Sudan University of Science and Technology

College of Graduate Studies

A Study of the Concentration of Chromium and Radioactivity of Radioisotopes in the Ingessana Hills Region

دراسة تركيز الكروم والنشاط الإشعاعي للنظائر المشعة في منطقة جبال الأنقسنا

A thesis submitted for fulfillment of requirement

for degree of doctor of philosophy in physics

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*Jan*2019

الاستهلال

قال تعالى :

(يَا أَيُّهَا الَّذِينَ آمَنُوا إِذَا قِيلَ لَكُمْ تَفَسَّحُوا فِي الْمَجَالِسِ فَافْسَحُوا يَفْسَحِ اللَّهُ لَكُمْ وَإِذَا قِيلَ انْشُزُوا فَانْشُزُوا يَرْفَعِ اللَّهُ الَّذِينَ آمَنُوا مِنْكُمْ وَالَّذِينَ أُوتُوا الْعِلْمَ دَرَجَاتٍ وَاللَّهُ بِمَا تَعْمَلُونَ خَبِيرٌ)الآية (11)

صدق الله العظيم

سورة المجادلة

Dedication:

I dedicate this thesis for my family and my husband for all their support and encourage.And took advantage of this opportunity to thank all those who helped me even a little to the success of this research.

Acknowledgements

First and foremost , I would like to express my deepest gratitude to

Prof: Hassan I. Shaban &Dr : Ahmed Elhassan ELfaki

Thank you very much Dr. Mohammed Aydrous ,Deep thanks to my

family for their consistent mental support finally ,

I would like to thanks my friends.

Abstract

This study focused on the exploration of chromium metal and its use in the industriesthat are selected for its utmost importance.
In this study, glowing X-ray techniques were used to determine the concentration of chromium in the in the Ingessana Hills in the Blue Nile region.And also was the use of a gamma-ray spectroscopy to determine radioactivity of radionuclides found in the Ingessanahills.

A total of 30 rock samples were taken from this area, which were analyzed by XRF. Each sample was (25g) in the form of powder and was placed in the machine and according to the concentration of each element in the sample. The analysis showed that the average concentration of chromium (671550 ppm)), And this value gives about (67%) a very high percentage of chromium components, after the operation of the statistical results and take theaveragevalues.

The concentration of chromium obtained in the Ingessana Hills is a significant proportion of the world markets.

The cost of a kilogram of ferrochrome is about US $ 3.00, while the price of chromium is 1Kg high purity (99.5%) between US $ 30.00 to US $ 50.00[73,74], where the price of chromium has been shown in international markets.
It’s believes that these concentrations can contribute to the economy if exploited and invested correctly.

This is due to the X-ray sensitivity of the fact that heavy elements such as chromium emit high-energy x-ray photons more than photons of visible

light, because the photon energy is proportional to the square of the atomic number of the element.

The Gamma ray spectroscopy is one of the best techniques to study radioactivity of radionuclides, They are short-wavelength and high-frequency rays.

المستخلص

تركزت هذه الدراسة على تنقيب معدن الكروم وإستخدامه في الصناعات المخلتفة وذلكلأهميته القصوى.

في هذه الدراسة أستخدمت تقنية الاشعة السينية المتوهجة لتحديد تركيز الكروم في مناطق النيل الازرق (منطقة جبال الإنقسنا).وأستخدم جهاز اشعة جاما لتحديد النشاط الاشعاعي للنويدات المشعة الموجوده في منطقةجبال الإنقسنا .

أخذت 30 عينة صخرية من هذه المنطقة وطحنت وحولت الى بودرة ,وأستخدم في التحليل جهاز XRF حيث أخذت كل عينة بمقدار 25g في شكل بودرة ووضعت في الجهاز وحسب تركيز كل عنصر في العينة حيث وضح من التحليل ان متوسط تركيز عنصر الكروم (671550جزء من المليون) , وهذه القيمة تعطي حوالي (67 ٪) وهي نسبة عالية جدا من مكونات الكروم , وذلك بعد عمل العملية الإحصائية للنتائج وأخذ متوسط القيم.

نسبة تركيز الكروم المتحصل عليها في منطقة جبال الإنقسنا هي نسبة معتبرة في الأسواق العالمية

إذ تبلغ تكلفة الكيلوجرام الواحد من الفيروكروم حوالي 3.00 دولار أمريكي ، في حين أن سعر الكروم 1Kg عالى النقاء (99.5%) بين 30.00 دولار أمريكي إلى 50.00 دولار , حيث تم عرض أسعار الكروم في الاسواق العالمية .

إنهذه التراكيز يمكن ان تسهم في الإقتصاد لو أستغلت وأستثمرت بصورة صحيحة.

وتعتبر تقنية الاشعة السينية المتوهجة هي افضل تقنية للكشف عن المعادن , ويمكن أن يعزى ذلك لحساسية تقنية الاشعة السينية لحقيقة أن العناصر الثقيلة مثل الكروم تنبعث منها فوتونات الاشعة السينية ذات الطاقة العالية أكثر من فوتونات الضوء المرئي , لأن طاقة الفوتون تتناسب مع مربع العدد الذري للعنصر .

وتعتبر تقنية أشعة جاما من افضل التقنيات لدراسة النشاط الاشعاعي للنويدات المشعة , وهي أشعة ذات طول موجي قصير وتردد عالي .

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CHAPTER ONE

INTRODUCTION

1.1 Chrome Element

Minerals are natural inorganic substances possessing definite chemical compositions and atomic structures. An ore is described generally as an accumulation of mineral in enough quantity as to be capable of economic extraction. The minimum metal content required for a deposit to qualify as an ore varies from metal to metal while the suitability of a deposit for economic mining and processing is controlled by location and size of the deposit, the ore-feed grade, mineralogy, and texture of the ore, mining cost and the cost of ancillary services such as power–supply, water, roads, tailings disposal and amenability of the ore to economically viable treatment and the demand for and value of the metal and its concentrates [1].

Chromium is a member of the first-row transition series of elements, which consists of Sc, Ti, V, Cr, Mn, Fe, Co, Ni, Cu and Zn, and belongs to group 6 of the periodic table, along with Mo and W. The element has an atomic number of 24, an atomic mass of 52, two main oxidation states (+3 and +6) and four naturally occurring isotopes (^{50}Cr, ^{52}Cr, ^{53}Cr and ^{54}Cr), of which ^{52}Cr represents 84% of the total mass.

Chromium is a silver-gray metal that has a beautiful shine when polished. It is commonly seen as reflective “chrome” coatings on items like car bumpers, and the metal is an ingredient in stainless steel.

People also need tiny amounts in their food to help control the amount of sugar in their blood. Like most other metals, chromium combines with other elements to form compounds. Chromium compounds are usually brightly colored.

They give ruby and emerald gemstones their color and are used in paints and dyes. The most common natural form of chromium is a striking orange mineral called chromate.

Chromium atoms there are more than ninety elements in nature. All matter is made the elements – either pure, in mixtures, or a chemical compound, chromium is one of the elements in normal conditions. It is a hard metallic solid.

Pure chromium is a hard silvery metal. It is rarely found in a pure state in nature. Chromium metal has been extracted from ore [2].

In the chemical use group, chromium chemicals, primarily sodium chromate and sodium dichromate, are used to manufacture a wide variety of consumer-oriented chromium chemicals and products that have used in the following areas.

- Paints and pigments.
- Leather tanning liquors.
- Metal plating and finishing solutions.
- Corrosion inhibitors.
- Catalysts.
- drilling muds.
- Wood preservatives.
- Textile mordants and dyes[3].

Chromium pigments are used primarily in paints, inks, and roofing granules. Metal plating solutions, primarily chromic acid, are used in producing decorative automobile trim and appliance exteriors. Chromium leather tanning liquors are the most widely used tanning products, except for the tanning of heavy cattle hides in which vegetable tanning oils are predominant [4].

See Figure (1.1) present the part of Quilters East chromite workings.

Fig (1.1) : Part of Quilters East chromite workings, Cootamundra.

The deposit is highly variable, intensely fractured podiform chromite within poorly to unfoliated dunite of the Coolac Serpentine Belt. Chromite is the sole commercial source of chromium, which is mostly converted to one of several alloys for use in specialty steels.

Ferro-alloys are alloys of iron as the base metal and other leading alloying elements such as Silicon (Si), Manganese (Mn), Tungsten (W), Vanadium (V), and Chromium (Cr). They are mainly used as additives in steel making processes and many other refining processes. Based on the quality of steels desired, the following ferro-alloys are commonly used in the production of iron and steels in melting shops: Ferro-silicon (Fe–Si), Ferro-manganese (Fe-Mn), Ferro-Tungsten (Fe-W), Ferro-chromium (Fe-Cr),Ferro-vanadium (Fe-V). The use of ferro-alloys in steel making is very important because of their effect on the quality of steels in terms of physical and mechanical properties and other alloying effects such as deoxidation capability, desulphurisation and dephosphorisation potentials [5].

1.1.1 Occurrence

Chromite is the only ore of chromium metal. It consists mainly of oxides of chromium and iron (Cr.03 68 %, FeO 32 %). It shows considerable variation in composition and rarely conforms to the theoretical formula. Iron may be replaced by magnesium or aluminum, and ferric oxide may substitute chromium. The varieties containing chromium up to 14.6 % Cr_2O_3 are classified under picotite or chrome spinel (Mg, Fe) O.

(Al, $Cr)_2O_3$ [6]. It does not occur free in nature. Tt is most important ore is chromite $FeCr_2O_4$. It may also occur as lead chromate ($PbCrO_4$). Traces of chromium may occur in minerals like emerald, Jdge, and serpentine[7].It found in certain mafic igneous rocks specially large layered intrusions or accumulates as possibly oxide liquid segregation. Chromite may occur as cores within magnetite grains iron rich rims of chromite, commonly observed in serpentine are known as ferric chromite.

Chromium occurs principally in the silicates of very basic rocks where it substitutes easily for magnesium [8]. Rather high concentration of chromium is found in so called serpentine soils derived from the weathering of ultra-basic rocks. Chromium is usually found in ultra-basic rocks such as peridotite and peroxenite as $FeCr_2O_4$ or as picotite. The chrome spinel may also occur as the chrome ferrous varieties of many rocks commonly forming minerals [9].Chromium is found for the most part with ferro magnesium mineral or separately as chromite. Chrome occurs as frequently in serpentines as the results of decomposition of basic igneous rocks chiefly olivine rock[10].These deposits are considered to be as a result of oxide liquid segregation, while the mass was plained due to after action which took place during the alteration of the fresh rock to be serpentine or even to vaporous actions of the time of the rocks consolidation. From studies of chrome ores of North Carolina, scientests arrived to the same conclusion as others for other regions namely that the ores were actually magmatic segregation.

They favoured the same origin for other chromite deposits in the United States. Kemp after examining chromite deposits, he found that the most of these deposits have originated as magmatic segregation from the enclosing peridotitic rock [11].The chrome content in (Mg,Fe)Cr_2O_4 varies from about 40% to 50% chrome oxide, depending on iron content. Chromite occurs in association with rocks like pyroxenite, serpentinite, dunite, and gabbro. The occurrence of this metal in silicate rocks was also reported [12]. It appears to large extent in the earliest magmatic rocks to be crystallized in the olivine rock and to a lesser extent in the pyroxenites. Most of the chromium present in chrome rich silicate rocks is to be magma deposited in early ferromagnesium minerals. Among the sedimentary iron ores, carbonate rocks contain very little amount of chromium [13].The levels in some basic igneous soils such as serpentine are relatively high [14] .No class of deposits shows more clearly than chromite, the need for a better understanding of the processes which the mineral was employed if prospecting and development are to be carried out with system instead of haphazard dependence on chance which is now common. To be sure, it has long been recognized that chromite invariable lies within rocks were rich in olivine, but no other generalization seems to have gained general acceptance[15].

It widely distributed in soils although the concentrations are generally very low. In mining practice, the chrome ores that consist of chrome spinels are important commercially and serve as unique source of metallic chromium and the products of its chemical compounds [16].

Chromite can be classified on the basis of the Cr/Fe ratio. The highest grade chromites are those having the Cr/Fe ratio of more than 2.0, and containing a minimum of 46% - 48% Cr_2O_3. Chemical and refractory grade chromites typically have Cr/Fe ratios ranging from 1.4 to 2.0. Low-grade chromites are those which have low Cr/Fe ratios and contain relatively small amounts of chromium.

Chromite occurs as a primary mineral of ultra-basic igneous rocks, peridotites, and their modifications, serpentine, talc carbonate, and chlorite. It also occurs in basic gabbros under suitable conditions. Usually the chromite deposits occur as small grains, but by the segregation of these grains, ore-bodies rich in Cr2O3 may be formed.

1.2 Properties of Chromium

The chromium element has physical and chemical properties.

1.2.1 Physical Properties

Chromium is silver-white metal, (m.p. 1920 °C, b.p. 2300 °C). It is hard and malleable. It is fairly good electrical and thermal conductor. Its density is $7.1 g/cm^3$ [17].

1.2.2 Chemical Properties

Chromium does not corrode in air at normal temperature, but form chromic oxide Cr_2O_3 when heated strongly:

$$4Cr_{(s)} + 3O_{2(g)} = 2Cr_2O_3 \tag{1.1}$$

It is unattacked by water under normal conditions, but reacts slightly with steam when red hot to give chromic oxide and hydrogen:

$$2Cr+3H_2O = Cr_2O_3+ 3H_{2(g)} \qquad (1.2)$$

The metal dissolves in dilute mineral acids to give achromous salts and Hydrogen:

$$Cr + 2H^+ = Cr^{2+} + H_{2(g)} \qquad (1.3)$$

However, dilute nitric acid has very little reaction with metallic chromium. Concentrated hydrochloric and sulphuric acids react with the metal more vigorously than the diluted acids. Hot concentrated sulphuric acid attacks the metal to give chromic sulphate. Chromium combines with several other elements [17], e.g. chlorine when hot:

$$2Cr + 3Cl_{2(g)} = 2CrCl_3 \qquad (1.4)$$

The chief oxidation states of chromium are (II), (III), and (VI). A few compounds of Cr^{4+} and Cr^{5+} are known, but they are unstable. Chromium occurs in $Cr(CO)_6$ and $Cr(C_6H_6)$ [18].

1.3 Beneficiating Chromite Ore

Beneficiation operations typically serve to separate and concentrate mineral values from waste materials, remove the impurities or prepare the ore for further refinement. Beneficiation activities do not change the mineral values themselves other than by reducing (crushing and grinding) or enlarging (pelletising and briquetting) particle size to facilitate further processes [19]. Chromite ore is beneficiated for processing using several methods, depending on the ore source and the end use requirements. Coarse clean ore is hand sorted, while the fine clean ore is gravity separated. Lumpy ore mixed with host rock may require heavy medium separation. If chromite minerals occur in fine grains intermixed with host rock, crushing, gravity separation and magnetic separation may be used [20].

Various approaches have been used by different researchers to upgrade chromite ores. Thermal beneficiation was successfully carried out on a low-grade chrome ore from Vagda deposits, Ralnagiri District, Maharashtra India. The method employed was preferential roasting reduction and acid – leaching. The initial chromium – iron ratio of 1.53:1 was increased by this approach to 8:1 with more than 87% chromium recovery.

The preferentially reduced ore from 72 mesh to 170 mesh (B. S. S) was roasted at 12500 C for a period of two and a half hours with subsequent leaching with dilute tetraoxosulphate (VI) acid. The effect of temperature on reduction was investigated within the range 1,1000C to 1,3000C. It was observed that the percentage of ore reduced and dissolved on leaching sharply increased from 22.84% to 80.78% at 1,2000C and with no improvement noticed at higher temperature. (Ives, 1972). Beneficiation of chromite ore using selective chlorination was successfully employed to improve the low-grade ore in South Africa. The Cr:Fe ratio attained, using this approach was 20:1 [21].

1.4 Separation Techniques

Chromium is one of the most important industrial elements nowadays. The chromium metal is used in metallurgical, and chemical, industries, whereas in refractory, chromite, the main mineral of chromium, is a main constituent in the refractory bricks for lining of high temperature furnace. In metallurgy, chromium is used in stainless steels, tool and alloy steels, nickel-chromium heating elements, in metal plating, manufacture of Ferro-chrome alloys, and in the manufacture of grinding media, balls and rods, and mill liners in grinding plants. In chemical industry, it is used in the manufacture of paint pigments and chemical compounds, as an oxidizing [22].

1.4.1 Methods of Separating Cr from Fe

There are some methods for separating Cr from Fe such as:

1.4.1.1 Magnetic Separation Technique

Magnetic separation process exploits the difference in magnetic properties between the ore minerals and is employed to separate valuable mineral from nonmagnetic gangues. All materials are affected in some way when placed in a magnetic field though with most substances, the effect is too slight to be detected. Materials are classified into paramagnetic and diamagnetic depending whether or not the effect of magnetic field on them are strong respectively.

The magnetizing force which induces the lines of force through a material is called the field intensity. The capacity of a magnet to lift a particular mineral is dependent not only on the value of the field intensity, but also on the field gradient, which is the rate at which the field intensity increases towards the magnet surface.

$$F \,\alpha\, H\frac{dH}{dt} \tag{1.5}$$

$$F = \mu_0 H \frac{dH}{dt} \tag{1.6}$$

Where F is the force on the particle, H is the field intensity, and dH/dt is the field gradient

Thus, in order to generate a given lifting force, there are an infinite number of combinations of field and gradient which will give the same effect. Production of a high field gradient as well as high intensity is therefore an important aspect of separator design.

1.4.1.2 Gravity Separation Technique

The main raw materials for chromium metal is chromite. Geologically, chromite deposits are associated, by their nature of formation, with specific gangue minerals such as serpentine, olivine, and chlorite. These associated minerals are of lower densities than chromite. This criterion of density difference between chromite and the associated minerals suggests the use of gravity separation techniques for concentrating the low-grade chromite ores.

This technique is used for upgrading the concentration of the chromite ore, if the chromite of low-grade. The chromite content ranges from 20% to 35% Cr_2O_3. This grade is too low for industrial uses. The froth flotation technique failed to upgrade this type of ore to the marketable grade. Gravity separation was a possible solution for concentrating such ore. In the present work, a laboratory shaking table has been used for upgrading this type of low-grade chromite ore. The use of gravity separation technique shaking table .

One of the effective gravity techniques in this case is tabling. Shaking Table is a highly selective gravity separator. A laboratory shaking table of 50 cm x 90 cm was used for the concentration of the chromite sample. Figure 1 shows a schematic drawing for the used shaking table. The fixed operating parameters were: 300 stroke/min, 11 mm stroke length, 50 g/min dry solids feed rate fed at a solid/liquid ratio of 1:4, 9 dm3/min wash water flow rate. The positions of the products (tailings, middling's, and concentrate) splitters were fixed during the whole investigation. The studied variables were: the tilt angle of the table and the feed size [23], see Fig (1.2).

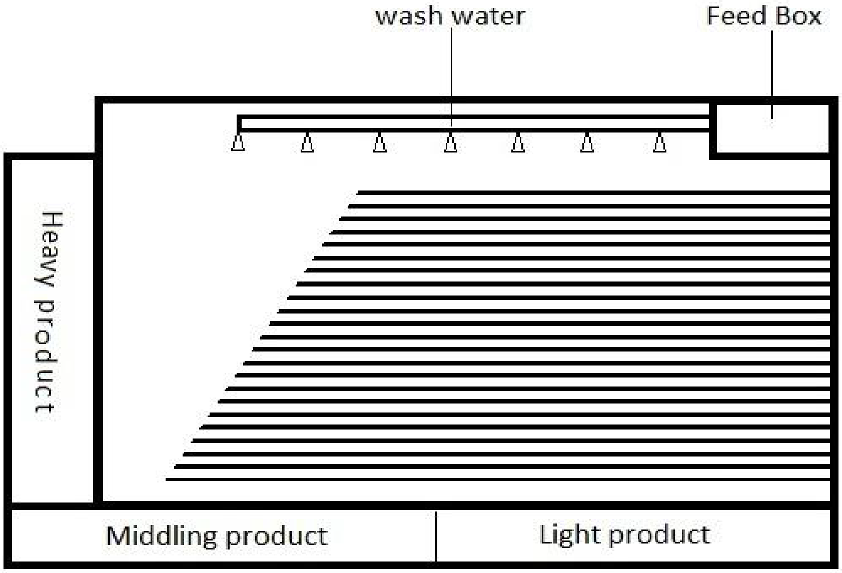


Fig (1.2) : A schematic layout of the shaking table

1.4.1.3 Chemical Separation Technique

Cr is produced in two forms: ferrochrome and Cr metal produced by the reduction of Cr_2O_3.Ferrochrome is produced by the reduction of $FeCr_2O_4$ with coke in an electric arc furnace. Using ferrosilicon instead of coke as the reductant can produce a low-carbon ferrochrome. This is a popular Fe-Cr alloy used directly as an additive to produce stainless and hard Cr-steels.

The reduction of chrome ochre (Cr_2O_3) produces Cr metal. This is obtained by oxidation of $FeCr_2O_4$ (by air) in molten alkali to yield sodium chromate (Na_2CrO_4), which is leached out with water, precipitated, and then reduced to the

Cr(III) oxide using carbon. The oxide can be reduced by aluminum in the aluminothermic process:

$$\mathbf{Cr_2O_3 + 2Al \rightarrow 2Cr + Al_2O_3} \qquad \mathbf{(1.7)}$$

The chrome oxide can also be reduced using silicon:

$$\mathbf{2Cr_2O_3 + 3Si \rightarrow 4Cr + 3SiO_2} \qquad \mathbf{(1.8)}$$

Chrome ochre (Cr_2O_3) can be dissolved in sulfuric acid (H_2SO_4) to yield the Common electrolyte solution used in the production of decorative and protective Cr plating. Sodium chromate (Na_2CrO_4) produced in the isolation of Cr itself the basis for the manufacture of all industrially produced Cr chemicals.

A chemical method of improvement of chromium concentration and Cr/Fe ratio in a low-grade chromite ore is described in a US patent. The process essentially consists of sulphur dioxide – oxygen roasting of the pulverized ore + Na_2SO_4 + (NH_4) CO_3 mixture at elevated temperatures under high pressures. After roasting the ore is leached in aqueous ferric sulphate solution to remove undesirable constituents. The beneficiated ore shows improved Cr concentration and Cr/Fe ratio [24]. Another technique adopted involved the reduction of iron oxide in chromite ore with a gaseous reducing agent at a high temperature followed by magnetic separation of the ferrous material [25]. beneficiation of low-grade chromite indicates that there is scope for upgradation of the chromium content and Cr/Fe ratio in the ore by adopting a combination of gravity concentration and other beneficiation methods. The present investigation was a feasibility study on such multiple stage beneficiations chromite ore.

For production of ferrochromium, a minimum Cr_2O_3 content of 45% and Cr/Fe ratio of 2.8 is necessary. Therefore, for effective utilization of chromite ore it is necessary to develop beneficiation techniques that will meet the above-mentioned chromium and Cr/Fe ratio requirements. Concentration of the chromite ore [26]. for enhancing the degree of concentration.

1.4.1.4 Flotation Techniques Separating

There are two general types of methods for separating chromium ore (chromite) values from associated gangue minerals by froth flotation techniques.

In the first method chromite ore which has been deslimed is subjected to flotation at a pH of 1.5 to 5.5 with a long chain fatty acid collector [27] . The selectivity of the process is enhanced by adding a soluble fluoride compound such as hydrofluoric acid, sodium fluoride or sodium silicofluoride in the flotation medium.

The flotation process is typically conducted by adding 0.5 to 5.0 pounds fatty acid, 0.1 to 10.0 pounds soluble fluoride ion and 1.0 to 11.0 pounds sulfuric acid per ton of ore to the aqueous treatment medium containing the chromite ore. A typical product obtained by such a process, from an ore containing 25.2% Cr_2O_3, is a recleaner concentrate containing 41.0% Cr_2O_3 and 2.5% SiO_2 with a chromium recovery of 77.0%.

In the second technique [28], chromite ore flotation is achieved with an undeslimed ore at a pH of 11.5 using a long chain fatty acid collector. The pH of the pulp is adjusted with NaOH with the pulp being dispersed by sodium silicate using carboxymethylcellulose as a depressant for silicate gangue minerals.

Typically, during processing, three pounds of sodium silicate, 1.0 to 3.0 pounds of tall oil, and 0.25 to 0.50 pounds of carboxymethylcellulose per ton of ore are added to the flotation cell.

From an ore containing 18.13% Cr_2O_3 and 23.98% SiO_2, a flotation concentrate was obtained containing 52.16% Cr_2O_3 and 3.72% SiO_2 with a chromium recovery of 80.0%. Also [29] studies on a Turkish chromite ore containing 30% Cr_2O_3, associated with oxides and sulphides and gangue minerals are chiefly serpentine and olivine. When grounded to-100µm the serpentine dominated the fines, chromite the medium particles and olivine the coarse. Strongly alkaline pulp (more than pH10) was used, with sodium oleate and oleic acid to float the serpentine.

The pulp was then rendered acidic (pH_3) and chromite was floated with 0.75lb/ton of fatty acid-amine collector. Olivine, which only floats in a neutral solution under these conditions, remained in the final tailing, the obtained concentrate grade was 45% Cr_2O_3. Preconditioning with fuel oil permitted flotation of the chromite from the flocculated siliceous-gangue slimes.

Recoveries of up to 91 percent were realized with products containing up to 45 percent Cr_2O_3 [30]. The Cr/Fe ratios ranged from 2.17 to 2.46. Oleic acid was used for flotation. Sodium fluoride and sulphuric acid yielded better results than dilute hydrofluoric acid when these reagents were added to free the 'flocs' from the siliceous gangue.

A process developed for one ore does not usually yield optimum results for another ore of different origin. It is thought that differences in the composition of the gangue materials, as well as in the composition of the chromium spinels, are responsible for these variations in flotation behavior. Fundamental research is required to alleviate this problem. Investigations involving the flotation of a high-grade chromite sample and a high-grade serpentine using sodium oleate as the collector showed [31]. that the chromite can be floated at collector dosages between 0.3 and 1000 mg/l. As shown in table (1.1).

Table (1.1) : Particle size distribution of low chromite ore as feed for flotation tests.

Particle size(mm)	**Weight%**	**Cum.U.size %**
-0.180+ 0.076	41.42	100
-0.076 + 0.038	13.7	58.58
-0.038	44.9	44.9

1.6 Uses of Chromium

Chromium is largely used as alloying elements in steels for production of stainless steels. It is added in form of ferro-chromium, which is presently imported from Russia and Germany to meet the need of Nigerian Steel Industry. Chromite ore ($FeOCr_2O_3$) is the most important mineral occurrence of chromium, and some deposits are reported in Anka Local Government Area of Zamfara State. This work involves the analysis of collected ore samples from Anka in Zamfara State. The samples assaying 36.84% of Cr_2O_3 was subjected to beneficiation process in order to enrich the ore, in terms of the Cr_2O_3, using magnetic separation. The results obtained after the analysis of the beneficiated ore using wet chemical analysis and Atomic Absorption Spectrometer shows that Cr_2O_3 content increased to 48% with a maximum Cr:Fe ratio of 6.2:1. The content of Cr_2O_3 is high enough and can be used for ferro-chromium alloy production.

Most chromium consumption is closely related to the metallurgical industry; spite the fact that the ore is used by the refractory and chemical industry as well. Distribution of chrome ore consumption in the United State, reveals that 56% was used in ferroalloys manufacture, 33% in making of refractors and 11% was used in chemical production [32]. Most of the chrome refractors are used by the metallurgical industry for lining and patching furnaces, and a fair percentage of the chemicals is used for metal treating and plating and the manufacture of chromium metal [32]. A large portion of chromium produced is used in production of steel alloys that are very hard and strong. Stainless Steel, which usually contains chromium and some nickel, is used in the Manufacture of cutlery because of its corrosion resistance. Nonferrous Chromium alloys include nichrome and chrome (Ni and Cr) which are used in Various heating devices because of their electrical resistance property. Chromium is widely used as a protective and decorative coating for other Metals such as plumbing fixtures. Chromium is also used as paint pigments and mordent[33].

potassium chromate and sodium dichromate are used as oxidizing agents[34]. Sulphuric acid solutions of chromium (VI) are powerfully oxidizing agents that are widely used in organic chemistry, and as cleaning solution for laboratory glassware [35]. The cleaning action is largely due to oxidation of grease and organic residues. Potassium dichromate is largely used as an oxidizing agent in the manufacture of other chromium compounds such as chrome alum, lead chromate in dyeing industry, in the preparation of insoluble pigments, and in manufacture of inks. Dichromate solutions in concentrated sulphuric acid are used in degreasing glassware [36] .

Potassium and ammonium chrome alums are a source of chromium sulphate, which can be converted into basic salts by the addition of alkali[37] .The chromium sulphates have penetrating power and poor tanning properties, but on being made basic, it forms basic cationic chromium salts with good tanning properties. The chrome alums are useful for making white" leather :

$$K_2SO_4Cr_2 (SO_4)_3 + H_2O + Na_2CO_3 = Cr_2(Sa_4)_2(OH)_2 + CO_2 + Na_2SO_4 + K_2SO_4 \qquad (1.9)$$

Golbally demand for stainless dropped sharply during the slowdown consequentlythe market for feroochrome which fines 90% of its use in stainless steel manufacturing contracted severely [38].

A wide range of ferroalloys are produced using chrome ore, with the composition of the ore in terms of its Cr_2O_3 content and its Cr:Fe ratio varying depending upon the metallurgical application. The main alloys are high-carbon ferrochromium (HCFeCr) and charge chrome, collectively referred to as high-carbon ferrochromium.

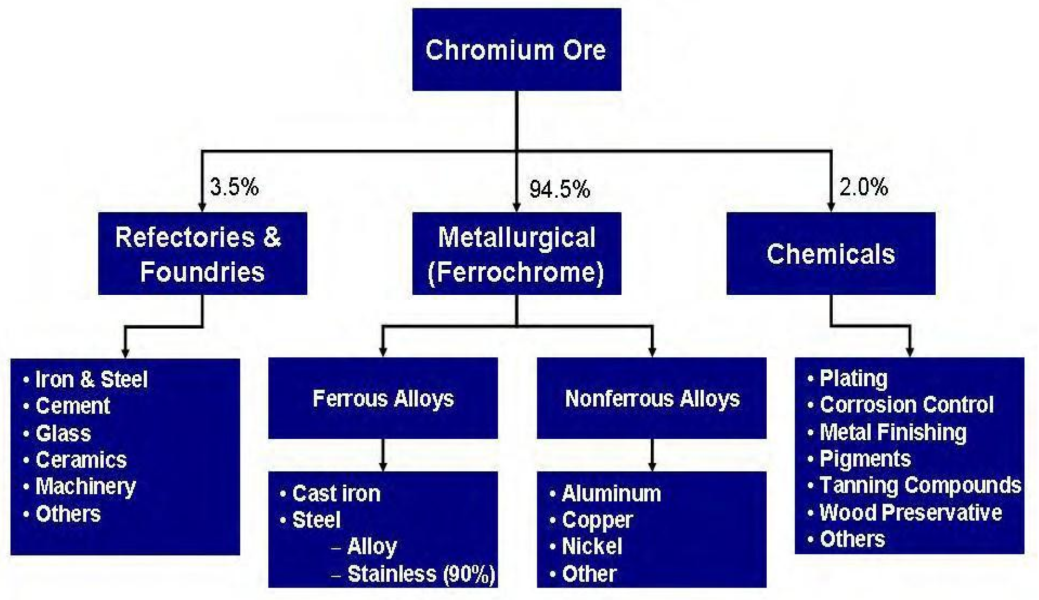


Fig (1.3) : Diagram Chromium Ore - 94.5% is used to produce ferrochrome for the metallurgical industry.

Fig (1.3) presents the total world chrome ore output about 94.5% is used to produce ferrochrome for the metallurgical industry, with 2.0% being used in chemical industry and the balance 3.5% in the refractory and foundry industry.

1.5.1 Chromium In Steel Industry

The only important ore mineral of chromium is the chromite – $FeO.Cr_2O_3$ (68% Cr_2O_3, 32% FeO) which crystallizes in the isometric system. The hardness value is 5.5 on Mohr scale and its specific gravity is In colour, it is iron – black to brownish –black. Pure chromite with composition $FeCr_2O_4$ is rare because magnesium usually substitutes for some ferrous ion and aluminum and ferrous ion substitutes for chromium.

Chromium is produced in the form of ferro-chromium by various methods ranging from reduction in an electric furnace, electrolysis, thermal dissociation, thermal decomposition. Ferro-chromium has been produced by reduction of chromite ores with carbon or silicon in an electric furnace. It can also be produced by a silicon thermic reaction in the presence of suitable oxidizing agents such as calcium chromate $CaCrO_4$, sodium nitrate $NaNO_3$, or manganese dioxide MnO_2 in an exothermic reaction. It can equally be produced by exothermic reduction of chemically produced Cr_2O_3 using powdered aluminum as the reductant. The use of aluminum is associated with explosive hazards and with considerable losses of chromium while molten aluminum in an arc furnace at 14930C reacts vigorously with Cr_2O_3. To avoid this explosion the molten aluminum is best poured at a lower temperature into a melt of Cr_2O_3 and with vigorous stirring, nearly 94% of chromium recovery has been reported. Chromium metal is also produced on a commercial scale by electrolysis of an ammonium chromium alum solution prepared either from chromium ore or from high carbon ferro-chromium. In addition it is produced in more limited quantities by thermal dissociation of chromium iodide in contact with a suitable heated deposition surface under vacuum conditions. This gives the purest chromium presently available [39] .

The stainless steel industry is the largest consumer of ferrochrome and the revival in stainless steel production has been remarkable in Europe, the USA, Japan and South Korea. In addition, China has been increasing its production of stainless steel since 2009 and this whole aspect is multiplying the world consumption of ferrochrome [40].

The split between the main stainless steel grades shows an increase in the volume of 300 series produced. The decline in the production of 400 series has been caused by the global drop in automobile manufacturing which accounts for a large volume of chromium stainless. The market share of 200 series has decreased over the course of 2009 due to the recovery of stainless steel production outside China [41].

As per USGS, if all of the chromium in stainless steel comes from ferrochrome, one ton of ferrochrome would be required to produce 3 to 3.5 tons of stainless steel. However, since some chromium comes from recycled stainless steel scrap, the actual requirement of ferrochrome is little less.

Stainless steel is basically a low carbon steel which contains a minimum of 10.5% of chromium. The unique stainless, corrosion resisting properties is because of the addition of chromium. The corrosion resistance and other useful properties of steel are enhanced by increased chromium content and by the addition of other elements such as molybdenum, nickel and nitrogen. Stainless steel is mainly categorized into three series, depending on the type and amount of alloying material.

The chromium industry comprises of chrome ore, chromium chemicals and metal, ferrochrome, stainless steel, and chromite refractory producers. The industry structure has been showing changing trend in the past years.

Chromite ore mines tend to be owned and operated by chromite refractory, chromium chemical, or ferrochrome producers as:

- Chromium chemical industry has eliminated excess production capacity, concentrating on production growth in surviving plants.
- Chromite refractory use has been declining; however, foundry use has been increasing slowly.
- Environmental concerns have reduced the use of chromite refractories and chromium chemicals.

- The proportion of chromite ore from independent producers is declining, while that from vertically integrated producers is increasing.

This trend is associated with the migration of ferrochrome production capacity from stainless-steel-producing countries to chromite ore-producing countries, a trend that has been interrupted with the emergence of China as a significant ferrochrome and leading stainless steel producer.

1.6 Supply, Markets and Price

Chromium is the 21st most abundant material in the earth’s crust and geologists estimate that there are about 12 billion tons of chromite in the world that could be mined. “This is enough chromium ore to meet world demand for hundreds of years into the future” [42] .In addition, scrap metal that contains chromium can be recycled as an alternative, more environmentally responsible source. About 45% of the mined chromite ores in the world are produced in South Africa [43]. Kazakhstan, India, Russia and Turkey are also substantial producers, and Finland, Iran and Brazil produce smaller amounts. The world’s largest producer of ferrochrome is Xstrata in South Africa (45%) with seven operating chromite mines and six others that are not operating [44] .Other top chromite producing companies are (in alphabetical order) Anglo Platinum Ltd, Aquarius Platinum Ltd, Merafe Resources Ltd and Outokompu OYJ [45] Fourteen percent of all chromite is consumed in the USA, but there is almost no domestic production .The Stillwater Mine produces chromite but does not market it, and a small new mine in Oregon is about to go into production.

The price of chromite is determined, not by metal exchanges like the London Metals Exchange, but by negotiation between individual buyers and sellers [46]. It is confusing (to say the least) to sort out the price of raw chromite from processed ferrochromium and processed chromium. In 2007, in the midst of the huge steel and metals commodity boom, a USGS presentation to the Metal Powder Industries Federation in Denver on the price of chromium and other metals [47] said the following:

The chromium industry’s production capacity expansion to meet sustained stainless-Steel demand was delayed by antiapartheid policies and dissolution of the Soviet Union, an event that reduced demand, and put chromium-containing materials on the market [recycled stainless-steel scrap] until 1994 as stocks in the former Soviet Union were sold off. It took until 1995 for world demand to catch up with installed capacity as indicated by the price increase in that year. ...In 2003, the price of chromium rose 40% following two consecutive years of strengthening of the South African rand, which rose 24% against the U.S. dollar in 2003 alone. ...The rising cost of ferrochromium production and a strengthening South African rand, along with increased demand for ferrochromium and limited supply of stainless-steel scrap, caused the price of ferrochromium to reach historically high levels in 2004. See Fig (1.4) Ferrochrome Prices During the period 2013- 2017.

Fig (1.4) : Ferrochrome Prices During the period 2013- 2017

Chromium market is highly consolidated and is represented by a few miners and producers in South Africa and Kazakhstan. This makes it possible to cut down supply whenever there is a reduction in stainless steel production to curb the downfall in prices. The chrome ore and ferrochrome industry are struggling hard to meet the demand emanating from the stainless-steel producers particularly from China.

Considering the various triggers and concerns, it seems that shortage of chrome ore and ferrochrome may last for many years; probably till 2013 and the industry will be subject to wild price fluctuations. Overcoming the concerns will bring new dimensions and way forth for the chrome ore and ferrochrome producers and will also keep a balance in the demand supply situation.

Ferrochrome companies who have already integrated backwards into chrome ore mines and power plants have an edge to “Outperform” for a long period keeping the existing scenario in view.

1.7 Research Problem

The problem is related to the fact that the element of chromium in the Blue Nile region (in Ingassana Hills) has high rates that can be utilized, which contribute to the economy of Sudan.

In this study, we address through the analyze sample of chromium, using x-ray fluorescence (XRF) technique, and were used Gamma rays to determine the radionuclides found in rock samples and radioactivity of radionuclides.

1.8 Aim of the Work

The objective of study is divided into two main sections:

1. Upon completion of previous studies, a laboratory study will be conducted on the Sudanese chrome ore. Using an XRF device, the crystal structure of the ore and its components, especially C_2O_3, is studied in X-ray crystallography and the chromium separation methods are identified.

2. Study of radionuclides found in rock samples using gamma rays .

3. The second part of the study is a proposal for the development of a project for the mining of chromite and crude processing in Sudan, including:

a. Explore and methods of choosing the area

B. Resource assessment.

1.9 Methodology

1. Prepare 30 samples of rock, from the Ingessana hills in the Blue Nile region.
2. These samples were grinded into powder and each sample was 25 grams.
3. Use XRF to measure the concentration of heavy metals in samples.
4. Use of gamma rays to measure radioactivity of radionuclides.
5. T-Test program to compare between results concentration of heavy metals measured by EDXRF technique.
6. Use correlation analysis to estimated heavy metals levels in some rock.

1.10 Layout of The Research

The thesis consists of five chapters. Chapter one is the introduction, chapter two is Theoretical Background, chapter three Literature review, chapter four material and method, chapter five is results and discussions.

CHAPTER TWO

THEORETICAL BACKGROUND

2.1 Introduction

Many useful techniques can be used to detect metals, Electronic techniques are based on the discovery of heavy metals found in the soil. These techniques include spectral techniques such as radiographic x-ray techniques.

Energy Dispersive X-ray Fluorescence (EDXRF) is an analytical method for qualitative as well as quantitative determination of elements in a sample, independent of their chemical form. It is built on the fact that elements that are irradiated with high-energy X-rays have a certain probability of emitting characteristic X-rays. The energy, E, of this radiation is uniquely dependent on the element, which emits the characteristic X-rays by Moseley's law, $E = K (Z - s)$[48] ,where K and s are constants that vary with the spectral series and Z is the atomic number of the element. In ED systems, the emitted X-rays are detected by their energies, where as in wavelength-dispersive X-ray fluorescence (WDXRF) systems, the physical equivalent to energy, the wavelength of the characteristic photon is measured. This statement can be explained by the simple relation

$$E = h\nu\ ,\ \lambda . \nu = c > E = hc/\lambda > E(keV)$$

$$= 1.2396/\lambda\ (nm) \qquad (2.1)$$

from which it is seen that the wavelength and energy of the X-rays are reciprocal to each other. WDXRF utilizes the properties of single crystals to diffract X-rays of a specific wavelength under a specific angle (Braggs law) and the intensity of the diffracted radiation is counted by a simple radiation counter e.g. Geiger–

Muller counter. As characteristic radiation for one element has a fixed well-defined value λ only at specific angles, a high intensity of the refracted radiation is measured. So using a goniometer with the Bragg crystal as the dispersive element in its center and a detector at the circumference, a continuous rotation will result in intensive peaks whenever the condition of Braggs law

$$2d \sin \theta = n \lambda \tag{2.2}$$

is fulfilled. Theta θ is the refraction angle, λ is the characteristic wavelength, and d is the distance between lattice planes of the single crystal. By continuous rotation of the detector from 0 to 180°, angle 2θ, while the crystal is in position θ, collects the photons reflected. This sequential measurement leads to a spectrum ‘‘intensity versus wavelength’’ allowing determination of elements and concentration in the sample because the intensity is proportional to the concentration of the respective element.

In the case of EDXRF, the detector crystal, made of lithium-drifted silicon Si(Li) or hyper pure Ge, takes on two tasks together, namely, dispersion according to the energy and counting of the photons of individual energy.

This collection process results in a spectrum ‘‘intensity versus energy’’ of the characteristic radiation emitted from the sample. More details about energy-dispersive detectors are presented later. Typical applications for EDXRF are analyses of agricultural material, medical samples, archaeological and historical objects, and environmental samples such as soil, water, and aerosol particles. EDXRF working is simultaneous, multielement, and nondestructive, and can be applied to small samples (about 0.1mg). For scanning objects and mapping small areas in a specimen, EDXRF instruments with narrow beams of X-rays can be used.

WDXRF is widely used for routine analysis and severalhundred thousand instruments are distributed in steel production, cement industry, geologic sample analysis, worldwide. In scientific research, the high resolution is appreciated allowing precision measurements in cases where the line overlaps represent a problem in EDXRF.

Owing to the heavy weight of the components, there are no portable WD spectrometers available. The use of the EDXRF technique has accelerated
since the 1960s as a result of the development of solid-state detectors, nuclear electronics, and small computers. Today about 14 000 EDXRF spectrometers are in use, many of which belong to research laboratories. This number is rapidly growing because handheld portable spectrometers combining new detector technologies for charge collection and cooling are available. The composition of fine art objects, scrap metals, wall painting,
or environmental samples can be analyzed on the spot, within seconds [48,49]. A vast number of scientific publications exist about EDXRF and its applications. Authoritative textbooks on the principles and instrumentation for EDXRF[50,51].

2.2 Physical Principles

The physical properties of x-ray are:

2.2.1 Interactions of X-rays with Matter

When a beam of X-rays (originating e.g. from X-ray tubes) impinges on a sample, it will interact with the atoms in the sample by three processes, namely, the photoelectric effect and coherent (Rayleigh) and incoherent (Compton) scattering. For the photoelectric effect to occur, the energy of the impinging photons has to be large enough to create a vacancy in one of the shells of the studied elements. The photoelectric effect may result in emission of characteristic X-rays, but once a vacancy has been created in an inner shell the atom can also de-excite by emission of Auger electrons. The probability that characteristic X-rays will be emitted – and not an Auger electron – varies from one element to another and is described as the fluorescence yield. For elements of low atomic number, emission of Auger electrons dominate, whereas emission of characteristic X-rays is more likely for elements of high atomic number. A sketch of the XRF process leading to emission of a characteristic X-ray is shown in Figure (2.1). Based on Moseley's law, the wavelength or energy of the emitted radiation is characteristic for the element and thus the element can be identified. The scattering processes are of two types, incoherent and coherent. The probabilities of both kinds of scattering vary with photon energy and the composition of the sample. The scattered X-rays are an important part of the background radiation on which the characteristic peaks are superimposed. Figure (2.1) shows a typical X-ray spectrum with characteristic and scattered radiation.

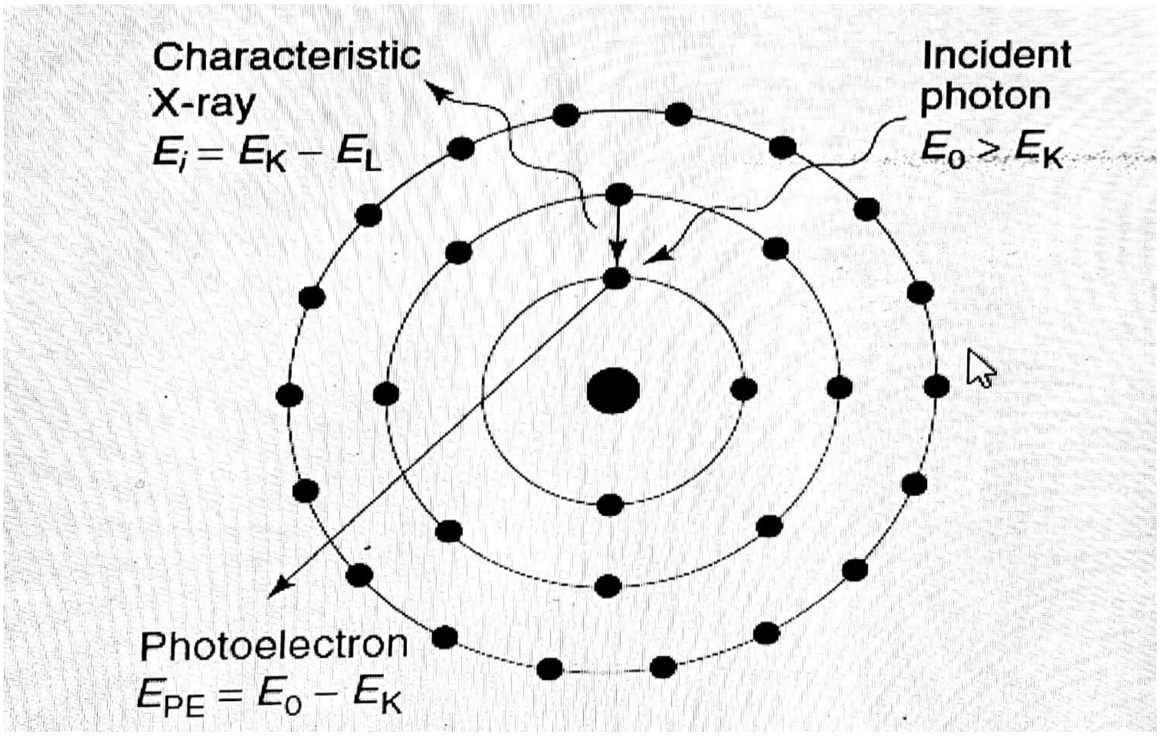


Fig (2. 1): Schematic drawing of the XRF process in an atom. An incident photon of energy E0 transfers its energy to an electron in the K-shell.

The electron is expelled from the atom and leaves a vacancy. An electron from the L-shell can transit to the K-shell to fill the vacant site. The difference in binding energy between the two shells, $E_K - E_L$, is used by the atom to emit a characteristic X-ray of energy E. Note that the distances between the atomic shells are not drawn to scale but shown schematically only.

2.2.2 Principles in Quantitative Evaluation of Element Concentration

The quantitative evaluation of element concentrations in EDXRF depends on whether the source is monochromatic or contains a range of different energies. Polychromatic X-ray sources can, however, be treated as a sum (or an integral) of monochromatic sources, and the discussion below is therefore limited to the case of monochromatic excitation. For this case, with further limitations to homogeneous samples and in the absence of interelement effects, a simple relationship can be obtained between the mass thickness (or areal density), mi, of a specific element and the measured intensity Ii of its characteristic X-ray peak:

$$I_i = I_o K_i m_i D_i \qquad (2.3)$$

where I_0 is the intensity of the primary beam of energy E_0, which, in the case that the source is a secondary-target Xray tube arrangement, is influenced by the anode material and operating voltage and current; I_i is the intensity of characteristic X-rays (K- or L-radiation) of element (i) of energy E_i .;D_i is a correction factor for attenuation of both the incident X-rays and the characteristic Xrays of element (i) in the sample; and K_i is a factor that depends on the setup of the instrument and basic physical processes. K_i thus depends on instrumental factors and on fundamental physical parameters related to the energies of the incident and characteristic X-rays. The important parameters to be considered are

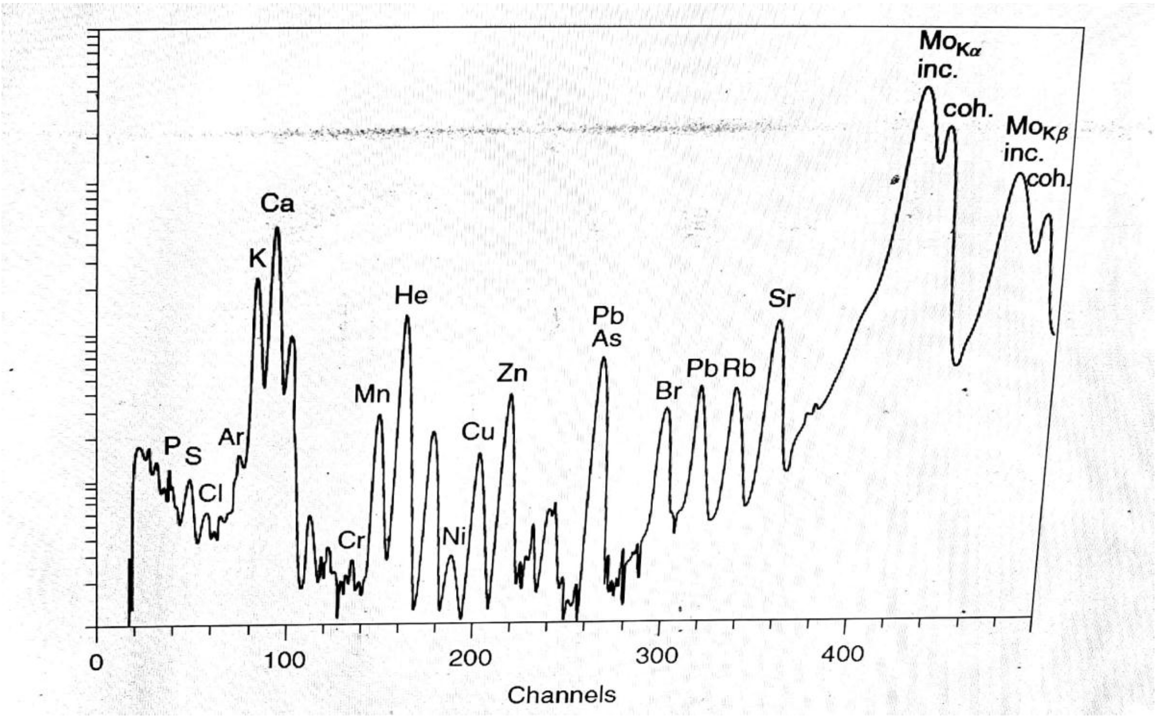


Fig (2.2) : X-ray spectrum of a biological standard reference material, SRM1571 (National Institute of Standards and Technology (NIST)), ‘‘orchard leaves’’, measured in a secondary-target EDXRF spectrometer of the geometry.

The sample thickness is 30mg cm−2. The excitation conditions were as follows: tube voltage 55 kV and current 10 mA. The characteristic K α lines are denoted by chemical symbols, except for Pb, for which both L α and L β are marked. Note the high intensities of the coherently and incoherently scattered K α and K β radiation of the secondary target, which, in this spectrum, is Mo. The X-ray spectrum has been recorded with an Si(Li) detector.

- the geometry of the XRF spectrometer.

- the attenuation of the exciting and characteristic radiation along the beam paths and in the detector window.
- the detector efficiency for radiation of energy E_i .
- the probability of producing a vacancy with incident radiation of energy E_0 in the relevant shell of element (i).
- the fluorescence yield of element (i).

Note, however, that the essential feature of Equation (2.3) is that – under the assumptions of homogeneity and absence of interelement effects in the sample – the factor K_i is independent of the mass thickness, mi, of the analyzed element and of the attenuation correction, $D_i.K_i$ can be determined through calibration of the instrument with suitable calibration standards under well-defined conditions. The amount of analyte is often written as :

$$m_i = W_{im} \tag{2.4}$$

where W_i is the weight fraction mi is the mass thickness of element ''i'' in the sample, and m is the sample mass. The attenuation correction, D_i , in Equation (3) has the form given in Equation (5):

$$D_i = \frac{1 - \exp-[(\mu\,(E0)\csc\phi1 + \mu\,(Ei)\csc\phi2)\ \cdot\ m]}{[\mu\,(E0)\csc\phi1 + \mu\,(Ei)\csc\phi2]\ \cdot\ m} \tag{2.5}$$

In this expression, $\mu\,(E_0)$ and $\mu\,(E_i)$ are the mass attenuation coefficients for the exciting and characteristic radiation of energies E0 and Ei , respectively; they can be expressed as weighted sums of the individual mass attenuation coefficients for all elements in the sample. ϕ1 is the glancing angle between the exciting radiation and the sample surface plane and ϕ2 the glancing angle between the characteristic radiation and the sample surface plane. For two special cases, the attenuation correction and thus Equation (2.3) simplifies tremendously, namely, for ''thin'' and ‘‘infinitely thick’’ samples. In some cases, it is also necessary to take into account the fact that the characteristic radiation produced by an element as well as the scattered radiation can cause fluorescence of another element (interelement and related effects, as discussed below). This effect leads to the enhancement of one spectral line, the absorption already having been taken into consideration. Furthermore, to perform quantitative evaluation, one needs to know whether impurities are present in the spectrometer material and the properties of the detector. Equations (1.3) , (2.3) and equation (2.4) require the net peak areas of the characteristic peaks in the X-ray spectrum to determine element concentrations in a sample. This can be done automatically by means of computer programs. In evaluation of net peak areas in a spectrum, the problem of interference between spectral lines will, however, have to be addressed. In a number of cases, the K-lines from one element will overlap or coincide with the L-lines of another element, as is illustrated in Figure (2.2) by the overlap of As K α with Pb L α. In other cases, the K α from one element will coincide with the K β from another. By knowing relative ratios, K α/K β, L α/L β, it is possible to resolve the overlapping peaks. This problem is not so severe in WDXRF as the crystal resolution is in the range of a few electron volts at 5.9 keV, whereas the energy resolution of an ED detector is, for this energy value, at its best around 130 eV at 5.9 keV. However, this procedure of spectrum deconvolution will reduce the precision of the measurement to an extent determined by the statistics of the measurement.

2.3 Energy -Dispersive X-ray Fluorescenceins Truentation

A typical feature in element analysis in practice is that samples may contain major as well as trace concentrations different elements. Samples such as alloys, mineral ores, and ceramics usually contain a number of elements, the concentrations of which may vary by several orders of magnitude. In an EDXRF spectrometer, the important parts to consider are the X-ray source, the beam and spectrometer geometry, and the detector. An obvious goal for the designer of XRF spectrometers is to maximize the intensity of the characteristic X-rays from the elements while keeping the background radiation as lowas possible. Most ED spectrometers have an elemental range from Na to U and, if special detectors with ultrathin windows, polymers of 300nm supported by a Si grid are used, the range can be extended to still lighter elements such as Be, B, and C[52]. There are many different designs of ED spectrometers for laboratory and field work[53].

Combinations of WDXRF and EDXRF systems are also used, in which the better resolution of WD instruments is utilized for the lightest elements and the simplicity and higher sensitivity of ED systems is utilized for elements above Ca. The cost of an ED system is about US$ 70, 000 and upward.

2.3.1 X-ray Sources

In photon-induced XRF, the most common sources are X-ray tubes, which can be used directly for broadband excitation or in combination with filters or secondary fluoresces to obtain semi monochromatic radiation. In some spectrometers, especially portable instruments for field work, and for problems in which only one or a few elements are of interest (for example, in routine process control), radioisotopes are still useful.

2.3.1.1 X-ray Tubes

In X-ray tubes, the radiation spectrum is influenced by two major processes that occur when electrons are accelerated by the high voltage from the cathode to the anode. One process is the creation of characteristic X-rays in the anode material itself, which occurs when the kinetic energy of the impinging electron is larger than the binding energy of a particular shell in the anode material. The other process is the creation of continuous bremsstrahlung, which is created when the electrons are slowed down in the anode. The bremsstrahlung spectrum contains energies from zero up to the kinetic energy of the electrons, which is equal to the electron charge times the tube voltage. Accordingly, the spectrum from the X-ray tube contains a continuous distribution overlaid with the characteristic radiation from the anode material about 100 times higher in intensity compared to bremsstrahlung in that energy range. By varying parameters such as anode Material and thickness, tube voltage, and current settings, the broadband spectrum from the X-ray tube can be optimized for the elements of interest. Some special X ray tubes are equipped with dual (W/Sc or W/Mo alloy) or multiple an ode mechanically exchangeable in the high vacuum of the tube. Furthermore, the spot size of the electron focus on the anode material is an important factor defining the emitted brightness. The applicable electric power depends on the size as the heat dissipation is the limiting factor. X-ray tubes with standing anodes have, for Mo and W, typically 3 kW(60 kV and 50mA) if a focus of about 0.4 × $12mm^2$ is used. Broad focus tubes with 7 × $7mm^2$ can dissipate up to 40–50 kW. Rotating anodes where the anode is formed like a wheel and rotated at 10 000 rpm allows up to 18 kW for a 0.5 × $10mm^2$ electronic focus. Low-power X-ray tubes of 50–75W (50 kV and 1–1.5mA) with a focal size of 100 μm × 100 μm emit a high flux of photons and can be ideally combined with X-ray optical elements to focus the beam to micrometer dimensions with a flux of 1 × 1010 photons/s and are perfect for microanalysis in the lab. These X-ray tubes are air cooled and of light weight, ideally suited for the design of hand carried portable spectrometers [54] .As the MDL for a given element is dependent on the intensity of the characteristic as well as the background radiation, there is often a desire to use monochromatic or quasi-monochromatic radiation. This can be achieved by use of filters and/or secondary-target Arrangements. Filters inserted between the X-ray tube and the sample will allow transmission of the characteristic line of the filter but will attenuate the low-energy part of the tube radiation by a substantial factor. Thus, filtering may change the shape of the tube spectrum and improve MDLs for elements lighter than the filter material. By varying filter material and filter thickness, this method can give a high flexibility in the use of tube excitation.

In secondary-target arrangements, the radiation from the X-ray tube is allowed to excite a target made of a material whose characteristic radiation (only the intensive K α and K β lines are emitted) is used as a source to excite the sample. Figure (2.3) shows an arrangement of this kind, often called triaxial geometry due to the three orthogonal

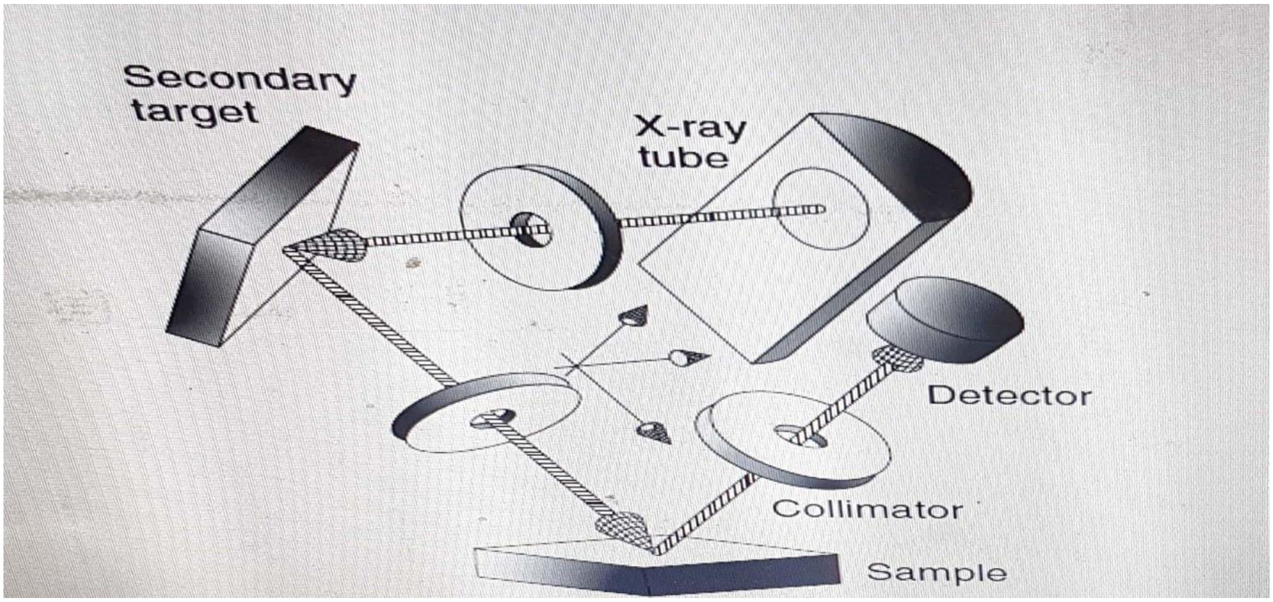


Fig (2.3) : Preferred geometry of a secondary-target EDXRF spectrometer.

The broadband radiation from an X-ray tube excites a secondary target of a pure specimen, most often a metal. The characteristic K α and β radiation from the secondary target is used as semimono chromatic X-ray source to excite the different elements in the sample. A detector registers the radiation from the sample. Note that the three X-ray beams are mutually orthogonal and that the sample plane is horizontal.

directions of primary beam path, secondary-target beam path, and path from sample to detector. The material in the secondary target can be chosen so that its characteristic radiation is just above the K-edge of the elements of most interest in the sample. The anode material in the X-ray tube is generally chosen to have a high output over a wide range of energies in order to allow different secondary-target materials to be used. Most ideal are combinations where the characteristic radiation from the anode is with its energy just above the absorption edge of the target material e.g. Rh anode–Mo secondary target. Also the tube radiation is linearly polarized after 90° scattering on the secondary target in this orthogonal geometry (all axes have an angle of 90° to each other), thus not contributing to spectral background in the triaxial geometry of Figure(2.3). Although the intensity of the primary beam is reduced considerably by the secondary-target arrangement, the technique usually gives low detection limits for many elements. This is mainly because of the low background in the x-ray spectra. Other techniques to modify the output from an X-ray tube utilize low-Z elements (carbon or Plexiglas) scatterers to polarize the entire spectrum of X-rays from the tube or multilayers to obtain an intensive purely monochromatic beam, as demonstrated for TXRF spectrometers [55]. For microbeam EDXRF, microfocus low-power X-ray tubes with anode spots of the order of 100 μ m2 are now available, as are high-intensity rotating anode sources (18 kW) with various focal spot sizes [51].

Radioisotopes as X-ray sources utilize the γ -rays from the decay of the radioisotope or the characteristic X-rays emitted from the decay product. The output intensity is lower than that which can be achieved by an X-ray tube, but the advantages are that the intensity of the source is stable and no electric power supply is needed. Radioisotopes are therefore practicable in portable field instruments. The drawback is the limited half-lives for some of the most commonly used isotopes (for example 2.7 years for 55Fe with 5.9- and 6.4-keV X-rays (Mn Kα and Kβ lines) and 1.3 years for 109Cd with 22.2- and 25.5-keV X-rays (Ag Kα and Kβ lines) plus 88.2 keV γ -rays). Also, 241Am with 59.5 keV γ -rays is useful for higher-Z element excitation and this isotope has a halflife of 433 years which is convenient. The most common geometries of the radioisotope sources are either that of a point source or that of an annular source. The sensitivity and MDLs are, for some instruments, almost identical to those for X-ray tube secondary-target arrangements [56].

2.4 Sample Handling And Quantification In Practice

A typical feature in element analysis in practice is that samples may contain high as well as trace concentrations of different elements. Samples such as alloys, mineral ores, and ceramics usually contain several elements whose concentrations may vary by several orders of magnitude.

EDXRF analysis can be performed on a vast number of samples of very different composition and status. Examples of common samples are:

- geological – for example minerals, rock, soil, and sediments.
- biological – roots, leaves, stems, moss, lichens, algae, fish, and animals.

- medical – blood, hair, skin, muscle, brain, teeth, bone, enzymes, and metalloproteins.
- industrial – metals, ores, paper, and pulp.
- cultural – pottery, paintings, statues, coins, books, and clothes.
- environmental – water, air pollutants, waste, and pollen.
- pharmaceuticals.
- food stuff and drinking water, wine, or brandy.

There is no strict division between the different categories, but the above list gives an idea of the diversity of the samples concerning range of elemental concentrations – from traces in biological material to major components in minerals – as well as the range of densities involved. The material may exist in different forms, such as airborne particles, liquids, and solids

2.5 Gamma decay

In 1900 Villard (Mann et. al., 1980) had found a type of radiation with more highly penetrating property emitted by radium, this radiation was given the name gamma-ray.

Most alpha and beta decays, and most nuclear reactions as well, produce nucleus in an excited state. These excited states decay rapidly to a lower excited state or to the ground state through the emission of one or more gamma-rays, which are photons of electromagnetic radiation of energy equal to the difference in energy between the nuclear states. Gamma rays were observed in all nuclei that have excited bound states (A>5), and usually follow alpha and beta decay since those decays will often lead to excited states in the daughter nucleus. Gamma-rays have energies typically in the range of 0.1 to 10 MeV, and thus corresponding wave length between 10-19 and 10-13 meters (Krane, 1988).

Gamma-rays interact with matter by imparting energy to atoms and there by raising electrons to higher energy levels within the atom (excitation) or removing the electron entirely from the atom (ionization). Eventually all of the energy given in ionizing events is dissipated in atomic or molecular excitation. In addition, γ-radiation will lose energy by the creation of electron-positron pairs. Method of γ-interaction depends upon the photon energy.

2.6 Natural Gamma Radiation

The most common source of ionizing radiation received by humans is the natural environmental radiation. Background radiation levels are usually from a combination of terrestrial and cosmic radiations. All common rock types and the soils derived from them contain natural radioactive elements. Presence of these radio elements is apparent in any γ-ray survey.

2.6.1 Cosmic Radiation

High energy primary cosmic rays interact with matter in the upper atmosphere, and produce protons, helium nuclei, electrons, photons and neutrinos. These particles interact with atmospheric air and produce: ^{3}H, ^{7}Be, ^{10}Be, ^{22}Na,^{24}Na and^{14}C. The dose from cosmic radiation varies in different parts of the world due to differences in elevation and to the effects of the earth's magnetic field .

2.6.2 Terrestrial Radiation

The terrestrial component of the natural background is dependent on the composition of the soils and rocks, containing natural radionuclide . Gamma radiation emitted from naturally occurring radioisotopes, also called terrestrial background radiation, represents the main external source of irradiation of the human body. Natural environmental radioactivity and associated external exposure due to gamma radiation depend primarily on the geological and geographical conditions, and appear at different levels in the soils of each region in the world. A significant part of the total dose contribution in the form of natural sources comes from terrestrial gamma radionuclides. Only nuclides with half-lives comparable with the age of the earth or their corresponding decay products, existing in terrestrial materials, such as 40K, 238U, and 232Th are of great interest. These radionuclides are mainly responsible for internal exposure, through ingestion of food and water, and through inhalation of air particulates-of special concern are the long-lived alpha emitters of the uranium decay chain . The knowledge of radionuclide distribution and radiation levels in the environment is important for assessing the effects of radiation exposure due to both terrestrial and cosmogenic present in varying amounts in soils, building materials, water, rocks, and atmosphere. The most common terrestrial radioelements, which produce γ-radiation, are potassium (^{40}K), uranium (^{238}U) and thorium (^{232}Th). Whereas potassium undergoes a simple form of radioactive decay, the decay of uranium and thorium is complex, and proceed sequentially along series of disintegrations.

CHAPTER THREE

LITERATURE REVIEW

3.1 Introduction

About 80 percent of the chromium consumed worldwide is used in stainless and specialty steels to increase resistance to oxidation and corrosion. There is no substitute for chromium in these steel products. World resources of chromite (chromium, iron and oxygen; the ore mineral of chromium) are sufficient to meet world demand for centuries to come. Currently, chromite is produced from a limited number of sources in Kazakhstan, South Africa, Zimbabwe, India, Turkey, Philippines, and Albania. A significant portion of world chromium resources (~95percent) is concentrated in southern Africa in the Bushveld Complex of South Africa and the Great Dyke of Zimbabwe [57] .See(3.1) Fig for production chrome in world from 1990 to 2009 .

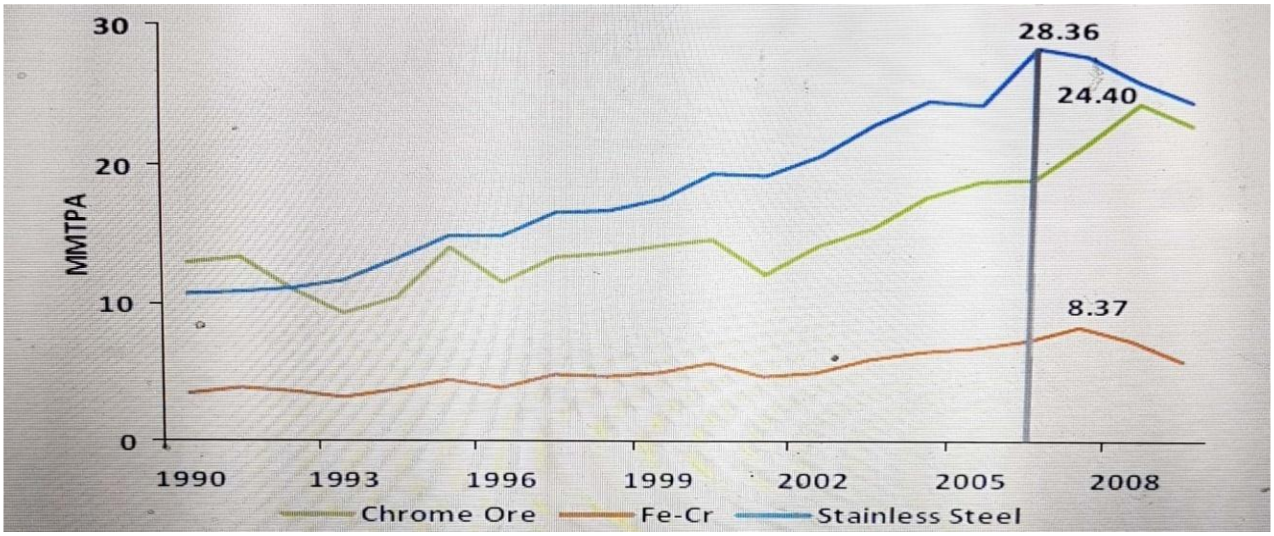


Fig (3.1): World Production (1990 – 2009)

” Globally, the demand for steel, iron, chrome ore has Improved party due to recovery in industrial activities in US, EU, Japan, India, Russia and Brazil.”

Chromium metal is produced on a commercial scale by electrolysis of an ammonium chromium alum solution prepared either from chromium ore or from high carbon ferro-chromium. In addition, it is produced in more limited quantities by thermal dissociation of chromium iodide in contact with a suitable heated deposition surface under vacuum conditions. This gives the purest chromium presently available [58].

3.2 Chrome Production in the World

In South Africa and Zimbabwe hold about 90% of the world's chromite reserves and resources, with South Africa having reserves of about 3.1 billion tonnes and a further estimated resource of 5.5 billion tonnes.

In Zimbabwe has reserves of about 140 million tonnes with resources of a further 1 billion tonnes. It is the only country to exploit both stratiform and podiform deposits. The stratiform deposits occur in the Great Dyke, approx. 550 km long and 11 km wide, while the podiform deposits occur in the Selukwe and Belingwe areas.

In Kazakhstan has podiform deposits in the southern Ural Mountain region with reserves of 320 million tonnes and a further 320 million tonnes resource. The ores vary greatly in chromium content and in Cr: Fe ratios.

In India's output is from podiform bodies on the east coast of the state of Orissa. Its reserves are put at 27 million tonnes with a further resource of 67 million tonnes.

In Finland has podiform deposits near Kemi in northern Finland. Although the Cr_2O_3 content is very low, the ore has been successfully mined, concentrated and smelted to ferrochromium, and then converted to stainless steel on site. Reserves are given as 41million tonnes and resources as 120 million tonnes.

In Brazil, production is concentrated in Bahia and Minas Gerais, although chromite deposits have been identified in other states. These are mainly stratiform deposits with reserves of 14 million tonnes and resources of 17 million tones.

In China’s chromium resources are contained in podiform and stratiform deposits but are largely unknown in terms of possible reserves and resources. There is a chromite mine in Tibet. Russia also has mines in the Ural Mountains with further developments above the 5 Arctic Circle [59].

Table (3.1) : below the imports of chrome ore increased from 2.82MMTPA in 2005 to 6.76 MMTPA in 2009.

	China's Imports of Chrome ore				
Country	**2005**	**2006**	**2007**	**2008**	**2009**
			MMTPA		
India	0.98	1.34	0.98	0.55	0.41
South Africa	0.33	0.87	1.96	2.60	2.90
Turkey	0.62	0.74	1.08	1.18	1.29
Australia	0.20	0.22	0.22	0.07	0.14
Kazakhstan	0.07	0.11	0.20	0.20	0.17
Oman	0.05	0.07	0.34	0.81	0.69
Pakistan	0.15	0.20	0.30	0.38	0.30
Others	0.42	0.52	0.79	1.05	0.86
Total	**2.82**	**4.07**	**5.87**	**6.85**	**6.76**

India was a major exporter to China in 2005 and 2006, but because of the increase in the export tax on chrome ore by the government this demand of China was drawn out of the country. During 2007 to 2009, South Africa and Turkey have been increasingly catering to the chrome ore demand of China, with South Africa supplying almost 42.89% of the total imports of chrome ore by China in 2009.

- In Nigeria, the demand for ferro-alloy is expected to be on increase annually following the country's emphasis on accelerated industrialization hinged on fast growth in iron and steel industries. At the peak of capacity utilization of Aladja Steel Company, the annual demand for the various grades of ferro-alloys is about 15,000 tones per annum [60]. The prospect of rapid increase in the demand for ferro-alloys is envisaged with the success of the current reforms of present regime aimed at attracting investors with technical expertise, managerial skill and resources to turn the public Iron and Steel plants around. This couple with the emphasis of the present regime on the development of the solid minerals in the country has made investigation into the locally available sources of chromite ore and other ferro-alloys inevitable [61,62]. Fig (3.2) present the production for chromite and ferro chromite of world (2002 – 2008).

[redacted]

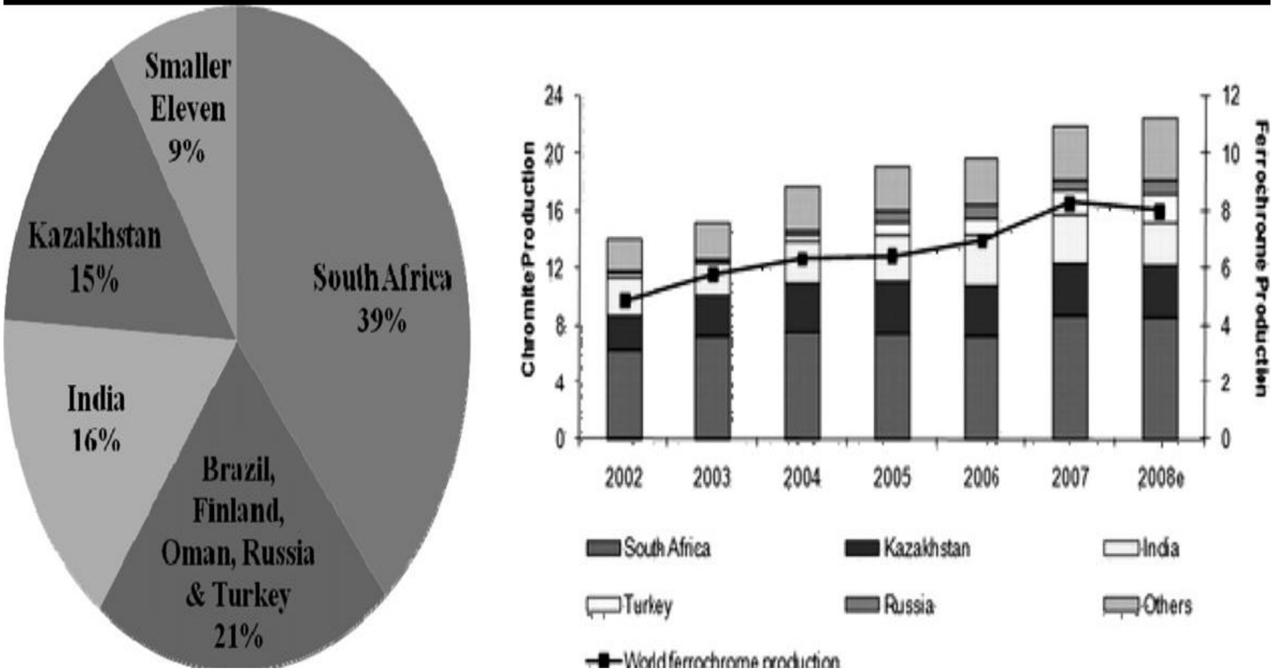


Fig (3.2)

(a) World chromite ore production. (b) World chromite and ferrochrome production (2002–2008).

Table (3.2) it clear that the world chrome resource and chrome ore-world production as shown in table (3.3).

Table (3.2) : World Chrome Resources [Source: International Chromium Development Association (ICDA)]

Country	Proven Resource	World Rank	Output (Production)	World Rank
South Africa	72.7%	1	39.3%	1
Zimbabwe	13.2%	2	2.0%	6
Kazakhstan	4.2%	3	14.8%	2
India	0.9%	4	16.0%	3
Finland	1.6%	5	2.5%	7
Brazil	0.8%	6	3.3%	8
Turkey	0.3%	7		5
Other Countries (Oman, Iran, Turkey and Albania	7.1%	8	22.1%	4
Total	100.00%		100.00%	

Table (3.3) :Chrome Ore - World Production

	South Africa	**Kazakhstan**	**India**	**Russia**	**Brazil**	**China**	**Others**	**Total**
				(MMTPA)				
2008	9.60	3.60	3.90	NA	0.80	NA	6.50	**24.40**
2007	9.65	3.69	3.32	0.78	0.63	0.20	3.23	**21.49**
2006	7.42	3.37	3.60	0.97	0.56	0.20	2.89	**19.00**
2005	7.55	3.58	3.26	0.77	0.62	0.20	2.89	**18.87**
2004	7.68	3.29	2.95	0.32	0.59	0.20	2.76	**17.78**
2003	7.41	2.93	2.21	0.12	0.38	0.20	2.27	**15.51**
2002	6.44	2.37	2.70	0.07	0.28	0.18	2.21	**14.25**
2001	5.50	2.05	1.68	0.07	0.41	0.18	2.25	**12.14**
2000	6.62	2.61	1.95	0.09	0.60	0.21	2.63	**14.71**
1999	6.82	2.41	1.47	0.12	0.49	0.22	2.76	**14.28**
1998	6.48	1.60	1.31	0.15	0.54	0.22	3.40	**13.70**
1997	5.74	1.80	1.36	0.15	0.30	0.12	3.93	**13.40**
1996	5.02	1.19	1.36	0.10	0.41	0.13	3.38	**11.58**
1995	5.10	2.42	1.54	0.15	0.45	0.09	4.33	**14.08**
1994	3.64	2.10	0.91	0.14	0.36	0.06	3.19	**10.41**
1993	2.83	2.90	1.03	0.12	0.31	0.05	2.12	**9.36**
1992	3.36	3.50	1.16	0.12	0.45	0.03	2.37	**10.98**
1991	5.10	NA	0.94	NA	0.34	0.03	6.93	**13.34**
1990	4.62	NA	0.94	NA	0.27	0.03	7.13	**12.98**

Others include Afghanistan, Albania, Australia, Brazil, Burma, China, Cuba, Finland, Greece, Iran, Madagascar, Oman, Pakistan, Philippines, Sudan, Turkey, United Arab Emirates, Vietnam & Zimbabwe

3.3 Chrome in Africa

Africa has the largest ore reserves in the world and it is estimated that Zimbabwe and South Africa have more than 80% of the world's ore reserves.

3.3.1 Chrome in South Africa

South Africa has a mature chrome value chain, the socioeconomic impact of which includes approximately 200,000 jobs and approximately R42 billion in GDP a year. However, the South African ferrochrome industry, the baseline for beneficiation.

In the chrome value chain, is under threat and its rapidly declining market share is putting jobs at risk. At the same time, exports of unbeneficiated South African chrome Ore to China are rising. These exports, which are providing chrome ore feedstock to the South African ferrochrome industry’s chief competitor, China, are creating jobs in China and reducing job creation opportunities in South Africa’s ferrochrome industry [63].

3.3.2Chrome In Zimbabwe

In Zimbabwe, chrome occurs in two distinct geological environments; the Great Dyke and the Greenstone belts.

About 95% of chromium resources are geographically concentrated in southern Africa and Zimbabwe is estimated to host over 80% of the world’s resources of metallurgical1 quality chromite, mainly on the Great Dyke. By far, the largest deposits are contained in 11 narrow seams (stratiform) in the Great Dyke (approximately 550 km long and 11 km wide). Although the seams are narrow, averaging 10cm in thickness, they extend on both sides of the entire length of the Dyke. In addition to the seams, neighbouring rock formations contain disseminated chromite, which on weathering is concentrated into rich alluvial deposition on the flanks of the Dyke.

Greenstone belt deposits occur as pods and pipes in some ultramafic rocks of the Shurugwi and Mashava Greenstone belts, and ultramafic bodies in the Limpopo Mobile Belt in Mberengwa district. The Shurugwi deposit is one of the most important sources of metallurgical chromite in the world. These ore deposits are refractory and lumpy and are therefore perfect ferrochrome refiners. However, this type of ore is quickly depleting. Zimbabwe has total reserves of about 140 million tonnes with resources of a further 1 billion tones and is the only country in the world that has exploited both stratiform and Podiform deposits [64].see Fig (3.3).

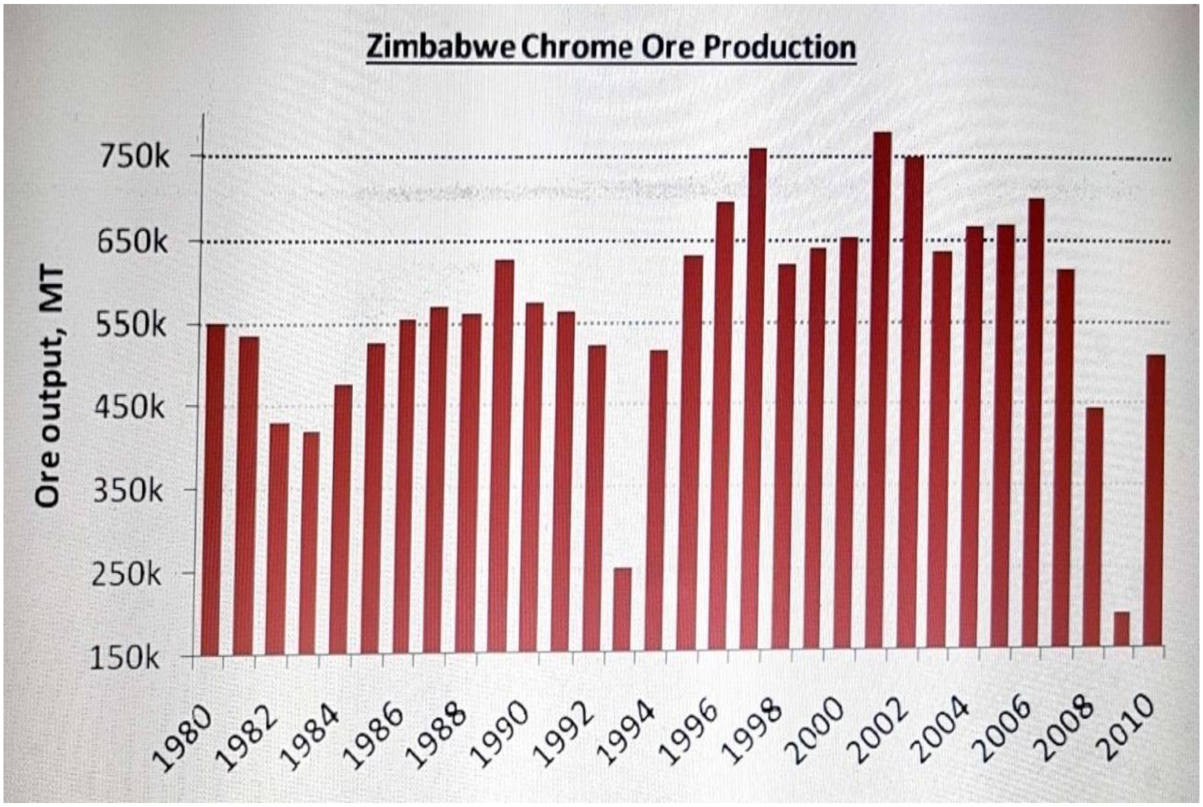


Fig (3.3): Zimbabwe Chrome ore production

3.4 Chrome Deposit in Sudan

In Sudan, chromite's ore deposits occur mainly in the Ingessana Hills in the Blue Nile region. Other occurrences have been reported at Hammissana, Sol Hamid in the Northern Red Sea Hills, the Nuba Mountains in Southern Kordofan, Jabal Rahib Northwest Sudan, and Jabal El-Tawil in Central Butana in Southern Sudan. The Ingessana chromite ore is considered as one of the largest chromite ore deposits in Sudan. Its chromite reserves was estimated to be 2 tera-grams (Tg or million tons), with chromium oxide assay in the range from 20% to 51% Cr_2O_3[65,66]. The mining area at Ingessana Hills is connected to Khartoum, Port-

Sudan and other important parts of Sudan with fairly maintained motor roads and railways through Damazine city, the capital of Blue Nile Governorate [66].

Chickay Chromite Mine in the Ingessana area is about 80 km from Damazine city. The Chromite ore in the Chickay Mine is in the form of a vein of complicated shape. Due to depletion of high-grade Chromite ore, and the presence of a large amount of low-grade ore in the area, it was necessary to come up with a suitable mineral processing technique to upgrade these low-grade ores together with the leftover fines from the previous Chromite mining operations.

The flotation technique was attempted for enriching the Chickay Chromite ore. The assay of the feed to the flotation cell was 20.3% Cr_2O_3. Under optimum conditions, the Chromite concentrate assayed 28.7% Cr_2O_3 at a recovery of 94.5%. Of course, the assay of the obtained concentrate is not satisfactory, which indicates that the flotation is not the right technique to concentrate this type of ore [67]. The main objective of the present work is to investigate the amenability of the Chikay low-grade chromite ore to be concentrated by gravity methods, utilizing the relatively large difference in the specific gravity of the main constituting minerals, chromite and serpentine, in particular by using the shaking table [66].

Chromium is one of the most versatile and widely used elements. Its main uses in the metallurgical, chemical, and refractory industries are well known. It is an essential element in the production of a wide variety of stainless steels, tool and alloy steels, nickel-chromium heating elements, and plating metals. Its widespread use in the metallurgical industry is attributed to its capability of enhancing properties such as resistance to corrosion or oxidation, creep, impact strengths, and hardenability.

However, the Ingessana chromite ore is considered as one of largest chromite ore deposits in Sudan [66].

3.5 Geology & Chromite Resources of The Ingessana Hills Area

Ingessana hills mining area ‘is a producer magmatic, podiform deposit district discovered in 1960 in Sudan territory, Sudan. it is a deposit, considered to be of world – class significance [68].

Chromium deposits are documented at “ingessana hills mining area “chromium is present at grade sufficient to have a strong effect on the economics of an excavation project. it may even be viable as the only commodity mined.

At the time this deposit was surveyed, there was a tapped production.

Mining opporations could be year-round, intermittent, or seasonal. production at “ingessana hills mining area “began in 1962. See Fig (3.4)

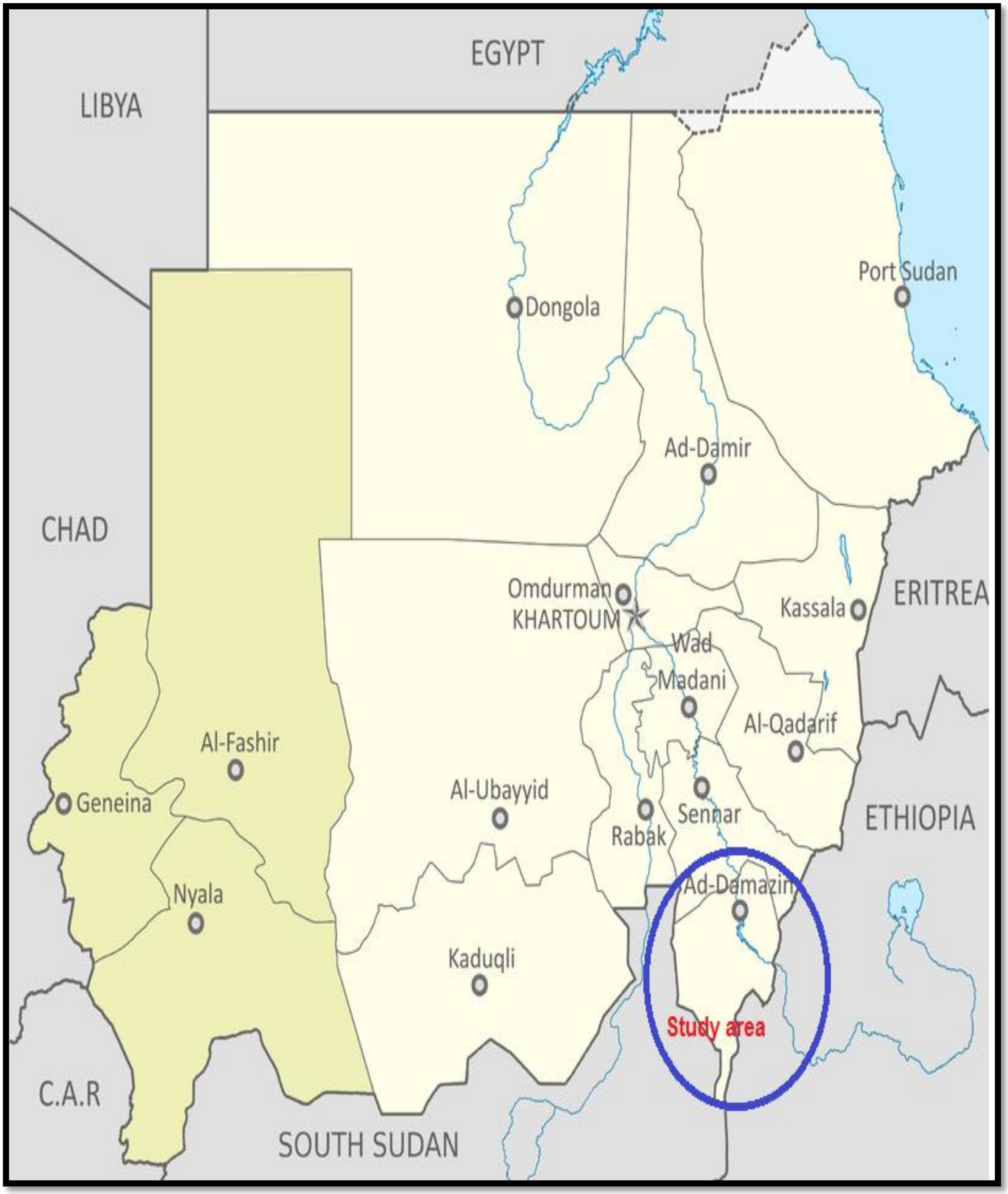

EGYPT
LIBYA
Port Sudan
Dongola
Ad-Damir
CHAD
Omdurman
KHARTOUM
Kassala
ERITREA
Wad Madani
Al-Qadarif
Al-Fashir
Geneina
Al-Ubayyid
Rabak
Sennar
ETHIOPIA
Nyala
Ad-Damazin
Kaduqli
Study area
C.A.R
SOUTH SUDAN

Fig (3.4): Study Area of Chrome in Sudan (Ingassana Hills)

3.5.1 Regional Geology

The regional geology of Blue Nile region has been extensively described by many authors e.g., and Vail and others. he Ingessana Hills area lies in Blue Nile region, which represents an important part of the Late Precambrian Arabian Nubian. The Ingessana – Kurmuk area, the western part of the above region pertains to the boundary between the Nubian Shield and the reworked pre-Pan-African basement (. It consists of a high grade (Tin Group) and a low-grade (Uffat Group) metamorphic terrains. The boundary between the two groups is a major structural break.

The Tin Group comprises a lower lithostratigraphic unit (Selack Formation) of migmatitic grey gneisses and amphibolites, overlain by a supracrustal metasedimentary unit (Gonak Formation). The low-grade Uffat Group has been subdivided into three lithostratigraphic units. The lower unit the Marafa Formation is a shelf sequence, which is in tectonic contact with the Ingessana Formation, a striking mafic-ultramafic association representing dismembered remnants of an ophiolite. The apparently uppermost units of the Uffat Group, the Kurmuk Formation comprises a thick calc-alkaline succession of volcanic and sedimentary rocks, with island-arc affinities. As the other parts of the Arabian-Nubian Shield, all the units have been pierced by various intrusions ranging from syn-to post-orogenic and anorogenic complexes [69].

3.5.2 Chromite Mineralisation

On the basis of a study of previous data reported concerning chromite deposits of Ingessana Hills of Blue Nile State mainly the preliminary. The chromite occurrences are localized within the dunite facies zone and only a small number of ore bodies occur in the harzburgite. The adjacent country rocks are mostly serpentinized. The forms of the ore bodies in the area are complex and changeful as well as very irregular, they may be grouped into three essential forms: vein, lens and band. Among them the vein, lens-shaped ore bodies usually display the feature of swelling and pinching, divergence and convergence, so they often occur in various kind of irregular shapes, such as vein like, stock work, pocket, branch fad pole, podiform, melon and vine shapes. The one bodies composed of bands comparatively persistent, but the bands often shows the phenomena of pinching out and reappearing alone the strike and dip [69].

3.5.3 Chromite Deposits

3.5.3.1 Mode of Occurrence Textures And Mineral Composition Of The Ores

In all the above-mentioned complexes chromite deposits occur as tabular, or irregular masses that invariably exhibit evidence of some degree of metamorphic deformation similar to podiform deposits in ophiolites throughout the world.

3.5.3.2 Mineral Composition and Texture of Ore

As other ophiolitic chromite ores, chromite’s from the Sudanese ophiolites exhibit a great variety of textures. Disseminated, massive, banded, nodular, orbicular, mottled, occluded silicate, chromite nets and chromite chains types of textures are common. All transitions between disseminated and massive ores occur. Graded bedding and rhythmically interlayered chromite and olivine layers, similar to stratiform chromite ores, are encountered in the banded ore bodies, but invariably show folding and deformation. At all localities the massive chromite ore bodies have partly retained original cumulate texture defined by accumulation of euhedral interlocked chromite grains. The most common texture is of add cumulus origin, resulted from the growth between chromite and chromite and / or silicate matrix minerals. It is characterized by concave-convex embayment of the grain boundaries and, in extreme cases, by thorn-like intergrowths. Late magmatic and/or post magmatic deformation led to the compaction of the ores and pull-part cracks.

The main ore mineral is chrome spinel with a grayish-white color and low reflectivity (12-14%) under the ore microscope. The chromite crystals often enclose serpentinized olivine’s, chlorite and talc. In areas of alteration, chrome spinel is rimmed by ferrochrome (iron-rich chromite). Magnetite is a common ore mineral sometimes occurring around the chromite edges and as specs and veinlets resulting from the breakdown of olivine in the gangue. Gangue minerals include serpentinized olivine, talc, magnisite and chlorite. Fuchsite (green chrome mica), chemererite (purple chrome chlorite) and uvarovite (chrome garnet) are common alteration products.

The sulphide minerals pentlandite, millerite, pyrite, pyrrohtite chalcopyrite and digenite are common accessory phases. They form euhedral and anhedral grains as inclusions both in the chromite crystals and in the silicate matrix. In areas of intense deformation e.g. the Hsmisana Massif the chromite bodies have been hydrothermally altered giving rise to hard green products with numerous thin veins of sulphides. Platinum-group element alloys and minerals are also common accessories in the Sudanese chromite deposits.

3.5.4 Chromite Reserves

A large number of chromite bodies have been located in the mantle sequence of the Ingessana-Kurmuk ophiolite, which contains the most economically important deposits. The most important deposits occur in the Ingessana Massive where more than a hundred occurrences. The chromite ore bodies are hosted by dunite in the deeper harzburgite-dunite tectonic complex of the western part of the massive. The form of ore bodies and their mode of occurrence are variable and complex. They can be grouped into two major categories: podiform deposits and disseminated bands or layers.

The former may include lens and vein-shaped ore bodies, which pinch and swell and have variable attitudes. The bands are more persistent along the strike and both the podiform and the banded ore bodies are generally conformable with the primary structures of the host tectonite mantle sequence, like lithofacies zones, igneous layering, dunite schlieren and primary flow planes. However, at many localities the ore bodies are orientated parallel to major shear zones, especially at the base of the ophiolite. Individual ore bodies may range in size from 10 to 50 m long, 1 to 3 m thick and 30 to 100 m down dip length. The largest body in the Ingessana Massif occurs in the Gam Mining area, in which it attains 307 m in strike length, 6 m in thickness and 120 m down dip length.

3.6 Chromite Occurrences In Other Areas

At least three ophiolite complexes other than the Ingessana contain podiform chromite deposits in their plutonic mantle. These are the Onib, the Oshib and the Jabel Rahib ophiolites. The detailed geology of these complexes is generally the same with some variation from one complex to the other. The chromite occurrences in each complex will are briefly summarized below respectively.

3.6.1 Onib Ophiolite

In the NW Red Sea Hills chromite mineralization has been described by. The most economically important deposits are found within the Hamisana Massive where five chromite-bearing structural horizons have been distinguished. In contrast to the Ingessana complex, the mantle sequence, more or less in the transitional zone between the tectonite facies and the cumulate succession. Moreover, the chromite ore bodies are associated with both serpentinized dunite and harzburgite and they are mainly concordant with the primary structural elements of the hosting ultramafic sequence. The contact between the ore bodies and the host rocks is of variable nature and has largely been modified by deformation and subsequent hydrothermal alteration. In area of less deformation, both gradational and sharp contacts of chromite ore bodies and the surrounding rocks have been observed. The most common are series of finger-like projections of chromite ores within the wall rocks that are parallel to the primary fabrics in the host ultramafic sequence. The chromite ore bodies vary from a few several meters long and 2 to 5 m thick, but unlike the Ingessana deposits, the dip length of the Hamisana chromite pods is unknown.

The largest chromite body in the Hamisana Massive of the Onib ophiolite is a lens (No. BF 1000 which is 250 m long, 5 m (average) thick and 100 m estimated down dip length.

3.6.2 Oshib Ophiolite

The highly sheared basal mantle sequence of the Oshib ophiolite contains many small pods of massive chromite only 30 lenses exceed 2 m in size; the largest attains 25 m on the surface. The chromite pods are located within the Oshib block and to a lesser extent, in the adjacent Nafaab block. During this work, chromite lenses of limited sizes have been found in the serpentinized tectonite sequence at the Igarairi block. At all localities the chromite lenses are hosted by serpentinized dunite. They are sheared, boudinaged and are drawn out parallel to the lineation and foliation, which are generally sub-vertical.

3.6.3 Jabel Rahib Ophiolite

In the newly discovered Jabel Rahib ophiolite of NW Sudan, three zones of chromite mineralization have been found, all in the Eastern Jabel Rahib Belt (EJRB). The major zone of mineralization extends for more than one km within an NNE-SSW trending serpentinized harzburgite-dunite tectonite complex. This zone is about 200 m wide and it contains several pods of massive chromite which may attain 50 m in length and about 2 to 4 m thick. The pods are dominantly tabular and lenticular in shape, and have sharp, but concordant contacts with the host rocks. The latter are pervasively carbonatized and chloritized. The chromite bodies are generally conformable with the structures of the host rocks, but conjugate and sub-vertical pods have been observed. The ore is very coarse (pegmatitic) at the centres of the pods and coarsegrained at their margins.

The second zone of mineralization probably marks the boundary between the mantle tectonite sequence and the cumulate succession (i.e. near the Moho Discontinuity). It comprises a number of meter-scale sub-circular to elliptical and irregularly-shaped pods of very massive chromite ore. The pods are hosted by serpentinized dunite schlierens within tectonized harzburgite overlain by wehrlite, pyroxenite and cumulate layered gabbro. The third chromitiferous zone occurs within the lower part of the cumulate succession. It contains numerous, but very small (ca 40 cm long) elliptical pods of disseminated chromite, hosted by highly serpentinized clinopyrox- ene-bearing peridotite. Both the pods and the host rocks are highly sheared, and the ore is rimmed by iron-rich chromite spinel.

3.7 Chromite Production in Sudan

Here reserves of the chromite deposits in the Ingessana-Kurmuk area has been estimated to one million tons and the approved reserves is up to 750, 000 ton. The ore can be transported to Port Sudan by trucks or by railway. Port Sudan harbour is capable to handle above 20, 000 tons.

Many mining licenses of investments have been issued for the exploitation of chromite in Ingessana Hills. The production increases and decreasing according to the international market needs for chromite. The main company for chromite production is the Advanced Mining Works Co. LTD but, other companies e.g. chromco, Elnilein, Abu Eljak, Rida, and the Sudanese Chrome Company have the same activity.

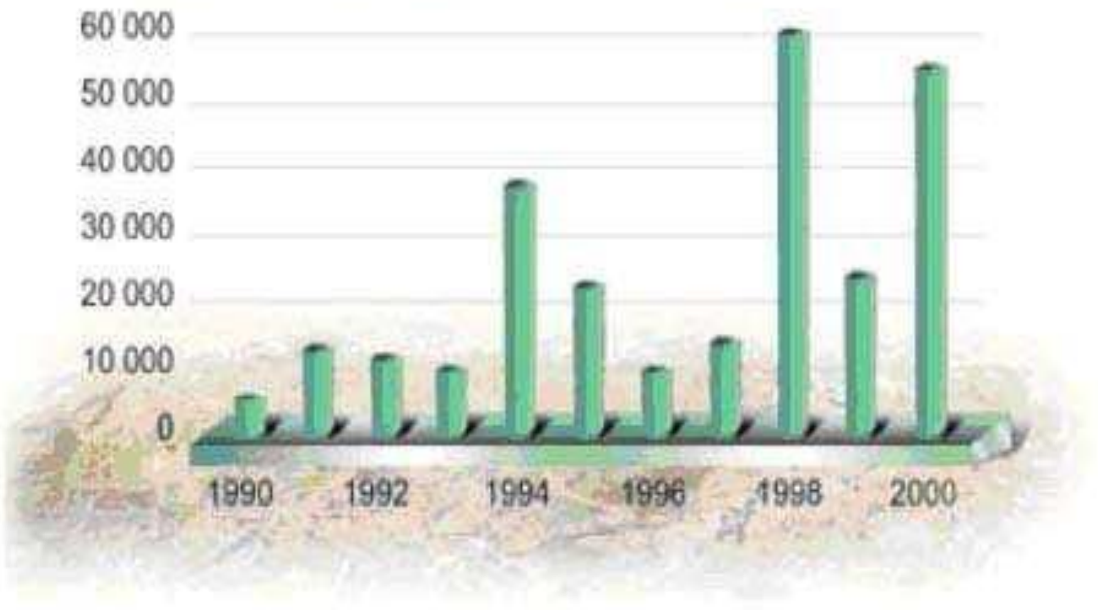


Fig (3.5) : The annual production of Chromite [69]

3.8 Geology Stratigraphy

The geology of the Sudan has very limited documentation. Our best available references being the geologic map of the Sudan republic Clarendon press- oxford, 1971 and a ground water survey by hunting. et al London consultants. The hunting report was available for reference at the rural water corporation office in Khartoum. Access was given to the open file reports and maps of the Sudan geological survey. These references note from a shell – BP. reconnaissance in the N.W. Sudan in 1960, plus personal observation during a cursory surface investigation by W M C, constitute the background for this discussion. The oldest exposed rocks in the permit area are a suite of gneisses and less altered met sediments of Precambrian age. These rocks are exposed throughout the permit area but are very prominent in the nub mountain area west and in the north and south portion of the area. This basement complex is cut by a series of southeasterly and easterly trending syenite and granite [70] .

CHAPTER FOUR

MATERIAL AND METHODS

4.1 Study Area

Ingessana Hills lies in the eastern part of the Blue Nile State between longitudes 33˚ 32´ N - 34˚ 15´ N. It is about 80 km from Damazin the capital of Blue Nile State and connected by fairly well-maintained motor roads. Railways and roads connect Damazin with Khartoum, and other parts of the country. Damazin has an airstrip.The Ingessana Hills area is characterized by high (600 ft above sea level) and steep relief topography, due to the presence of ultramafic and other intrusive rocks. The plains surrounding the Ingessana massif are covered with thick bushes and tall grass. The eastern part of the massif drains to the Blue Nile, while the western part of the area drains to the White Nile [69].

4.2 Samples Collection

Sample were crushed and ground to 2mm size, to facilitate chrome releasing and ending up in the leaching Solution. Sub-samples from bulk samples were taken using quartering technique which consists of piling the ore into conical heap , spreading this out into circles cakes , and dividing the cake into the quarters , taking opposite quarters . This process was repeated until a suitable sample was collected.

4.3 Samples Preparation

After collecting, the samples that were taking the dark gray to black color, when the samples were grinded and converted to powder, and take every 25 grams of the sample, and placed in the XRF device, and observe the results recorded on the results table on the device.

4.4 Sample Measurements

The sample was grinded firstly up to become soft, then pressed by the pressing machine and placed on the sample holder.

The XRF spectrometer system was used which composed of a radioisotope excitation source cd-109, together with (ORTEC) Si (Li) detector and associated electronics, Canberra multi-channel analyzer and computer.

The amplifier settings were adjusted for optimum values. then analyzed samples, respectively (onion, cucumber, jew mellow, water, cress and marrow) each sample was separate over lapping , fitting the spectra by the (win QXAS) , And appointed the elements within each sample by the (QXAS) software in addition to the peak area and concentration of each element . the bias supply was used 600V for Si (Li) detector [71].

The machine was cleaned before you start pressing to avoid inaccuracies in surface area of samples in the development of the sample holder specimens.

MCA and the QXAS software were calibrated before the start of analysis X-ray fluorescence spectrometers use high energy X-rays or gamma rays to excite fluorescent radiation (or photons) from a sample for chemical or elemental analysis. in an energy dispersive X-ray fluorescence spectrometer (EDXRF spectrometer), [72] the fluorescent photons from the irradiated sample are detected without being separated first (as they are in wavelength dispersive XRF spectrometers). limits of detection EDXRF spectrometers is typically in the parts per million (ppm) range.

4.5 Sample Analysis

The pellets were present to the XRF spectrometer system, where each of them was measured for 1000 sec.

The spectra obtained as a result of X-ray excitation using Cd-109 (30 mei) , X-ray source were transferred to a computer .

The spectra were the analyzed and concentration of the elements present in the samples were obtained using Axil, XRF software available in the compute a plant standard was used to ensure reliability of the results (Hay standard reference material obtained from the international atomic energy agency (IAEA)).

The concentration of the elements was calculated using relative method as in equation

$$C_{st} = KI_{st} \qquad (4.1)$$

Where C_{st} concentration of the standard is ,k is proportional constant, I_{st} is Intensity of the standard .

$$C_{un} = KI_{un} \qquad (4.2)$$

Where C_{un} concentration of the unknown sample is proportional constant , I_{un} is Intensity of the unknown sample.

$$K = Cst / Ist \qquad (4.3)$$

When we substitute the value of K from equation (2.3) in equation (2.2) we get :

$$C_{un} = \frac{C_{st}}{I_{st}} I_{un} \qquad (4.4)$$

Fig (4.1): X – Ray Fluorescence Machine

Using in sample analysis XRF machine where were taken every 25 grams of powder sample and put it in the machine and calculate the percentage of chromium which is the study element.

4.6 Gamma-ray spectroscopy

The gamma spectroscopy system which used consists of a detector, electronics to collect and process the signals produced by the detector, and a computer with processing software to generate, display, and store the spectrum. Other components, such as rate meters and peak position stabilizers, may also be . In this study gamma-spectrometry based on high efficiency NaI (Tl) detector.

Gamma spectroscopy detectors are passive materials that wait for a gamma interaction to occur in the detector volume. The most important interaction mechanisms are the photoelectric effect, the Compton Effect, and pair production. The photoelectric effect is preferred, as it absorbs all of the energy of the incident gamma ray. Full energy absorption is also possible when a series of these interaction mechanisms take place within the detector volume. When a gamma ray undergoes a Compton interaction or pair production, and a portion of the energy escapes from the detector volume without being absorbed, the background rate in the spectrum is increased by one count. This count will appear in a channel below the channel that corresponds to the full energy of the gamma ray. Larger detector volumes reduce this effect.

The voltage pulse produced by the detector (or by the photomultiplier in a scintillation detector) is shaped by a multichannel analyzer (MCA). The multichannel analyzer takes the very small voltage signal produced by the detector, reshapes it into a Gaussian or trapezoidal shape, and converts that signal into a digital signal. In some systems, the analog-to-digital conversion is performed before the peak is reshaped. The analog-to-digital converter (ADC) also sorts the pulses by their height. ADCs have specific numbers of "bins" into which the pulses can be sorted; these bins represent the channels in the spectrum. The number of channels can be changed in most modern gamma spectroscopy systems by modifying software or hardware settings. The choice of number of channels depends on the resolution of the system and the energy range being studied. The multichannel analyzer output is sent to a computer, which stores, displays, and analyzes the data. A variety of software packages are available from several manufacturers, and generally include spectrum analysis tools such as energy calibration, peak area and net area calculation, and resolution calculation. The instrumentation set-up of γ-ray spectroscopy system with NaI (Tl) detector is shown in Fig (4.2).

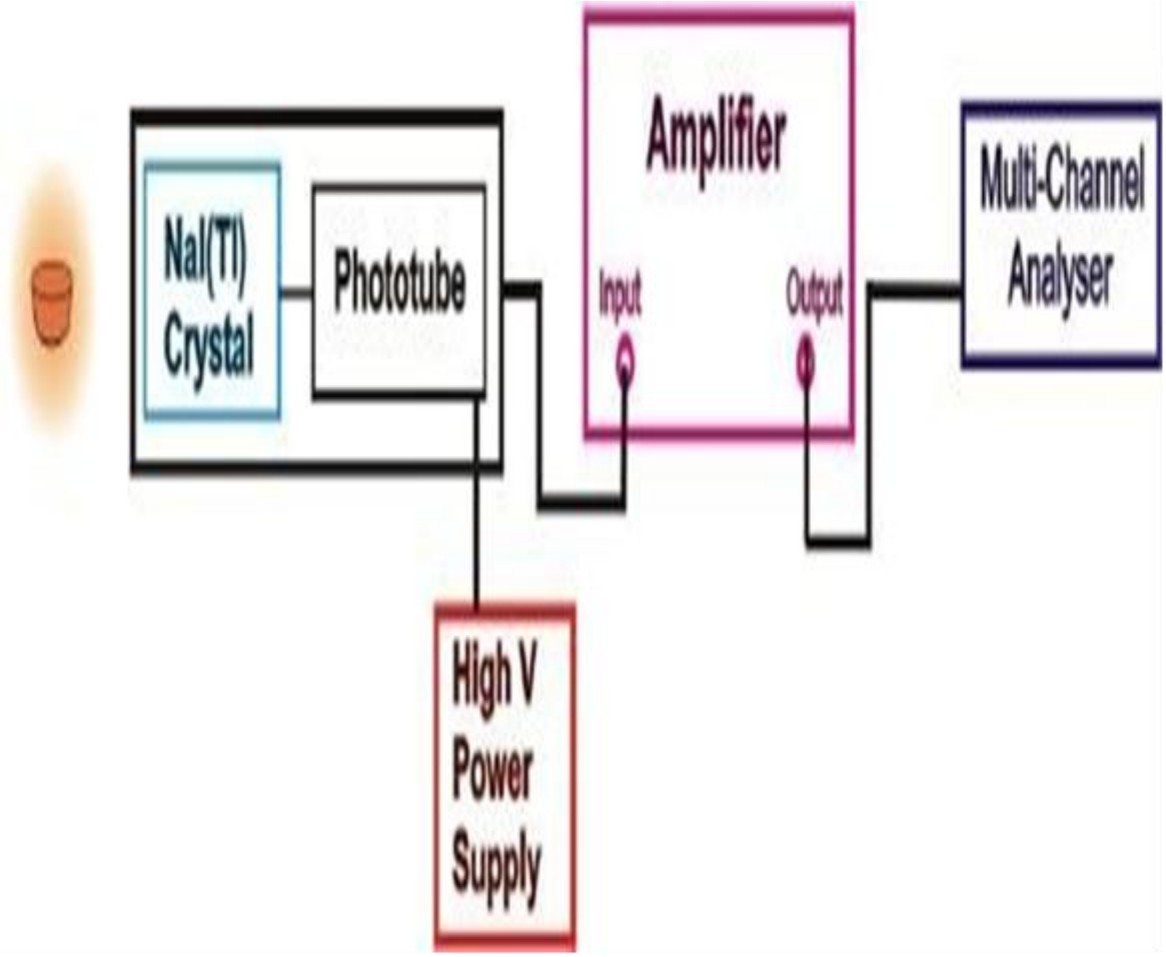


Fig (4.2): Block diagram of gamma-ray spectrometer

4.6.1 System calibration of gamma

To identify and quantify the concentration of the unknown radionuclides, the system must be calibrated with respect to energy, efficiency and resolution .The resolution measurement is required for identification of peaks in the peak search routine. Energy calibration is necessary for sample qualitative analysis. The efficiency calibration is required for sample quantitative analysis.

4.6.1.1Energy calibration

When a gamma spectroscopy is used for identifying samples of unknown composition, its energy scale must be calibrated first. Energy calibration was performed by using the peaks of a known source, such as ^{137}Cs or ^{60}Co. Because the channel number is proportional to energy, the channel scale can then be converted to an energy scale. Energy calibration was performed by using mixed radionuclide standard (MW625) obtained from IAEA in form of 500 ml.see fig (4.3).

Table (3.5): Types of mixed radionuclides used for system calibration and their corresponding gamma energies

Radionuclide	**Energy(keV)**
^{241}Am	59.496
^{109}Cd	87.981
^{57}Co	122.144
^{137}Cs	661.706
^{54}Mn	834.883
^{65}Zn	1115.301
^{60}Co	1173.337
^{60}Co	1332.571

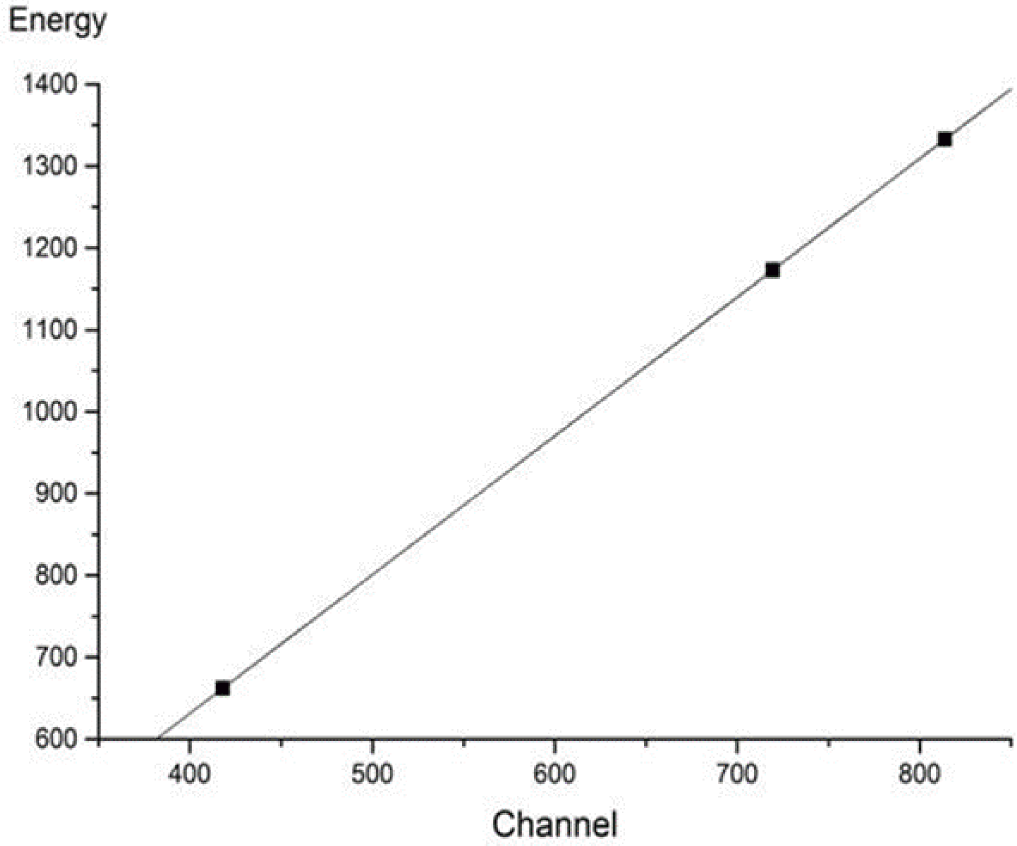


Fig (4.3): Energy calibration curve

4.7 Statistical Analysis

These two methods for statistical analysis

4.7.1 T- Test Analysis

In the study, statistical analysis of data was performed using Microsoft office excel and the computing package called statistical package for social science (SPSS 16.0 for Windows , SPSS Ine .,IL , U.S.A).

Parametic independent T-test has been employed to indentify the concentration of heavy metal by XRF techniques.

Statistical test shows that there has significant difference between two villages either.

4.7.2 Correlation Analysis:

In the study, statistical analysis of data was performed using correlation analysis to correlated concentrations of heavy metals in vegetables and soils measured by XRF techniques.

CHAPTER FIVE

RESULTS AND DISCUSSIONS

5.1 The results of X-ray fluorescence

Samples were taken from the region of the Ingessana hills and according to concentrations of the elements in each sample using XRF machine and the tables show the percentages obtained.

5.1.1 Quality Control of The Obtained Data

Table (5.1) and Fig (5.1) to Fig (5.30) :Heavy metal content in the evaluation in rock samples concentrations in ppm.

Table (5.1) : The concentration of the elements in samples .

Sample code	Cr	Fe	Ni	Mn	Mo	Nb	Cd	Sb	Zn	Sn	Zr
S1	639400	349200	6300	4800	ND	ND	ND	ND	ND	ND	ND
S2	669800	324100	1500	4300	ND	ND	ND	ND	ND	ND	ND
S3	648800	351200	ND	3822	ND	ND	ND	ND	ND	ND	ND
S4	700700	287100	ND	11900	ND	ND	ND	ND	ND	ND	ND
S5	689100	310300	ND	ND	ND	200	ND	ND	ND	ND	ND
S6	738000	254100	7700	ND	ND	ND	ND	ND	ND	ND	ND
S7	669600	324500	ND	5600	ND	ND	ND	ND	ND	ND	ND
S8	650700	333900	5700	8200	ND	ND	1000	ND	ND	ND	ND
S9	673200	315000	1400	8900	ND	ND	ND	1200	ND	ND	ND
S10	674000	318000	4000	ND	ND	ND	ND	4000	ND	ND	ND
S11	649800	338500	11400	ND	ND	ND	ND	ND	ND	ND	ND
S12	670300	316800	ND	11500	ND	ND	ND	1100	ND	ND	ND
S13	659000	321000	ND	14000	ND	ND	ND	ND	6000	ND	ND
S14	676900	318400	ND	3600	ND	ND	ND	ND	ND	800	ND
S15	682400	302400	ND	13100	ND	ND	ND	ND	ND	1800	ND
S16	670900	320200	ND	7200	ND	ND	ND	1400	ND	ND	ND
S17	635800	337200	ND	26800	ND	ND	ND	ND	ND	ND	ND
S18	684100	309100	1700	3500	ND	ND	ND	ND	ND	1300	ND
S19	689800	301500	4500	3600	ND	200	ND	ND	ND	ND	ND
S20	679800	311700	ND	7300	ND	ND	ND	900	ND	ND	ND
S21	640300	330600	ND	28600	200	ND	ND	ND	ND	ND	ND
S22	658000	282900	7100	50700	ND	ND	ND	ND	ND	100	ND
S23	665300	330300	ND	ND	ND	ND	ND	1500	ND	2600	ND
S24	675700	312900	7200	3800	ND	ND	ND	ND	ND	ND	ND
S25	678600	312300	3600	2900	ND	ND	ND	2200	ND	ND	200
S26	678200	321500	ND	ND	ND	ND	ND	ND	ND	ND	ND
S27	690600	293800	ND	13800	ND	ND	ND	900	600	ND	ND

S28	683500	292200	1000	23000	ND	ND	ND	ND	ND	ND	ND
S29	673400	326200	ND	ND	ND	ND	ND	ND	ND	ND	ND
S30	675000	318000	1700	5000	ND	ND	ND	ND	ND	ND	ND

From fig (5.1) it clear that the Cr has high concentration but Mn is low concentration.

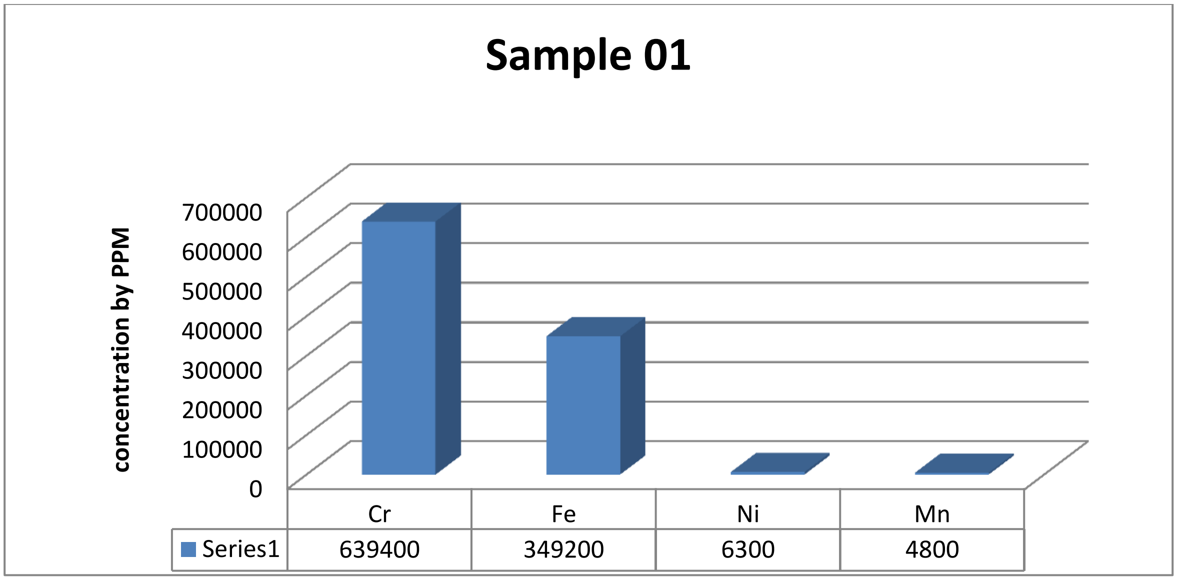


Fig (5.1) : plot show compare elements concentration in sample 1

From fig (5.2) it clear that the Cr has high concentration but Ni is low concentration.

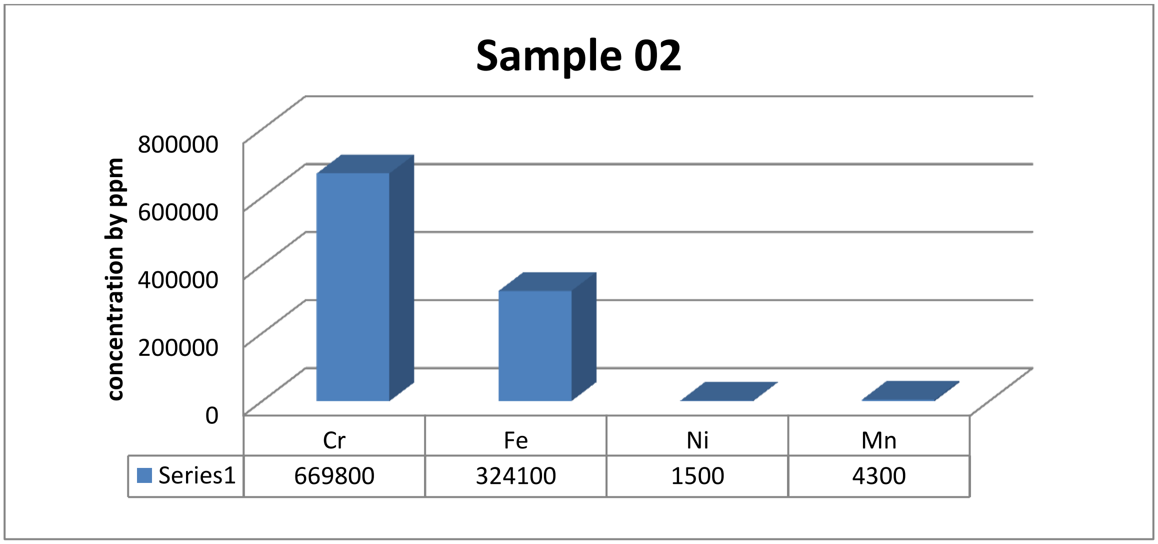


Fig (5.2) : plot show compare elements concentration in sample 2

From fig (5.3) it clear that the Cr has high concentration but Mn is low concentration.

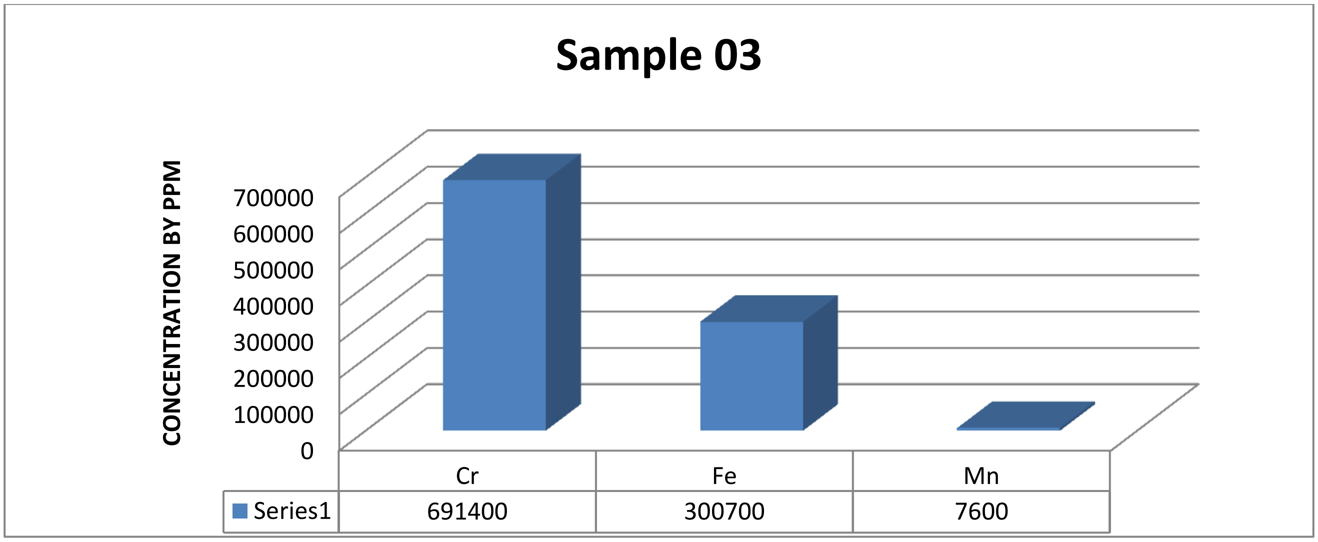


Fig (5.3) : plot show compare elements concentration in sample 3

From fig (5.4) it clear that the Cr has high concentration but Mn is low concentration.

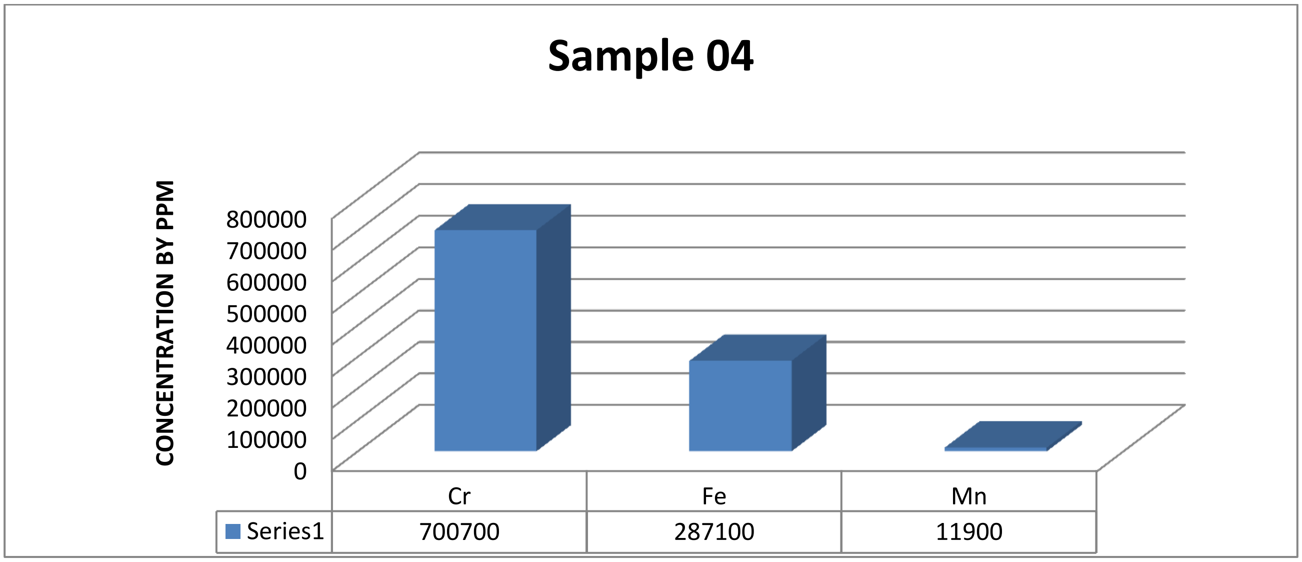


Fig (5.4) : plot show compare elements concentration in sample 4

From fig (5.5) it clear that the Cr has high concentration but Nb is low concentration.

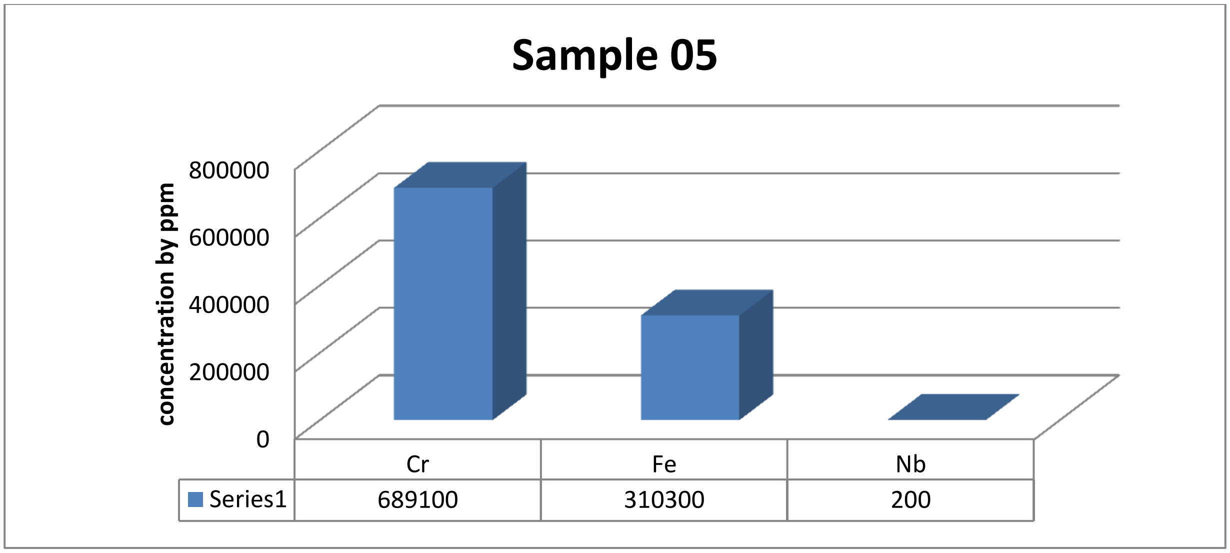


Fig (5.5) : plot show compare elements concentration in sample 5

From fig (5.6) it clear that the Cr has high concentration but Ni is low concentration.

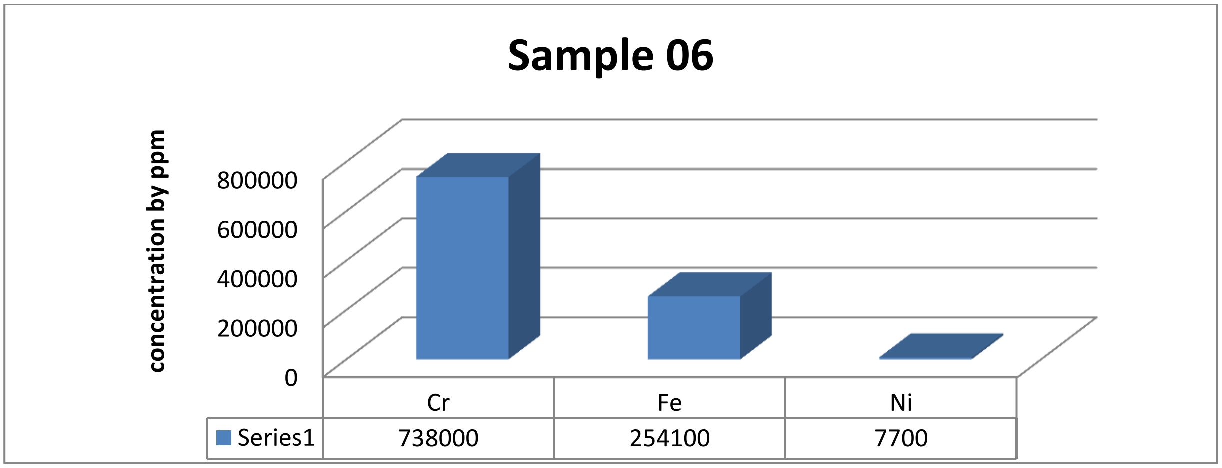


Fig (5.6) : plot show compare elements concentration in sample 6

From fig (5.7) it clear that the Cr has high concentration but Mn is low concentration.

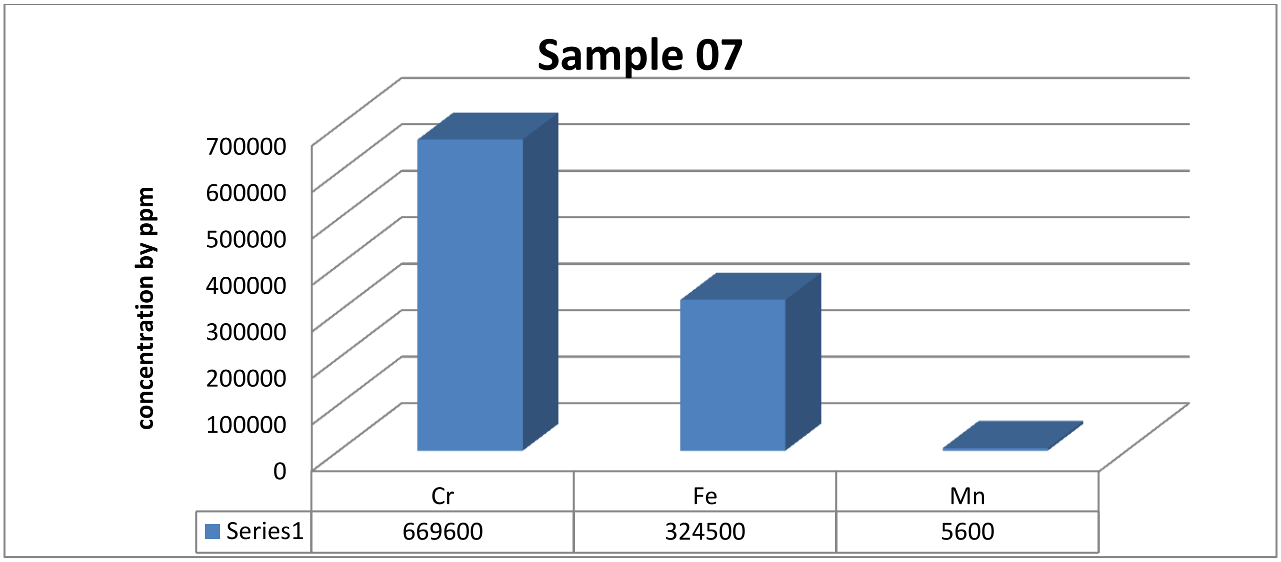


Fig (5.7) : plot show compare elements concentration in sample 7

From fig (5.8) it clear that the Cr has high concentration but Cd is low concentration.

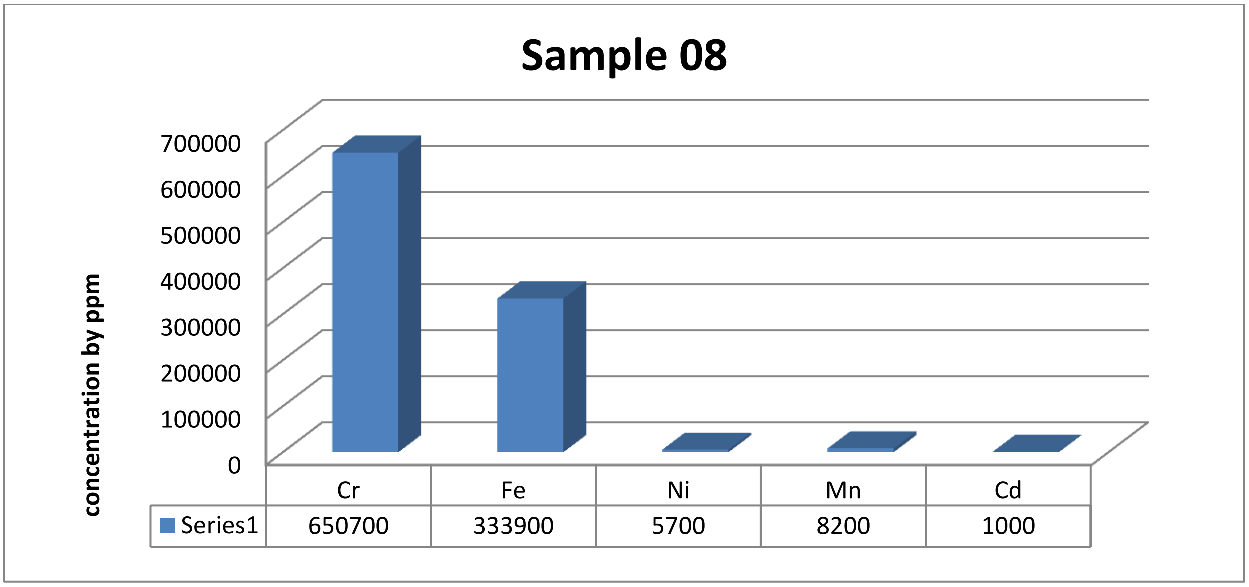
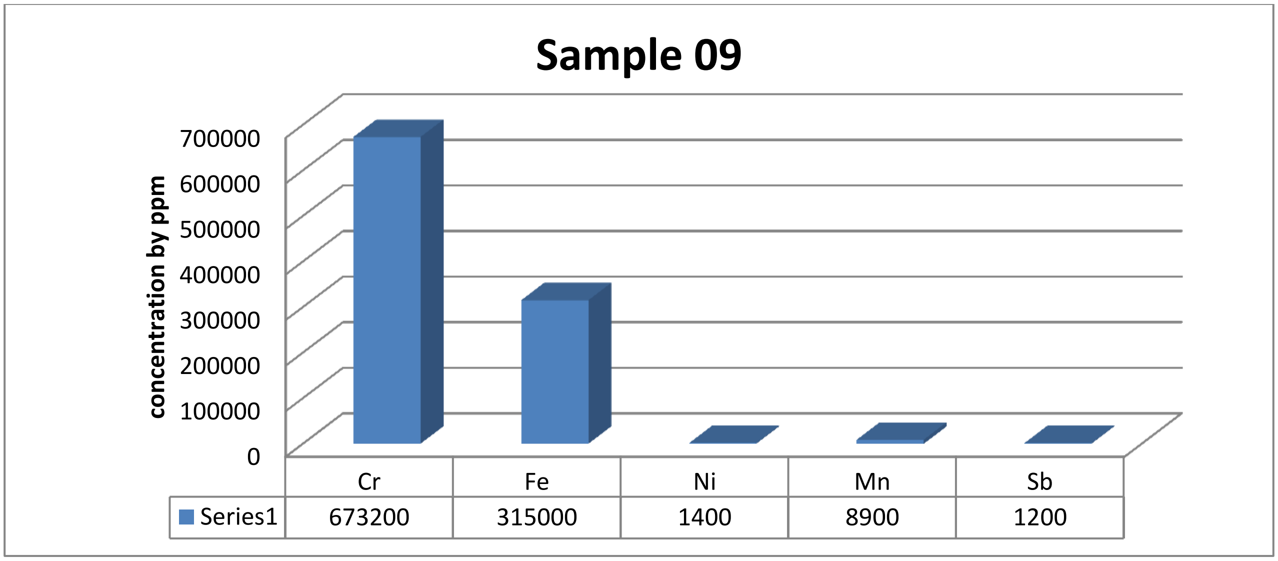


Fig (5.8) : plot show compare elements concentration in sample 8

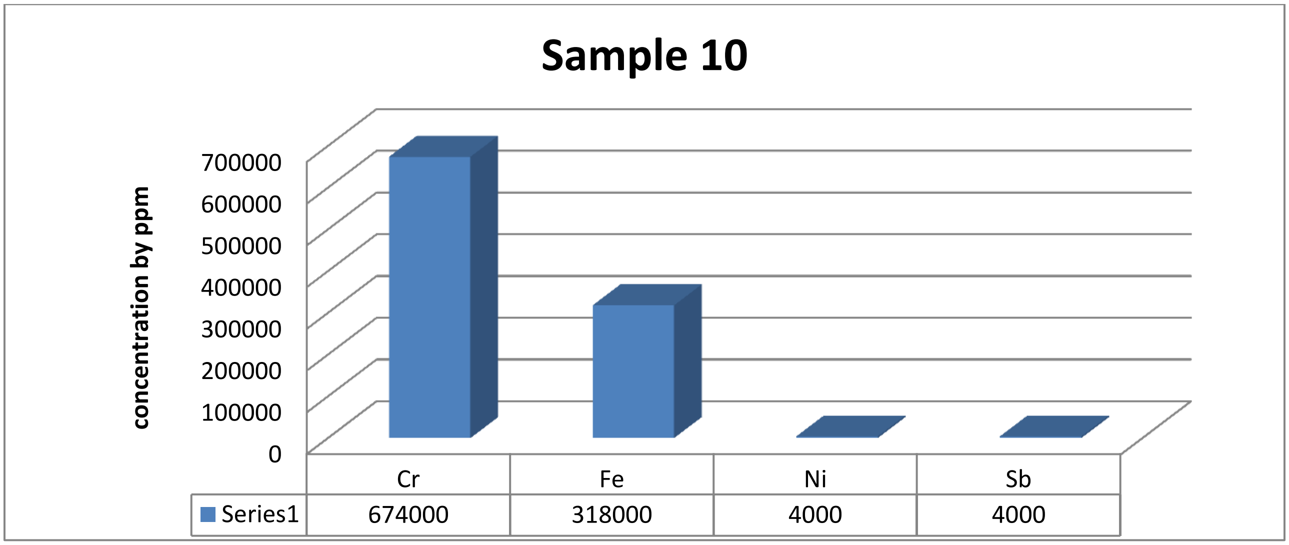
From fig (5.9) it clear that the Cr has high concentration but Sb is low concentration.



	Cr	Fe	Ni	Mn	Sb
■ Series1	673200	315000	1400	8900	1200

Fig (5.9) : plot show compare elements concentration in sample

From fig (5.10) it clear that the Cr has high concentration but Sb & Ni is low concentration.



	Cr	Fe	Ni	Sb
■ Series1	674000	318000	4000	4000

Fig (5.10) : plot show compare elements concentration in sample 10

From fig (5.11) it clear that the Cr has high concentration but Ni is low concentration.

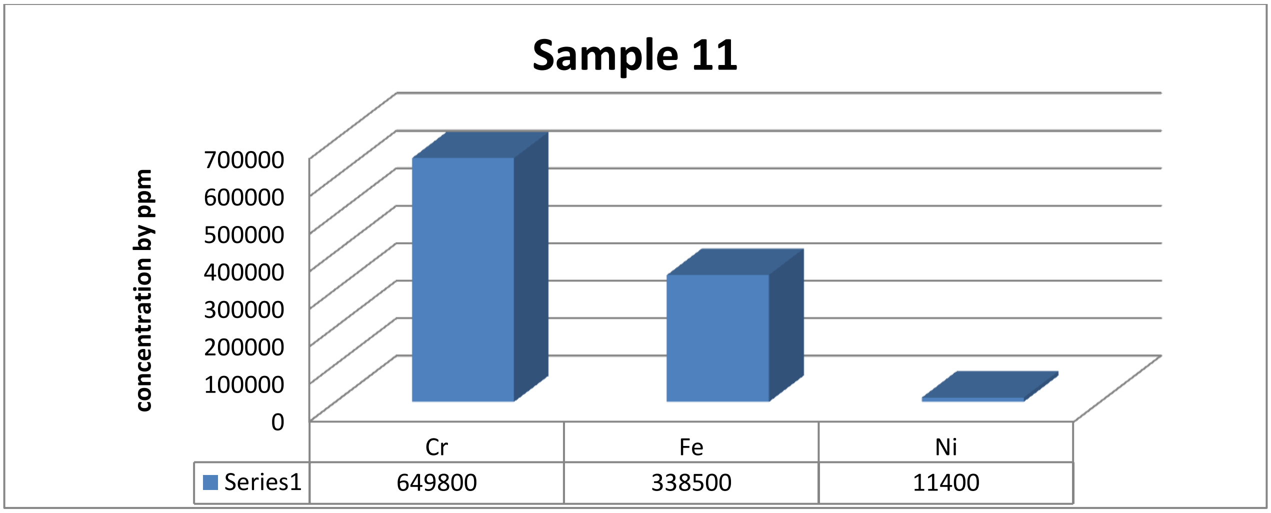


Fig (5.11) : plot show compare elements concentration in sample 11

From fig (5.12) it clear that the Cr has high concentration but Sb is low concentration.

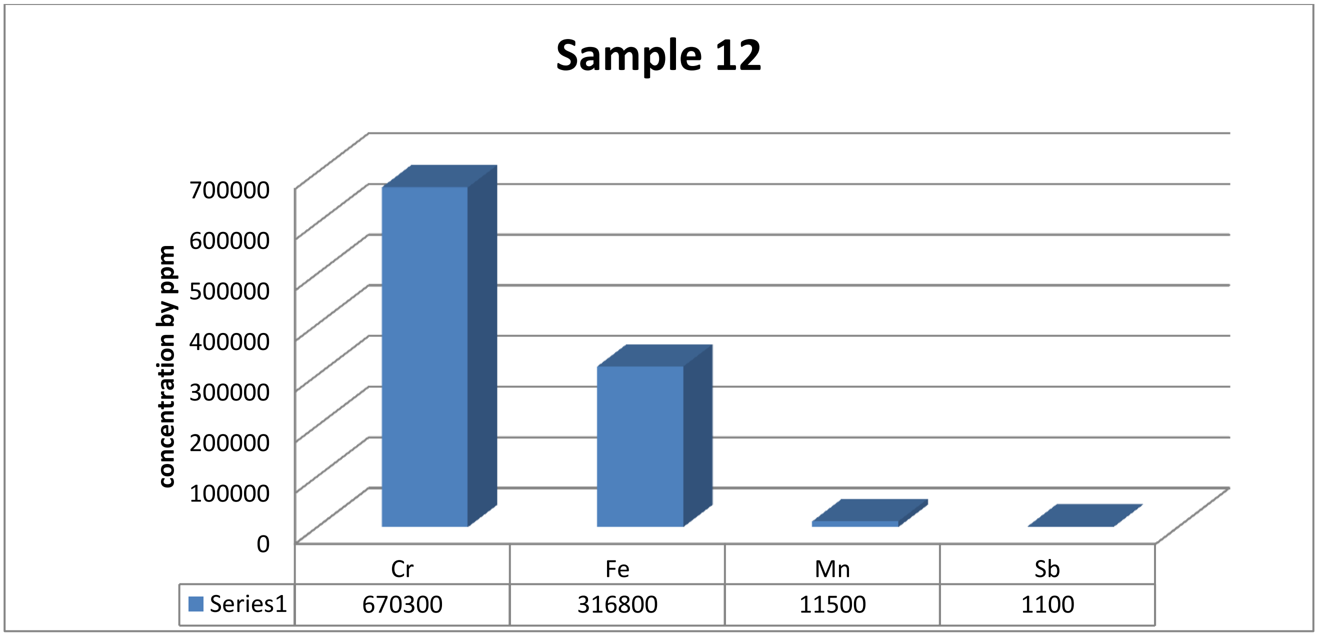


Fig (5.12) : plot show compare elements concentration in sample 12

From fig (5.13) it clear that the Cr has high concentration but Zn is low concentration.

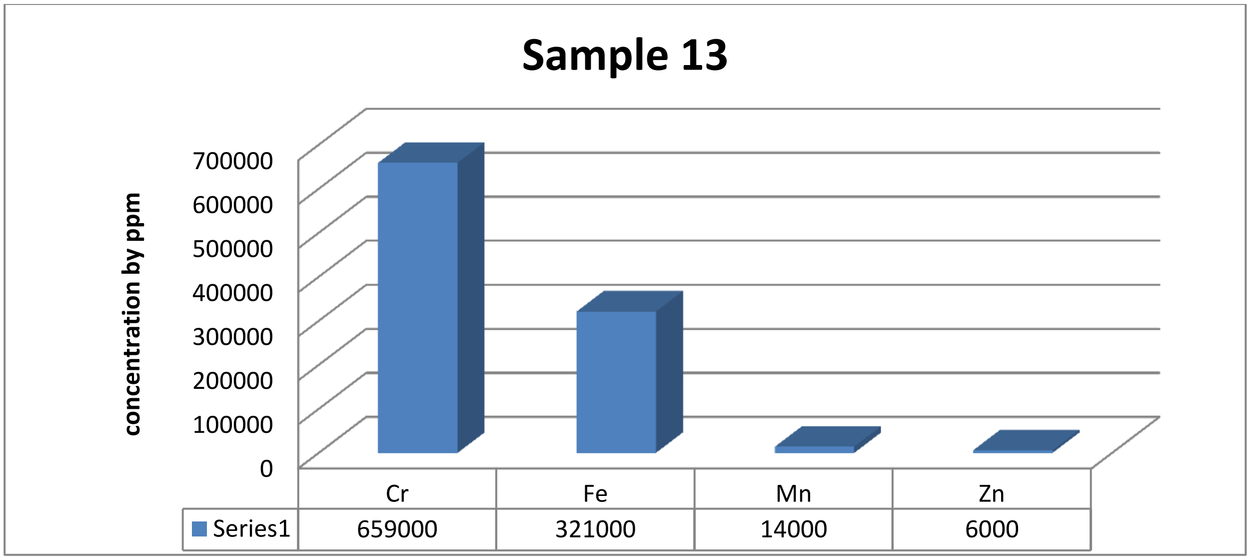


Fig (5.13) : plot show compare elements concentration in sample 13

From fig (5.14) it clear that the Cr has high concentration but Sn is low concentration.

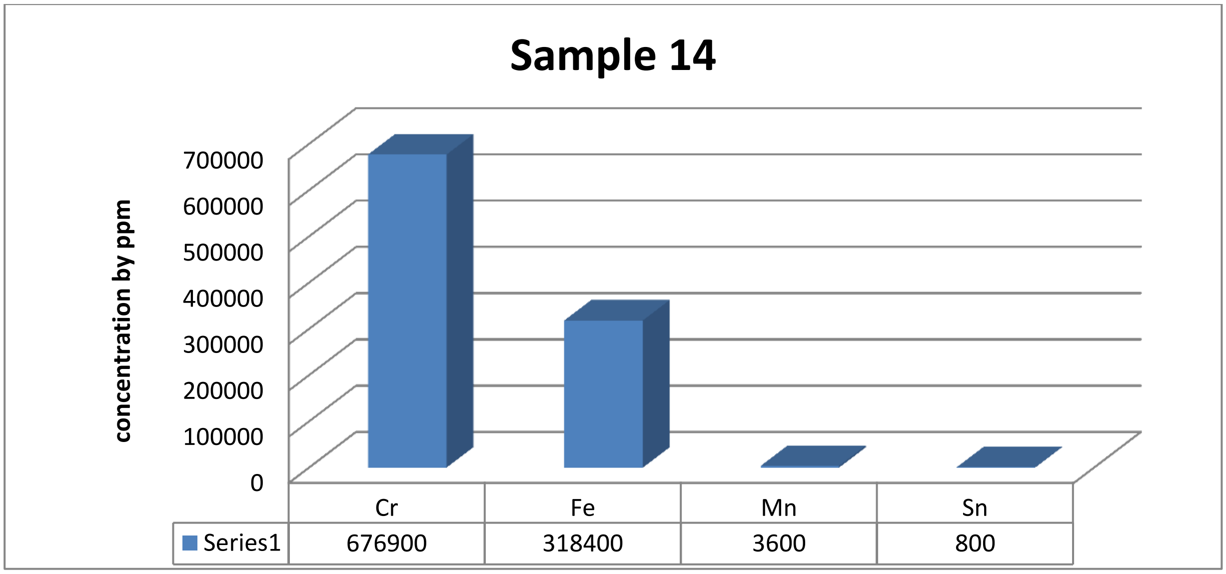


Fig (5.14) : plot show compare elements concentration in sample 14

From fig (5.15) it clear that the Cr has high concentration but Sn is low concentration.

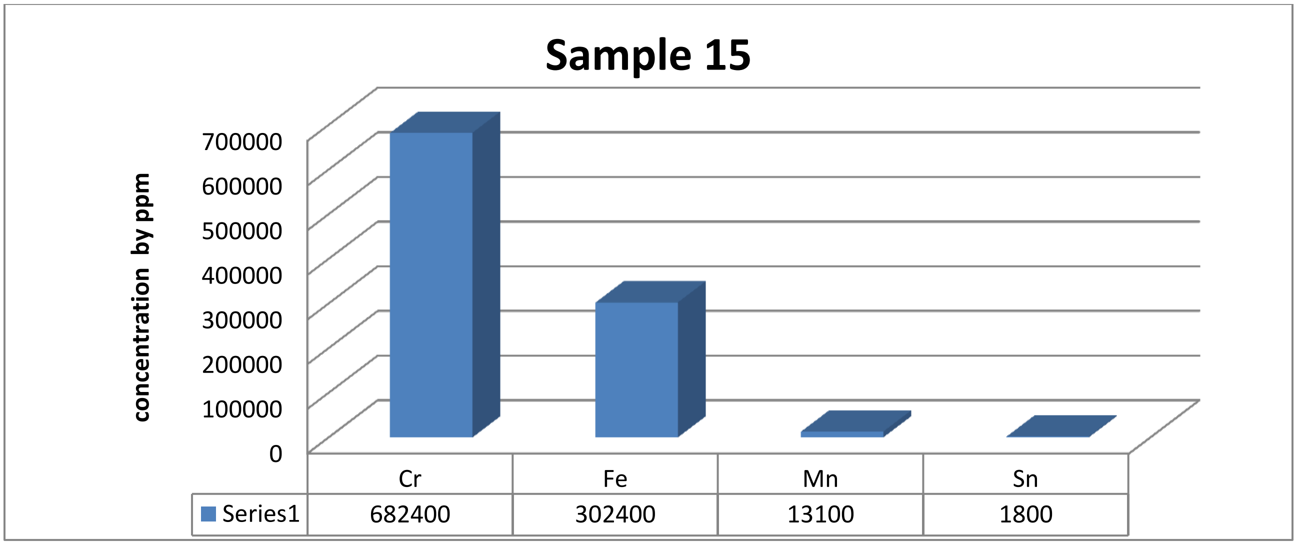


Fig (5.15) : plot show compare elements concentration in sample 15

From fig (5.16) it clear that the Cr has high concentration but Sb is low concentration.

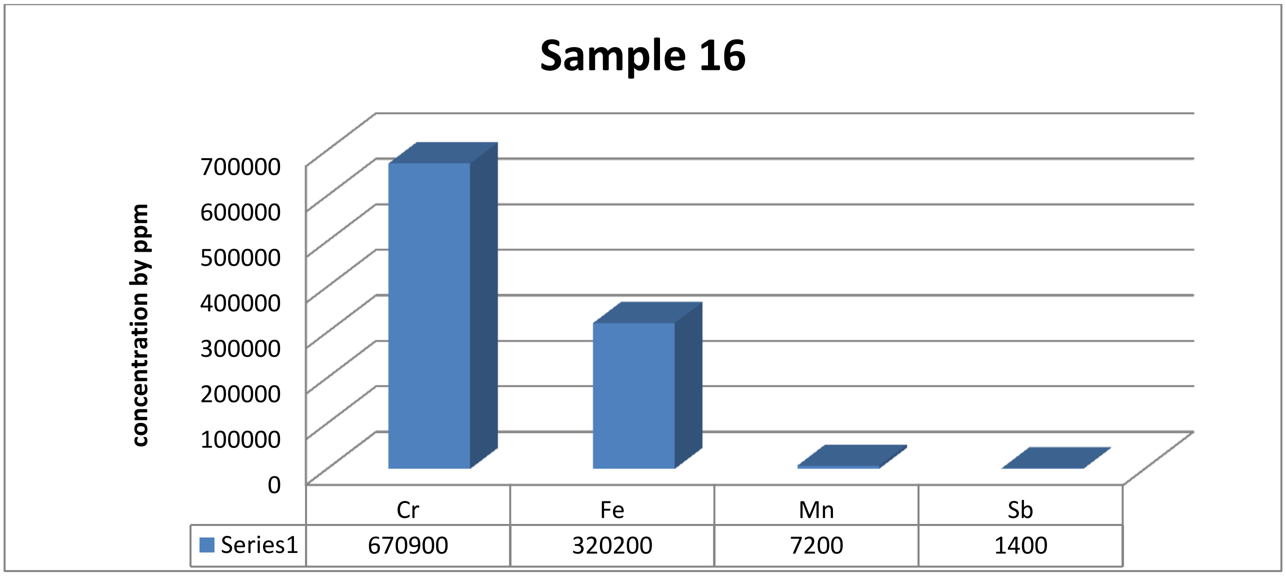


Fig (5.16) : plot show compare elements concentration in sample 16

From fig (5.17) it clear that the Cr has high concentration but Mn is low concentration.

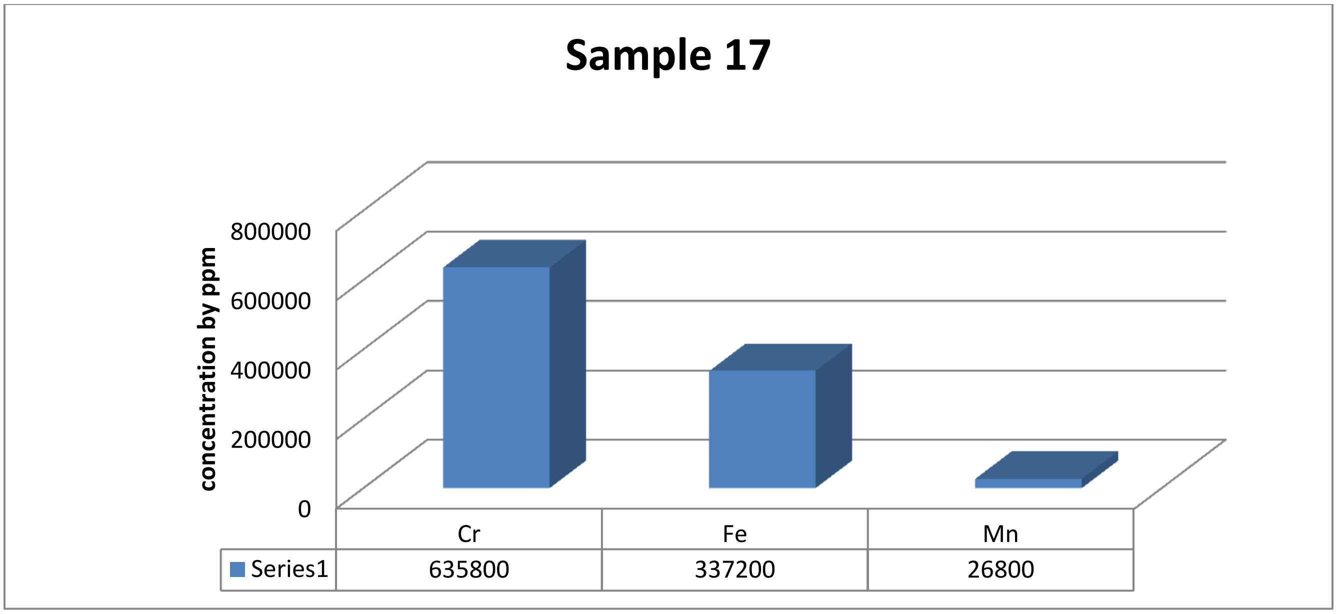


Fig (5.17) : plot show compare elements concentration in sample 17

From fig (5.18) it clear that the Cr has high concentration but Sn is low concentration.

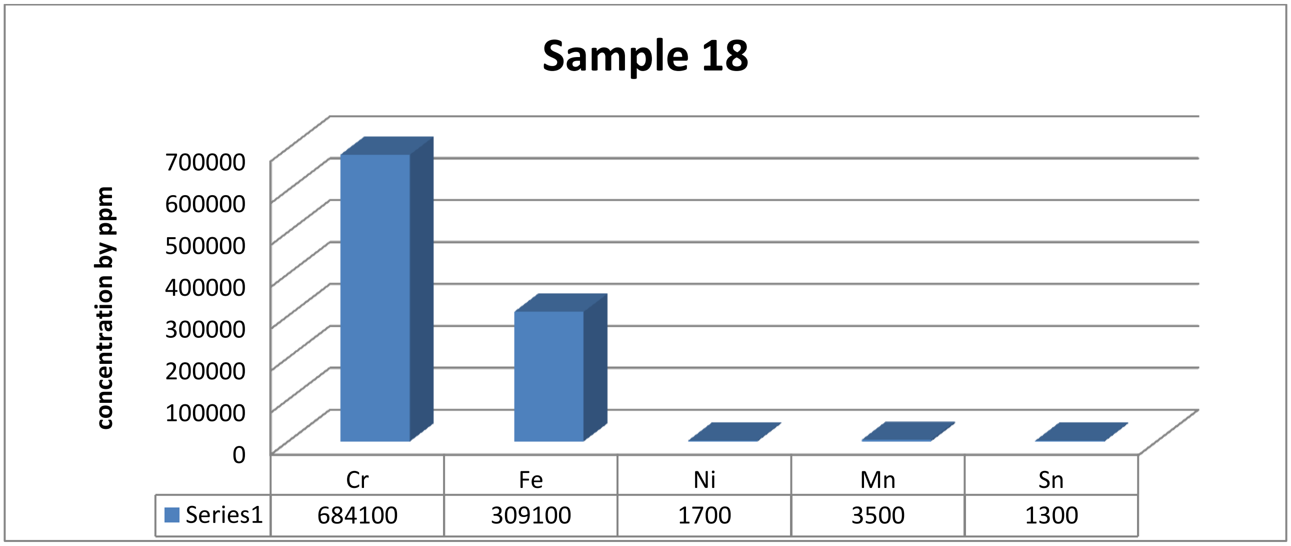


Fig (5.18) : plot show compare elements concentration in sample 18

From fig (5.19) it clear that the Cr has high concentration but Nb is low concentration.

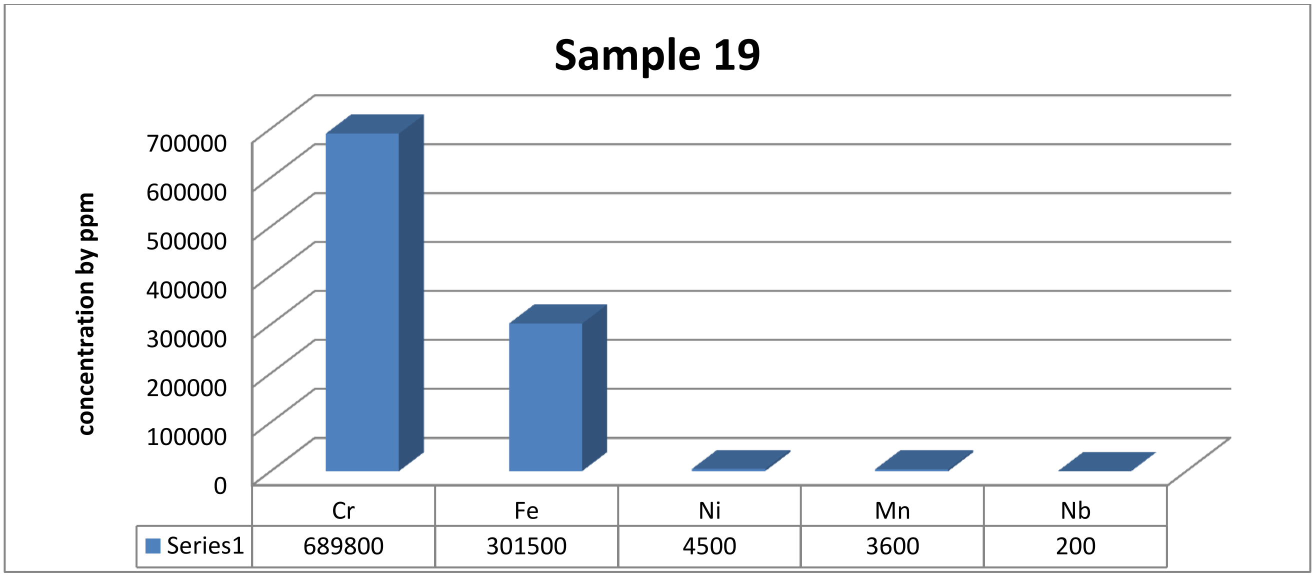


Fig (5.19) : plot show compare elements concentration in sample 19

From fig (5.20) it clear that the Cr has high concentration but Sb is low concentration.

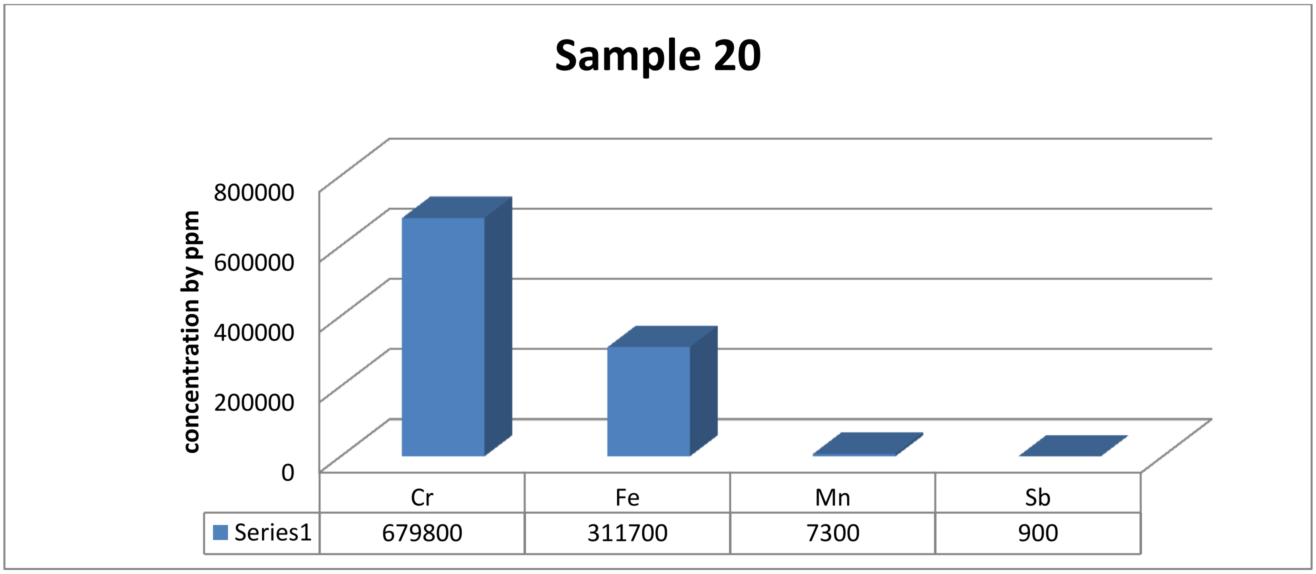


Fig (5.20) : plot show compare elements concentration in sample 20

From fig (5.21) it clear that the Cr has high concentration but Mo is low concentration.

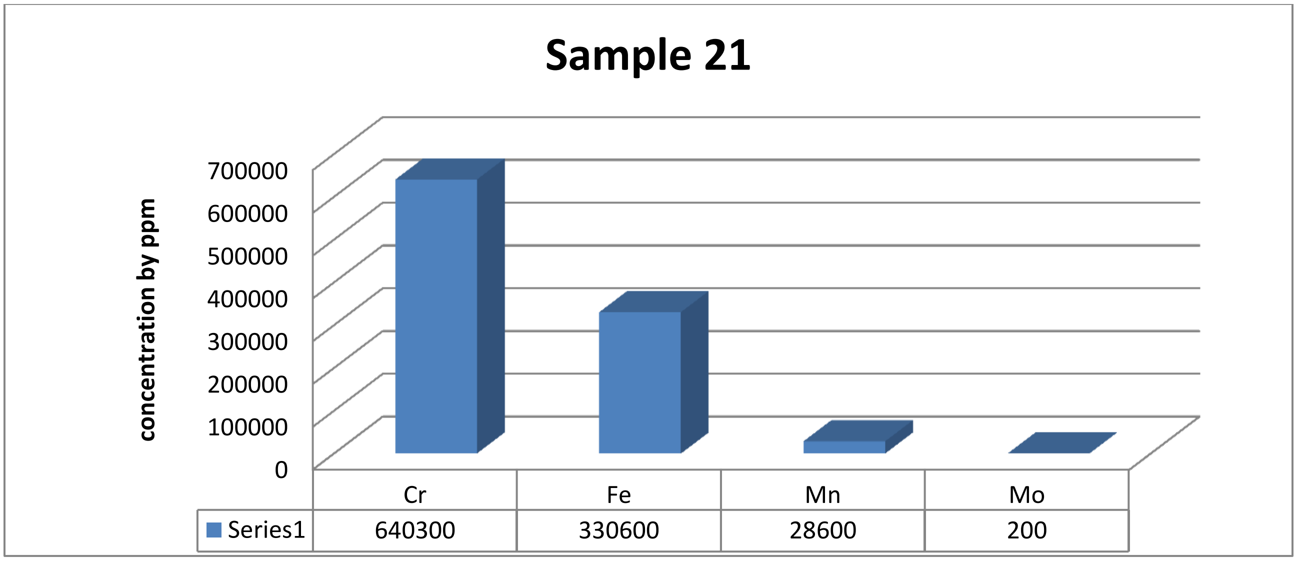


Fig (5.21) : plot show compare elements concentration in sample 21

From fig (5.22) it clear that the Cr has high concentration but Sn is low concentration.

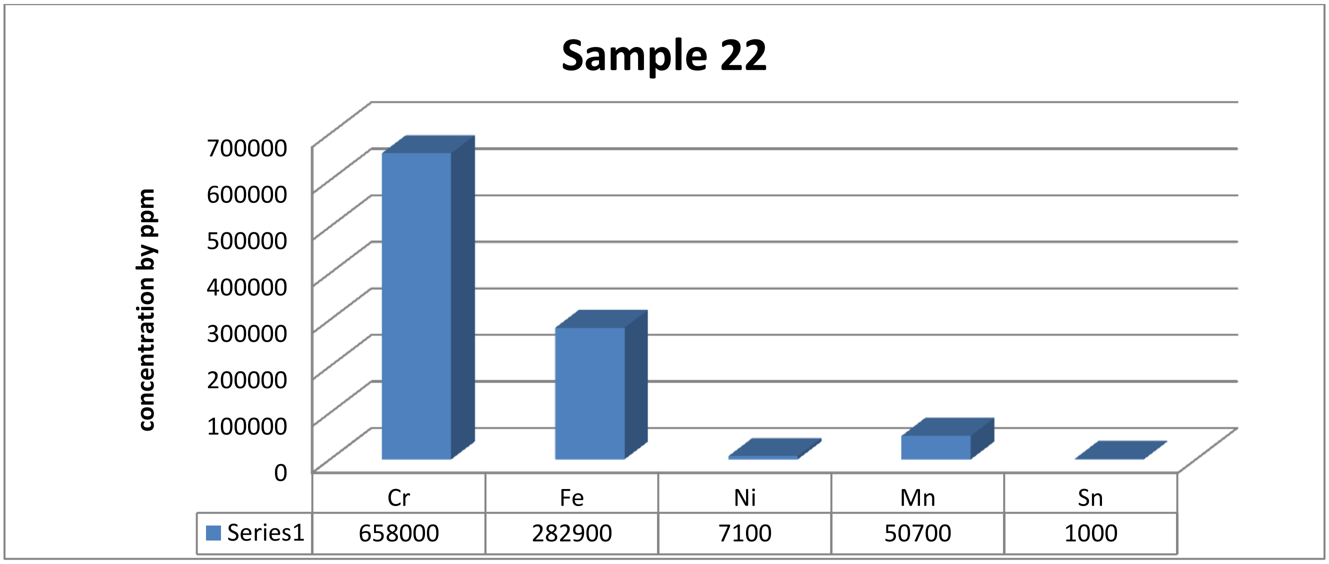
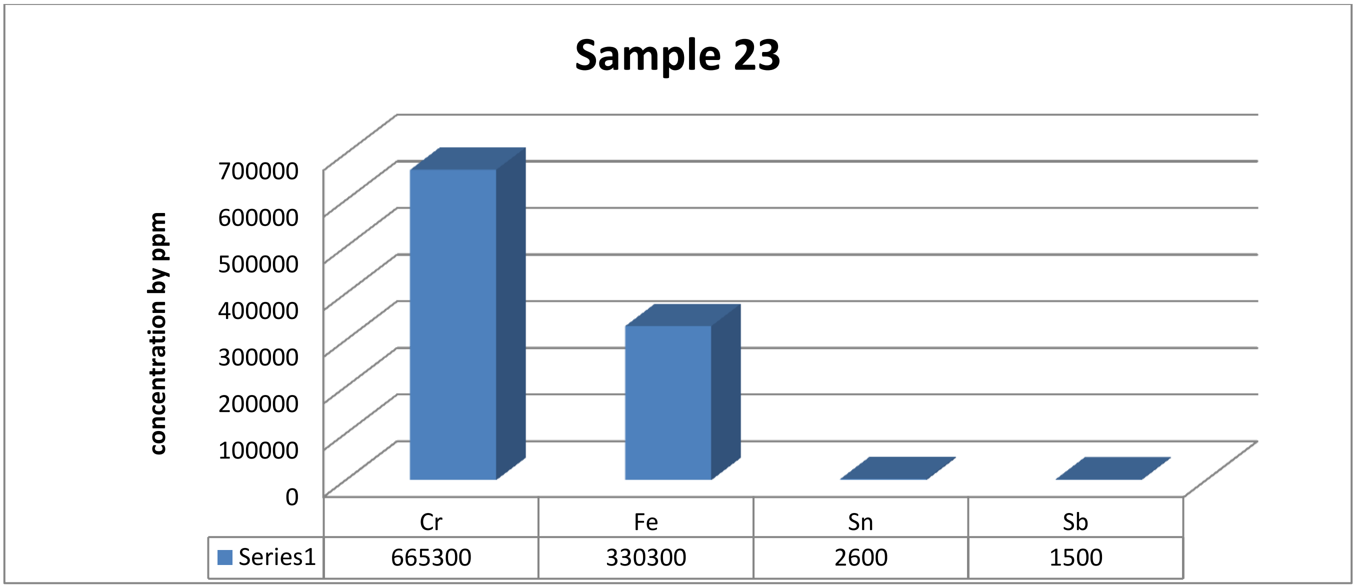


Fig (5.22) : plot show compare elements concentration in sample 22

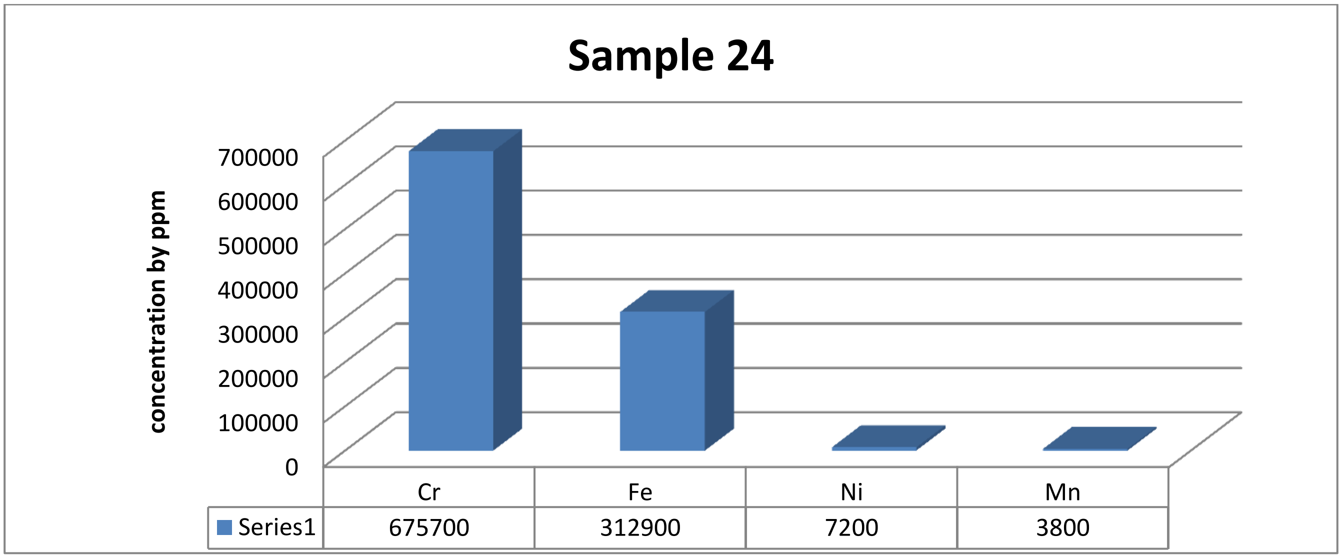
From fig (5.23) it clear that the Cr has high concentration but Sb is low concentration.



	Cr	Fe	Sn	Sb
▇ Series1	665300	330300	2600	1500

Fig (5.23) : plot show compare elements concentration in sample 23

From fig (5.24) it clear that the Cr has high concentration but Mn is low concentration.



	Cr	Fe	Ni	Mn
▇ Series1	675700	312900	7200	3800

Fig (5.24) : plot show compare elements concentration in sample 24

From fig (5.25) it clear that the Cr has high concentration but Zr is low concentration.

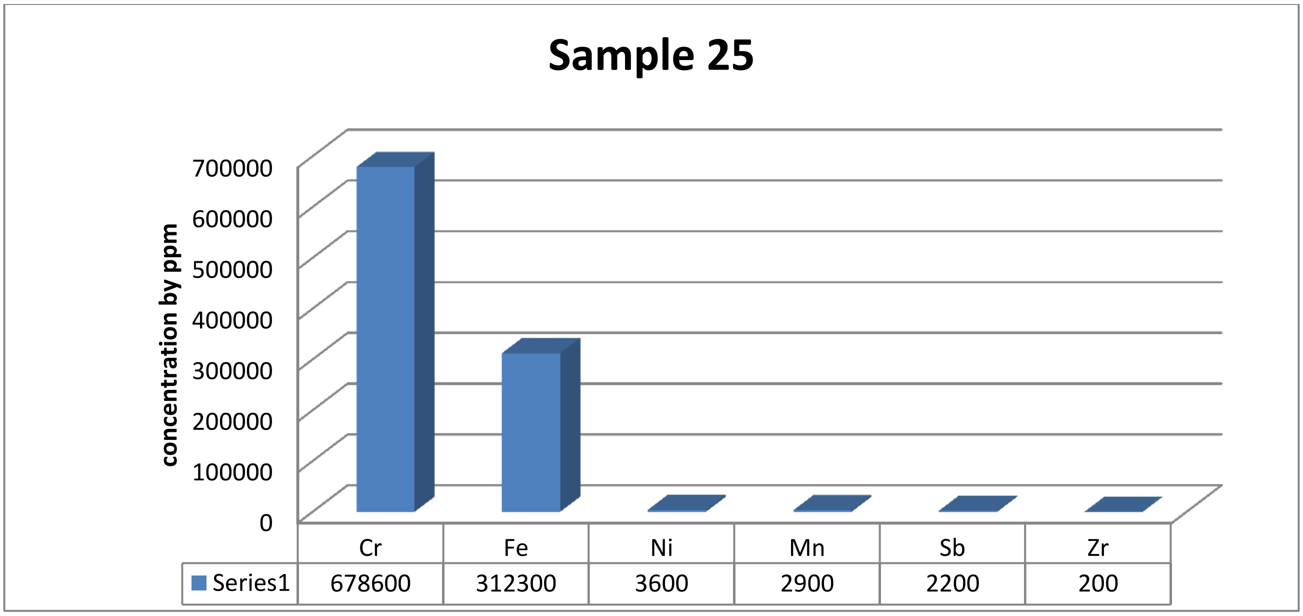


Fig (5.25) : plot show compare elements concentration in sample 25

From fig (5.26) it clear that the Cr has high concentration .

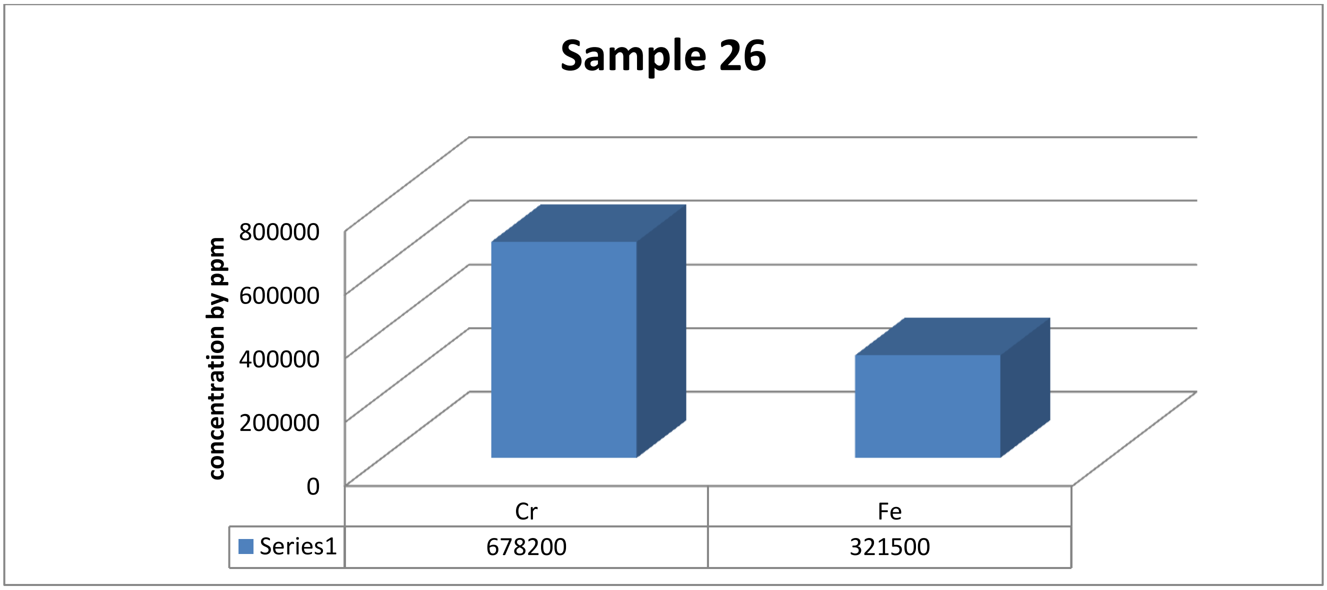


Fig (5.26) : plot show compare elements concentration in sample 26

From fig (5.27) it clear that the Cr has high concentration but Zn is low concentration.

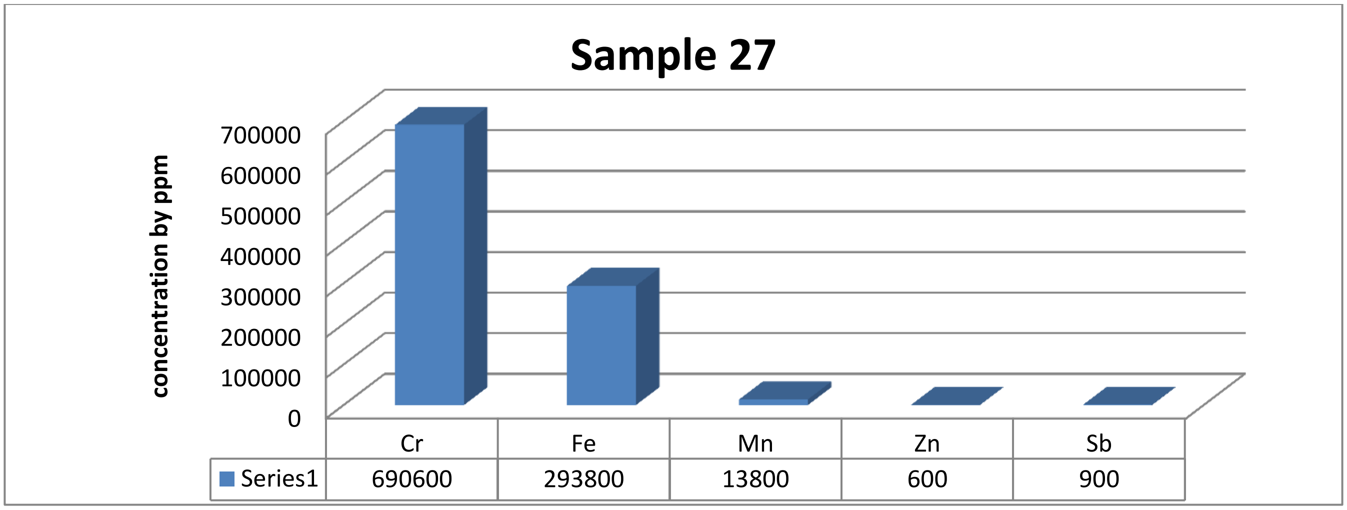


Fig (5.27) : plot show compare elements concentration in sample 27

From fig (5.28) it clear that the Cr has high concentration but Ni is low concentration.

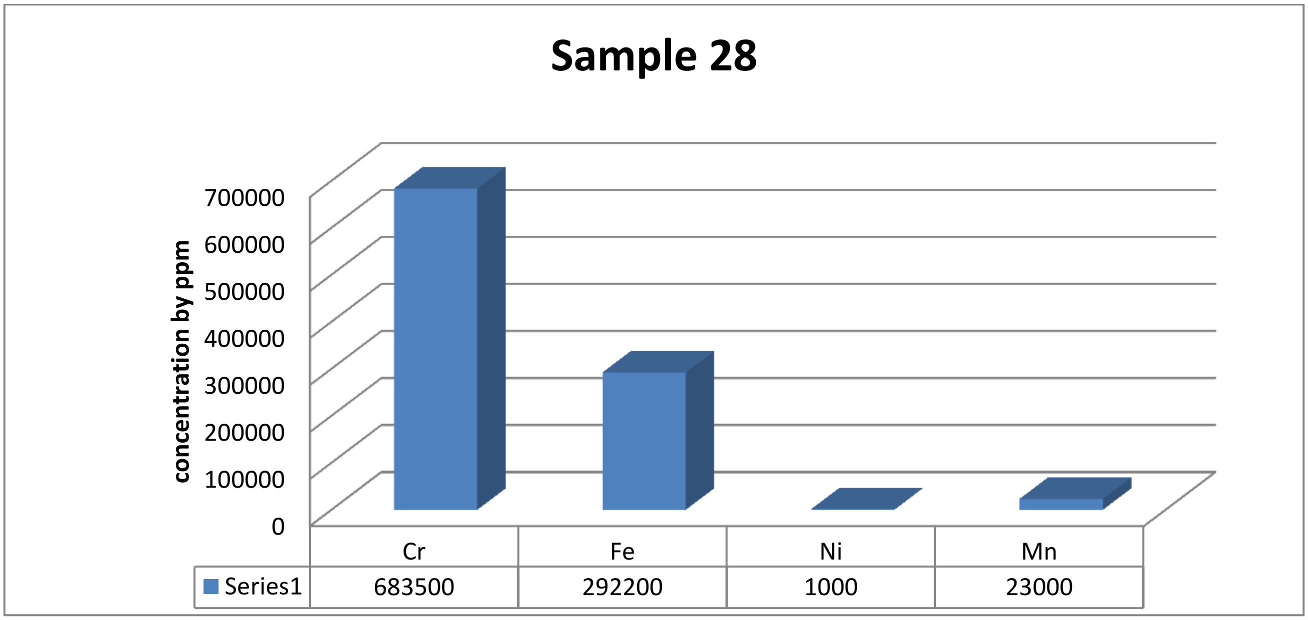


Fig (5.28) : plot show compare elements concentration in sample 28

From fig (5.29) it clear that the Cr has high concentration

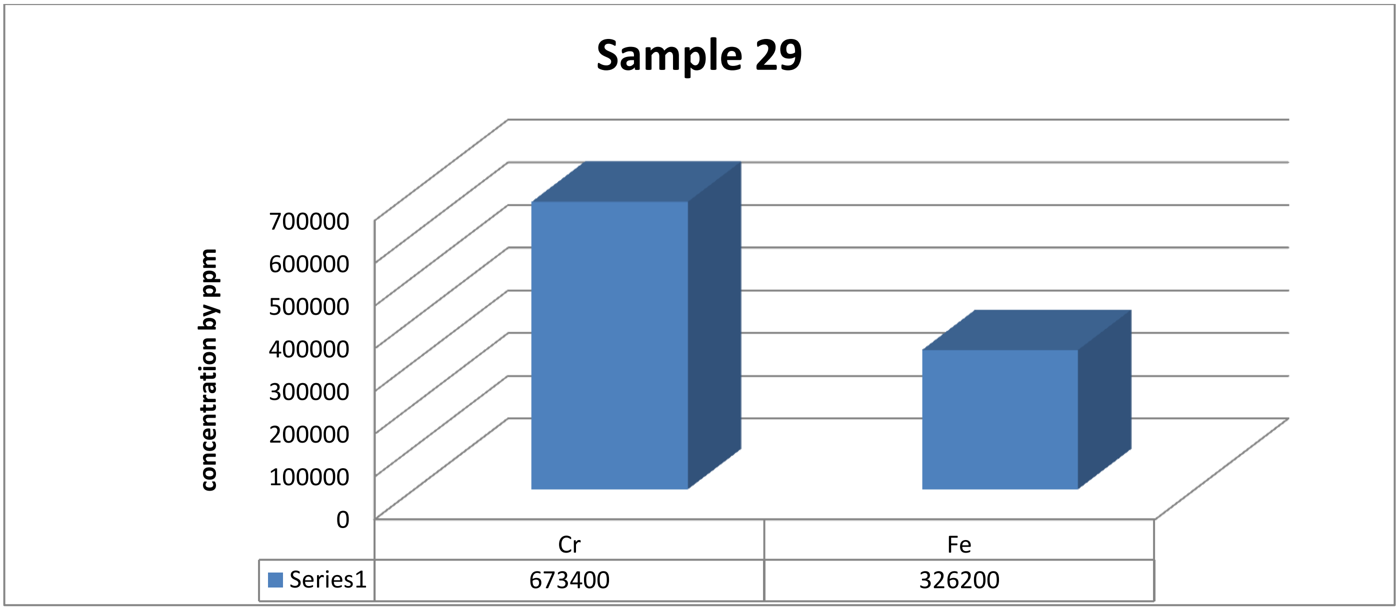


Fig (5.29) : plot show compare elements concentration in sample 29

From fig (5.30) it clear that the Cr has high concentration but Ni is low concentration.

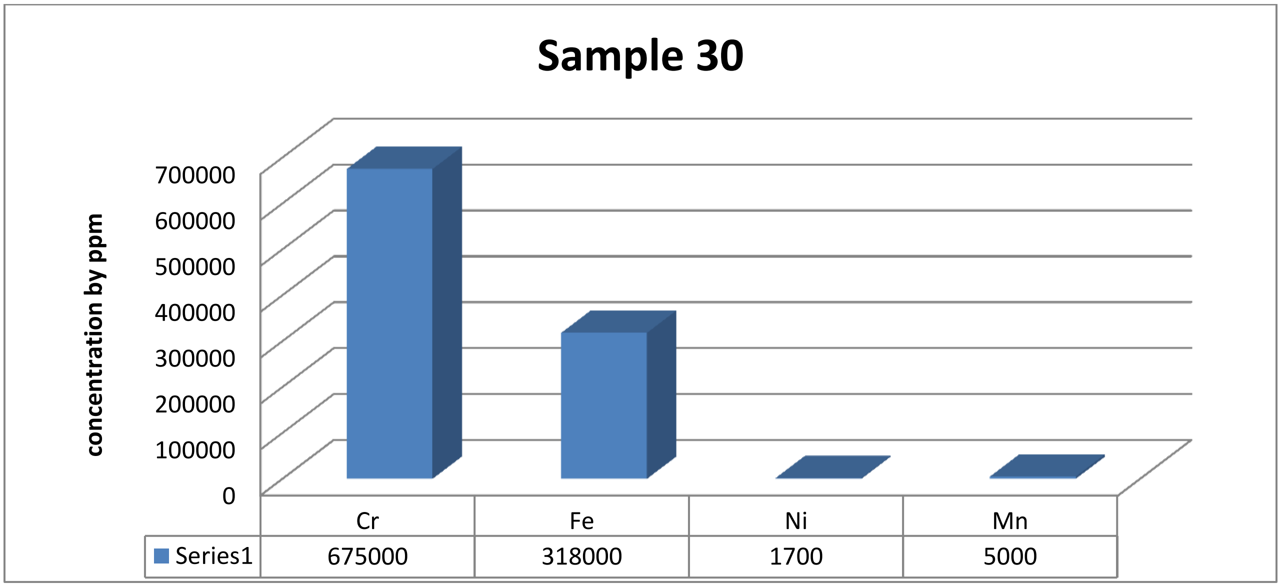


Fig (5.30) : plot show compare elements concentration in sample 30

5.2 Noticeable Results:

After analyzing 30 samples by XRF instrument, the result of the analysis shows that the concentration of chromium element in all samples and the range between (569000 – 738000) PPM, indicating that the samples are homogenous and also showed us that the area of Ingessana Hills high concentrations of chromium element, which heralds the economic future of the region and Sudan in general.

5.3 Statistical Analysis

From tables (5.2) to (5.4) and figures are presented the average concentration of the samples.

Table (5.2) : Statistical Analysis of concentration chrome in Ingessana hills .

No	Cr (PPM)	Deviation
01	569000	-102550
02	635800	-35750
03	639400	-32150
04	640300	-31250
05	649800	-21750
06	650700	-20850
07	658000	-13550
08	665300	-6250
09	669600	-1950
10	669800	-1750
11	670300	-1250
12	670900	-650
13	673200	1650
14	673400	1850
15	675000	3450
16	675700	4150
17	676900	5350
18	678200	6650
19	678700	7150
20	679800	8250
21	682400	10850
22	683500	11950
23	684100	12550
24	687100	15550

25	689100	17550
26	690600	19050
27	699800	28250
28	691400	19850
29	700700	29150
30	738000	66450
Average x^-	**671550**	-
Standard Deviation σ	8897.79	-

The average concentration of chromium in the ingassana hills is $(x^- \pm \sigma)$

(671550 ± 8897.79) parts per million . this means that one tone of ore gives (671550 ± 8897.79) grams of chromium

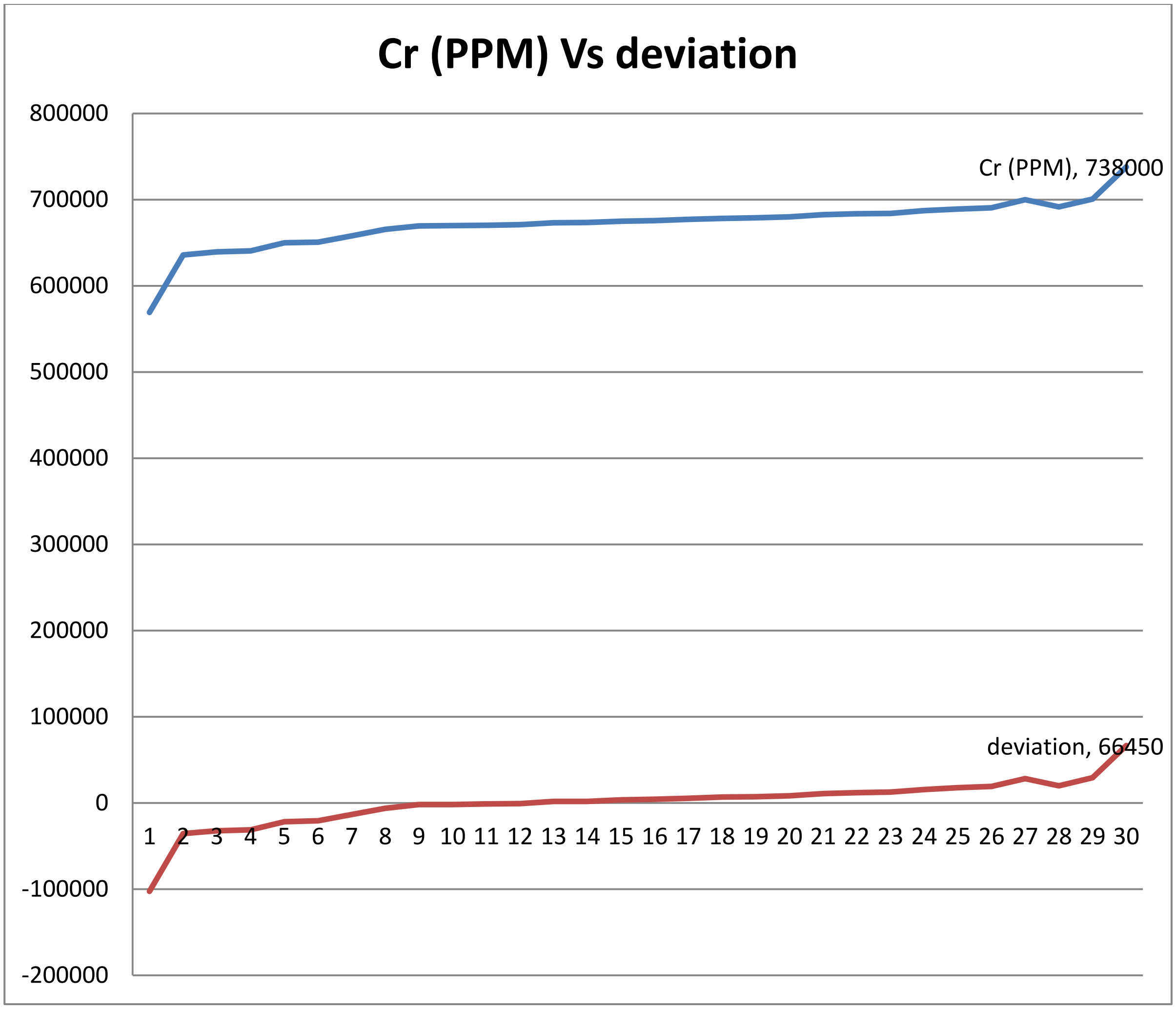


Fig (5.31): Statistical Analysis of concentration chrome in Ingessana hills

5.4The results of gamma spectroscopy measurements

Activity concentration of gamma-emitting radionuclides in rock samples from different locations in blue Nile State - ingassana hills for ^{226}Ra, ^{228}Th, ^{152}Eu, ^{134}Cs and ^{137}Cs and ^{40} K.

Table (5.3) : shows the concentration of radionuclides and their radioactivity found in rock samples in the Ingessana hills in blue Nile region .

ND refer to Non-Detection

Sample code	Element	Activity Bq/Kg	Relative uncertainty %	MDA, Bq
S1	K- 40	120	5	10.34
	Th-232	21.7	5	1.36
	Ra-226	13.7	6	0.89
	Th-228	4.7	16	2.22
	Eu-152	ND	ND	ND
	CS-134	ND	ND	ND
	Cs-137	ND	ND	ND
S2	K- 40	174	4	8.44
	Th-232	19.4	6	1.31
	Ra-226	10.9	7	0.92
	Th-228	ND	ND	ND
	Eu-152	4.7	17	5.22
	CS-134	ND	ND	ND
	Cs-137	ND	ND	ND
S3	K- 40	175	3	7.69
	Th-232	17.9	7	1.46

	Ra-226	16.8	6	0.79
	Th-228	ND	ND	ND
	Eu-152	ND	ND	ND
	Cs-134	ND	ND	ND
	Cs-137	ND	ND	ND
S4	K- 40	231	3	10.10
	Th-232	17.4	7	1.69
	Ra-226	13.7	6	0.89
	Th-228	ND	ND	ND
	Eu-152	ND	ND	ND
	Cs-134	ND	ND	ND
	Cs-137	ND	ND	ND
S5	K- 40	242	3	0.51
	Th-232	21.2	5	1.48
	Ra-226	15.7	6	1.00
	Th-228	ND	ND	ND
	Eu-152	ND	ND	ND
	Cs-134	1.06	15	0.65
	Cs-137	0.48	25	0.78
S6	K- 40	366	2.9	8.23
	Th-232	13.5	6	1.25
	Ra-226	12.5	6	0.87
	Th-228	4.1	14	1.88
	Eu-152	ND	ND	ND
	Cs-134	ND	ND	ND

	Cs-137	1.21	11	0.67
S7	K- 40	373	3	0.71
	Th-232	17.2	6	1.24
	Ra-226	12.4	7	0.97
	Th-228	3.00	26	0.35
	Eu-152	ND	ND	ND
	Cs-134	ND	ND	ND
	Cs-137	ND	ND	ND
S8	K- 40	184	5	0.86
	Th-232	25.6	5	0.82
	Ra-226	14.5	7	1.11
	Th-228	4.00	25	0.43
	Eu-152	ND	ND	ND
	Cs-134	ND	ND	ND
	Cs-137	0.38	22	0.88
S9	K- 40	312	3	9.32
	Th-232	16.2	5	1.16
	Ra-226	10.5	6	0.90
	Th-228	2.3	24	1.85
	Eu-152	ND	ND	ND
	Cs-134	ND	ND	ND
	Cs-137	ND	ND	ND
S10	K- 40	373	3	0.71
	Th-232	17.2	6	1.24

	Ra-226	12.4	7	0.97
	Th-228	3.00	26	0.35
	Eu-152	ND	ND	ND
	Cs-134	ND	ND	ND
	Cs-137	ND	ND	ND
S11	K- 40	316	3	4.33
	Th-232	17.1	6	1.28
	Ra-226	11.3	7	0.97
	Th-228	ND	ND	ND
	Eu-152	ND	ND	ND
	Cs-134	ND	ND	ND
	Cs-137	ND	ND	ND
S12	K- 40	65	6	5.93
	Th-232	23	5	0.07
	Ra-226	17.9	7	0.06
	Th-228	ND	ND	ND
	Eu-152	ND	ND	ND
	Cs-134	ND	ND	ND
	Cs-137	ND	ND	ND
S13	K- 40	197	3	6.32
	Th-232	15.5	7	1.40
	Ra-226	14.5	6	0.79
	Th-228	15.6	6	0.18
	Eu-152	ND	ND	ND

	Cs-134	ND	ND	ND
	Cs-137	ND	ND	ND
S14	K- 40	345	3	0.64
	Th-232	18.9	6	0.16
	Ra-226	9.6	7	1.10
	Th-228	ND	ND	ND
	Eu-152	ND	ND	ND
	Cs-134	ND	ND	ND
	Cs-137	ND	ND	ND
S15	K- 40	151	5	6.84
	Th-232	15.1	7	1.92
	Ra-226	13.7	7	0.99
	Th-228	13.2	8	2.16
	Eu-152	ND	ND	ND
	Cs-134	ND	ND	ND
	Cs-137	ND	ND	ND
S16	K- 40	151	5	10.97
	Th-232	10.3	10	1.94
	Ra-226	7.5	7	1.49
	Th-228	ND	ND	ND
	Eu-152	ND	ND	ND
	Cs-134	ND	ND	ND
	Cs-137	ND	ND	ND
S17	K- 40	283	4	0.73

	Th-232	12.2	7	1.20
	Ra-226	8.9	7	0.88
	Th-228	ND	ND	ND
	Eu-152	ND	ND	ND
	Cs-134	ND	ND	ND
	Cs-137	ND	ND	ND
S18	K- 40	373	2.2	3.52
	Th-232	8.00	8	0.71
	Ra-226	11.8	5	0.53
	Th-228	14.7	3	0.55
	Eu-152	ND	ND	ND
	Cs-134	ND	ND	ND
	Cs-137	ND	ND	ND

Table (5.4) : activity concentrations (Bq/Kg) of gamma emitters from ^{40}K, ^{226}Ra, ^{228}Th , ^{152}Eu , ^{134}Cs and ^{137}Cs in rock samples .

Sample code	**^{40}K**	**^{232}Th**	**^{226}Ra**	**^{228}Th**	**^{152}Eu**	**^{134}Cs**	**^{137}Cs**
S1	140	21.7	13.7	4.7	ND	ND	ND
S2	174	19.4	10.9	ND	4.7	ND	ND
S3	175	17.9	16.8	ND	ND	ND	ND
S4	231	17.4	13.7	ND	ND	ND	ND
S5	242	21.2	15.7	ND	ND	1.06	0.48

S6	366	13.5	12.3	4.1	ND	ND	1.21
S7	373	17.2	12.4	3.00	ND	ND	ND
S8	184	25.6	14.5	4.00	ND	ND	0.83
S9	312	16.2	10.5	2.3	ND	ND	ND
S10	352	19.7	11.8	2.5	ND	ND	ND
S11	316	17.1	11.3	ND	ND	ND	ND
S12	65	23.00	17.9	ND	ND	ND	ND
S13	197	15.5	14.5	15.6	ND	ND	ND
S14	345	18.9	9.6	ND	ND	ND	ND
S15	151	15.1	13.7	13.2	ND	ND	ND
S16	151	10.3	7.5	ND	ND	ND	ND
S17	283	12.2	8.9	ND	ND	ND	ND
S18	373	8.00	11.8	14.7	ND	ND	ND
Min	**65**	**8.00**	**7.5**	**2.3**	**4.7**	**1.06**	**0.48**
Max	**373**	**25.6**	**17.9**	**15.6**	**4.7**	**1.06**	**1.21**
Average	**246.1**	**17.21**	**12.63**	**7.12**	**4.7**	**1.06**	**0.84**

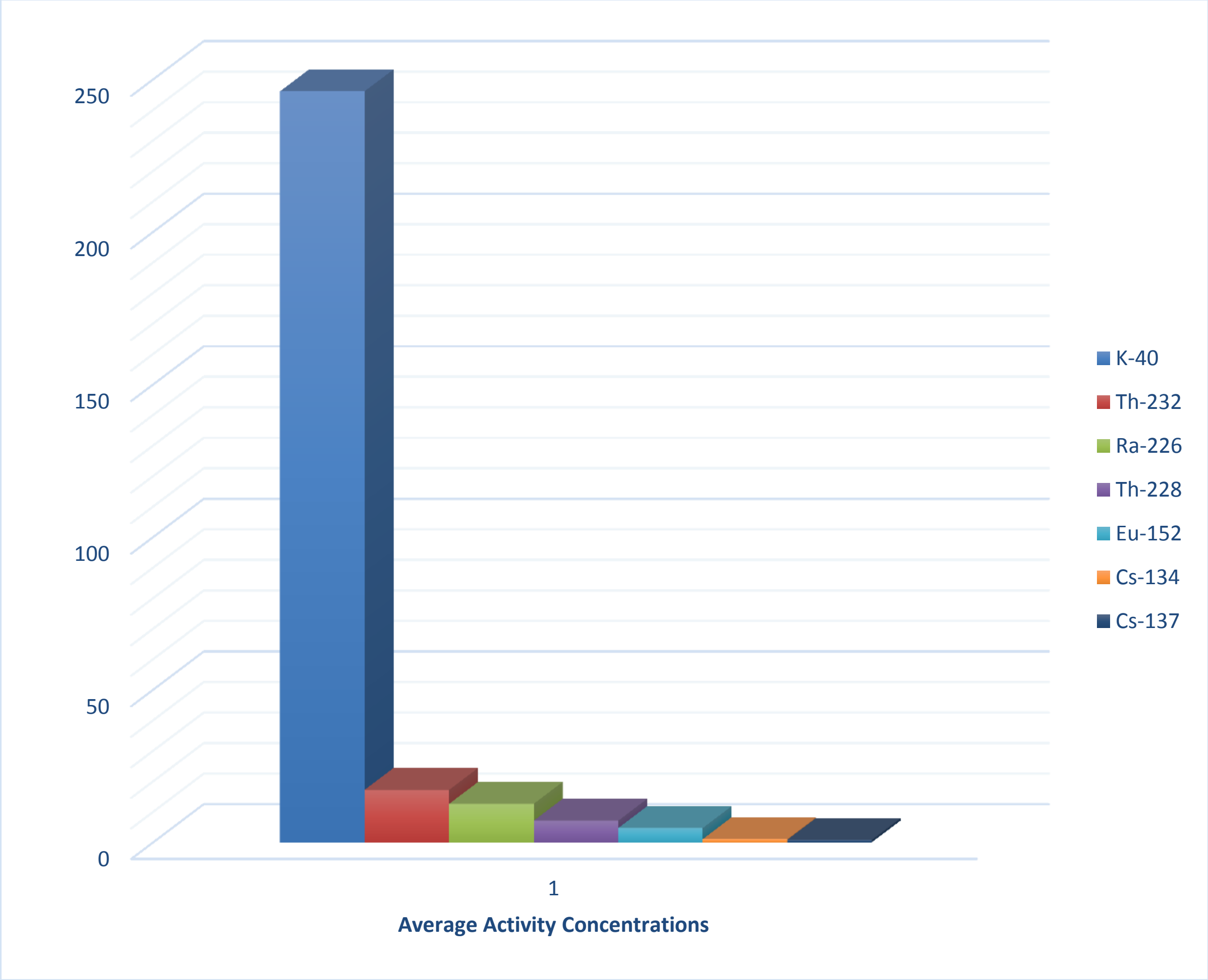


Fig (5.32): Average activity concentrations of ^{226}Ra, ^{228}Th, ^{152}Eu, ^{134}Cs and ^{137}Cs and ^{40} K. in rock samples from blue Nile state – Ingessana hills

5.5 Discussion

Form table (5.1) and fig (5.1) to fig (5.30) clear that The average concentration of chromium in the ingessana hills samples is (671550 ± 8897.79) (x^{-} ± σ) part per million. This means that one ton of ore gives (671550 ± 8897.79) grams of chromium.

Comparing these with some other values given in a previous study (chromium recovery from ingassana hills area chromium ore, Nile blue region, sudan .

Cr in some sample concentration measured by XFR TECHINQUE higher than control sample the higher contaminated found in watercress about (671550) ppm

Demand for ferrochrome, on the other hand, is significantly affected by fluctuations in production of stainless steel, the annual growth rate of stainless-steel production is expected to be about 3%, and the ferrochrome market has been and will continue to be in the state of oversupply. Accordingly, the prices of ferrochrome in the international market have been hanging low, and possibility of a price hike in the near future may be quite low.

Chrome in samples concentration measured by XRF Technique is higher concentration in ingessana hills area in Blue Nile region in Sudan the results for all samples about ((569000 – 738000) PPM).

It was observed through an analysis of the samples that the element of chromium is more related to the element of iron.

From table (5.3)note that the indicates radionuclides found in rock samples in terms of concentration and radiation activity.

From table (5.4) clear that the indicates average values of radiation activity obtained and the lowest and highest values of radiation activity It was observed that the radiation activity of the element k-40 was obtained at its highest values in all samples about (246.1) (Bq/Kg).

The significance of the current study relies on its contribution to the efforts being done to generate a radiation map for Sudan and on the targeted area.

The activity concentrations and the absorbed dose rates, due to ^{226}Ra, ^{232}Th and ^{40}K, These values obtained from the rocks samples were less than the recommended safe and criterion limits given by UNSCEAR.

The study uses Spectral HPGe detector to evaluate the activity concentrations of 226Ra, 232Th and 40K in 18 rocks samples taken from the Ingessana Hills , Blue Nile State,. The activity concentrations may be limited to the randomly taken samples and the results may not be generalized to the whole Ingessana Hills , Blue Nile State. More samples are needed to evaluate Results of the study could serve as an important baseline radiometric data for future epidemiological studies and monitoring initiatives in the study area. The statistical methods were applied to study the relationship between all the calculated natural radionuclides.

5.6 Conclusion

1. Through this study, the presence of chromium in the Blue Nile region of the Ingessana Hills was verified after samples were taken from this area. 2. The concentration of chromium in the analyzed samples was found to be highly variable. The average concentration of this element was 671550 PPM , after the statistical work of the results obtained. The samples were analyzed usingXRF.
   3. This element can be utilized because it enters many industries.

4. study radioactivity of radionuclides emitted ^{226}Ra, ^{228} Th, ^{152} Eu, ^{134} C, ^{137} C and ^{40} K was found in rock samples from different locations in someingassana hill by using gamma spectroscopy.

5.7 Recommendation

This study, conducted on the Ingassana Hills in the Blue Nile region, shows that the element of chromium is found in large quantities that can be used in the economy of the country by mining, processing and exporting. Whoever, it is difficult to provide water and fuel for that area. Also, there are difficulties in obtaining the appropriate drilling equipment and operators locally. The matter necessitates to be studied accurately and requires great effort to evaluate the project before the start of work, which is costly in terms of material, and must evaluate the necessary equipment and drilling equipment for work and transport means and study all aspects of the project, and the attraction of the work environment and the provision of hands The necessary package for that project.

Sudan has a considerable potential of chromite, which as yet has to be evaluated. The already evaluated resources at Ingessana must be best exploited. Grinding and gravity concentration will definitely add value to the mined high-grade ores of the Ingessana area. Low-grade ores likewise, can be upgraded and used locally for the production of chromium salts.

Ophiolitic belts in other parts of Sudan must be explored for chromite resources. Evidence of chromite mineralization exist in most of them.

The possible total reserve has been estimated at 250 million tons with 60% iron content.

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