	0.72
	20-40	0.2880	5	0.18754	0.02	0.49
	40-60	0.3900	1	0.00000	0.39	0.39
	Total	0.4050	12	0.19556	0.02	0.72
Total	1-20	0.3105	38	0.23768	0.02	1.08
	20-40	0.2423	56	0.16264	0.02	0.63
	40-60	0.3447	17	0.26547	0.08	1.12
	60+	0.3000	3	0.22000	0.08	0.52
	Total	0.2818	114	0.20943	0.02	1.12

Cr

Area	Age	Mean	N	Std. Deviation	Minimum	Maximum
Kassala Town	1-20	0.4460	10	0.27118	0.12	0.88
	20-40	0.4458	12	0.27124	0.07	1.00
	40-60	0.9500	1	0.00000	0.95	0.95
	60+	0.2000	1	0.00000	0.20	0.20
	Total	0.4567	24	0.27842	0.07	1.00
R. Kassala	1-20	0.2583	6	0.19041	0.05	0.55
	20-40	0.3808	12	0.32072	0.04	1.07
	40-60	0.3225	4	0.11701	0.20	0.45
	Total	0.3368	22	0.25957	0.04	1.07
Aroma	1-20	0.5350	6	0.39531	0.05	1.08
	20-40	0.3908	13	0.35486	0.02	1.28
	40-60	0.2600	3	0.25159	0.10	0.55
	Total	0.4123	22	0.35085	0.02	1.28
Eldelta	1-20	0.1300	1	0.00000	0.13	0.13
	20-40	0.1420	5	0.15643	0.01	0.39
	40-60	0.1500	4	0.04967	0.08	0.19
	60+	0.1600	1	0.00000	0.16	0.16
	Total	0.1455	11	0.10289	0.01	0.39
Wad eLhelaw	1-20	0.4250	2	0.07778	0.37	0.48
	20-40	0.3800	3	0.40706	0.14	0.85
	40-60	0.2867	3	0.19858	0.13	0.51
	Total	0.3562	8	0.25128	0.13	0.85
Telkok	1-20	0.3250	4	0.31097	0.14	0.79
	20-40	0.2967	3	0.26274	0.14	0.60
	40-60	0.1000	1	0.00000	0.10	0.10
	60+	0.5600	1	0.00000	0.56	0.56
	Total	0.3167	9	0.25880	0.10	0.79
Hameshkoreb	1-20	0.4725	4	0.28582	0.12	0.82
	20-40	0.5100	5	0.47482	0.07	1.29
	40-60	0.0300	1	0.00000	0.03	0.03
	Total	0.4470	10	0.38632	0.03	1.29
Total	1-20	0.4058	33	0.28136	0.05	1.08
	20-40	0.3828	53	0.32114	0.01	1.29
	40-60	0.2712	17	0.23353	0.03	0.95
	60+	0.3067	3	0.22030	0.16	0.56
	Total	0.3699	106	0.29430	0.01	1.29

V

Area	Age	Mean	N	Std. Deviation	Minimum	Maximum
Kassala Town	1-20	0.8570	10	0.58040	0.28	2.22
	20-40	0.5762	8	0.35721	0.15	1.10
	Total	0.7322	18	0.50149	0.15	2.22
R. Kassala	1-20	0.3700	6	0.26153	0.06	0.72
	20-40	0.5264	11	0.35733	0.04	1.12
	40-60	0.6033	3	0.52176	0.04	1.07
	60+	0.8400	1	0.00000	0.84	0.84
	Total	0.5076	21	0.34776	0.04	1.12
Aroma	1-20	0.6213	8	0.43139	0.09	1.32
	20-40	0.7860	10	0.62025	0.06	2.05
	40-60	0.8650	4	0.57070	0.28	1.44
	Total	0.7405	22	0.53178	0.06	2.05
Eldelta	1-20	1.8100	1	0.0000	1.81	1.81
	20-40	0.4775	4	0.25264	0.17	0.75
	40-60	0.3200	3	0.26287	0.13	0.62
	60+	0.2300	1	0.0000	0.23	0.23
	Total	0.5456	9	0.52431	0.13	1.81
Wad eLhelaw	1-20	0.8025	4	0.54064	0.37	1.50
	20-40	0.4400	2	0.12728	0.35	0.53
	40-60	0.7833	3	0.49116	0.48	1.35
	Total	0.7156	9	0.44320	0.35	1.50
Telkok	1-20	0.6200	4	0.39217	0.21	0.98
	20-40	0.4975	4	0.39152	0.08	0.87
	40-60	0.5700	1	0.00000	0.57	0.57
	60+	0.0300	1	0.00000	0.03	0.03
	Total	0.5070	10	0.36579	0.03	0.98
Hameshkoreb	1-20	0.9620	5	0.80936	0.08	2.09
	20-40	0.7943	7	0.35416	0.14	1.19
	40-60	0.6000	1	0.00000	0.60	0.60
	Total	0.8438	13	0.54155	0.08	2.09
Total	1-20	0.7387	38	0.54946	0.06	2.22
	20-40	0.6217	46	0.41789	0.04	2.05
	40-60	0.6500	15	0.44099	0.04	1.44
	60+	0.3667	3	0.42194	0.03	0.84
	Total	0.6620	102	0.47376	0.03	2.22

Ti

Area	Age	Mean	N	Std. Deviation	Minimum	Maximum
Kassala Town	1-20	0.7660	10	0.49708	0.30	1.75
	20-40	1.7175	12	1.22580	0.49	3.84
	40-60	1.4000	1	0.00000	1.40	1.40
	60+	1.7100	1	0.00000	1.71	1.71
	Total	1.3075	24	1.01879	0.30	3.84
Refi Kassala	1-20	1.5371	7	0.75626	0.59	2.74
	20-40	2.0577	13	0.92368	0.46	3.77
	40-60	1.5500	5	0.85431	0.74	2.89
	60+	1.7800	1	0.00000	1.78	1.78
	Total	1.8092	26	0.85433	0.46	3.77
Aroma	1-20	0.9533	6	0.67802	0.25	2.09
	20-40	1.3057	14	0.72467	0.30	2.59
	40-60	1.0720	5	0.70468	0.54	2.04
	Total	1.1744	25	0.69818	0.25	2.59
Shamal	1-20	0.4800	1	0.00000	0.48	0.48
	20-40	1.0867	3	0.41956	0.61	1.40
	40-60	1.8617	6	1.02788	0.65	3.54
	60+	1.8300	1	0.00000	1.83	1.83
	Total	1.5218	11	0.89867	0.48	3.54
Wad eLhelaw	1-20	1.9800	4	1.31767	0.68	3.46
	20-40	1.1550	4	1.01267	0.56	2.67
	40-60	0.7800	1	0.00000	0.78	0.78
	Total	1.4800	9	1.12904	0.56	3.46
Telkok	1-20	1.5671	7	0.70182	0.39	2.50
	20-40	1.4925	4	1.33742	0.13	2.79
	40-60	1.7600	1	0.00000	1.76	1.76
	60+	1.9400	1	0.00000	1.94	1.94
	Total	1.5877	13	0.84234	0.13	2.79
Hameshkoreb	1-20	1.2283	6	0.84741	0.52	2.78
	20-40	1.3500	4	0.49860	0.63	1.78
	40-60	1.2400	1	0.00000	1.24	1.24
	Total	1.2736	11	0.66129	0.52	2.78
Total	1-20	1.2410	41	0.81524	0.25	3.46
	20-40	1.5720	54	0.96223	0.13	3.84
	40-60	1.4730	20	0.81275	0.54	3.54
	60+	1.8150	4	0.09678	1.71	1.94
	Total	1.4495	119	0.87998	0.13	3.84