

**OCCURRENCE, MINERALOGICAL COMPOSITION
AND SIGNIFICANCE OF LATERITES
IN KENYA**

SGL 413: PROJECT IN GEOLOGY

KOILEGE TIMOTHY

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*A Research Project Submitted to the Department of Geology of the University of
Nairobi in partial fulfillment for the Degree of Bachelor Of Science in Geology*

JUNE, 2011

DECLARATION

Declaration by Student

I declare that the attached research paper is my own original work undertaken in partial fulfillment of my degree in Geology and it has not been presented to any other University

NAME:

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Approval by University Advisor

This Research Project has been submitted for examination with approval as Advisor.

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ABSTRACT

The study area is Kenya a country in Eastern Africa bordered by Ethiopia to the north, Somalia to the east, Tanzania to the south, Uganda to the west, and Sudan to the north-west, with the Indian Ocean running along the southeast border. It is bounded by latitudes 4°S' and 4°N' and longitudes 34°E' and 42°E with an area of 582,646 km². In Kenya Laterites distribution and occurrence has not been studied in detailed. However, studies on soil types in the country have shown that Lateritic soils that occur are of three types. a) Nitisols, the type common especially in the tropical highlands and volcanic steep slopes like Mt. Kenya. b) Ferralsols which occur on gently undulating to undulating topography like in Tsavo. They are very old, highly weathered and leached soils that are rich in Aluminium (Al) and Iron (Fe). c) Acrisols type which occur in the coffee zones in the sub-humid areas, on undulating to hilly topography like Thika area. Where deposits have been found they have found use in surfacing of most roads in the country and in making of bricks for building construction.

However, from research study, it has been found that Laterites is an important mineral resource that can be used in defluoridation of ground water with high fluoride concentrations especially, the Rift Valley. An experiment done showed that in 24 hours the fluoride concentration was reduced from 15 Mg/L to about 1 Mg/L in soil samples including Lateritic soils. It has also been found that supergene enrichment in Laterites show traces of Ni, Cr, and Cu that can form ore deposits. Apart from supergene enrichment, Laterites which occurs in association with mafics and ultramafics like serpentinites, dunites, Komatiites rocks and in ophiolite suites may hold ore deposits of mainly Fe, Ni, Co (\pm Cu) which can be mined commercially in any suitable geological terrane. A good example is the New Caledonia deposit in Australia where nickel occurs in highly serpentinitized ultrabasic Lateritic rocks.

Key Words: Laterites, Defluoridation, Supergene enrichment, Ore deposits

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DEDICATION

To my late father Stephen, mothers Eunice and Late Selly, Brothers Ng'etich, Kibe, Chirchir, Kiprotich, Kiplagat and Sister Jemu.

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CHAPTER ONE

1.1 Introduction

Laterites are surface formations rich in Iron and Aluminium, formed in hot and wet tropical areas. They are mostly rusty-red because of Iron oxides. It develops by intensive and long-lasting weathering of the pre-existing rocks by action of rainwater to produce a wide variety in the thickness, grade, chemistry and ore mineralogy of the resulting soils. As rainwater soaked through the rocks, it broke down mineral grains forming the rock and dissolved away elements like sodium, potassium, calcium, magnesium and silicon leaving Iron and Aluminium as hydrated oxides (Laterites).

An essential feature for the formation of Laterites is the repetition of wet and dry seasons. Rocks are leached by percolating rain water during the wet season; the resulting solution containing the leached ions is brought to the surface by capillary action during the dry season. These ions form soluble salt compounds which dry on the surface; these salts are washed away during the next wet season. The residue left after weathering may form layers of fine-grained material around much altered part of the original rock producing the round gravel pellets, as well as solid masses of oxide or may be cemented together to produce a kind of conglomerate.

Active laterization extended from about the Mid-Paleogene to the Mid-Quaternary periods i.e. (35 to 1.5 million years ago) forming thick lateritic deposits.

Laterites are mainly used in surfacing roads and making bricks for building construction in almost all parts of the country. Studies have revealed that the resource can also be used in exploration of important ore of nickel, cobalt, iron and copper and also in defluoridation of ground water by its adsorption properties thus reducing the concentrations of fluoride to amounts fit for consumption. Supergene enrichment of trace elements like Cr, Cu and Si are also present in Lateritic deposits.

1.2 General Introduction of the study area

1.2.1 Location

The study area is Kenya a country in Eastern Africa bordered by Ethiopia to the north, Somalia to the east, Tanzania to the south, Uganda to the west, and Sudan to the north-west, with the Indian Ocean running along the southeast border. It is bounded by latitudes 4°S ' and 4°N ' and longitudes 34°E ' and 42°E with an area of 582,646 km² as shown in geological map (figure 1.1).

1.2.2 Overview of the Geology of Kenya

Generally the geology of Kenya can be grouped into the following major geological successions: The Archaean (Nyanzian & Kavirondian); Proterozoic (Mozambique Belt & Bukoban) Palaeozoic/Mesozoic and Tertiary/Quaternary sediments. See Figure 1.1 (Geological Map).

Quaternary sediments consist of Soils, alluvial beach sands, evaporites, fossil coral reefs and sandstones at the coast: alluvial, lacustrine sediments and volcanic rocks from the younger volcanoes of the Rift Valley.

Tertiary succession consists of Coastal sediments, Late Miocene and Pliocene volcanics, Terrestrial and lacustrine inland sediments.

Palaeozoic/Mesozoic (Cretaceous, Jurassic, Triassic, Permian and Carboniferous) successions consist of the Karroo formations of the coastal hinterland, including the basal sedimentary formation in north-east Kenya.

The Proterozoic consist the Kisii series and Volcanics with sediments in the Bukoban 'system', while the Mozambique Belt consist of Biotite/hornblende, granitoid gneisses, schist, amphibolites, migmatites and quartzites. We also encounter syntectonic intrusive granites.

Lastly the older succession of Archaean is divided into one, Kavirondian 'system' which is a group of sedimentary sequence that consist of sandstones, mudstones, conglomerates. Two is the Nyanzian 'system' which is mainly volcanic and consists of shales, cherts, ironstones, Pyroclastics, Rhyolites, Andesites and Basalts.

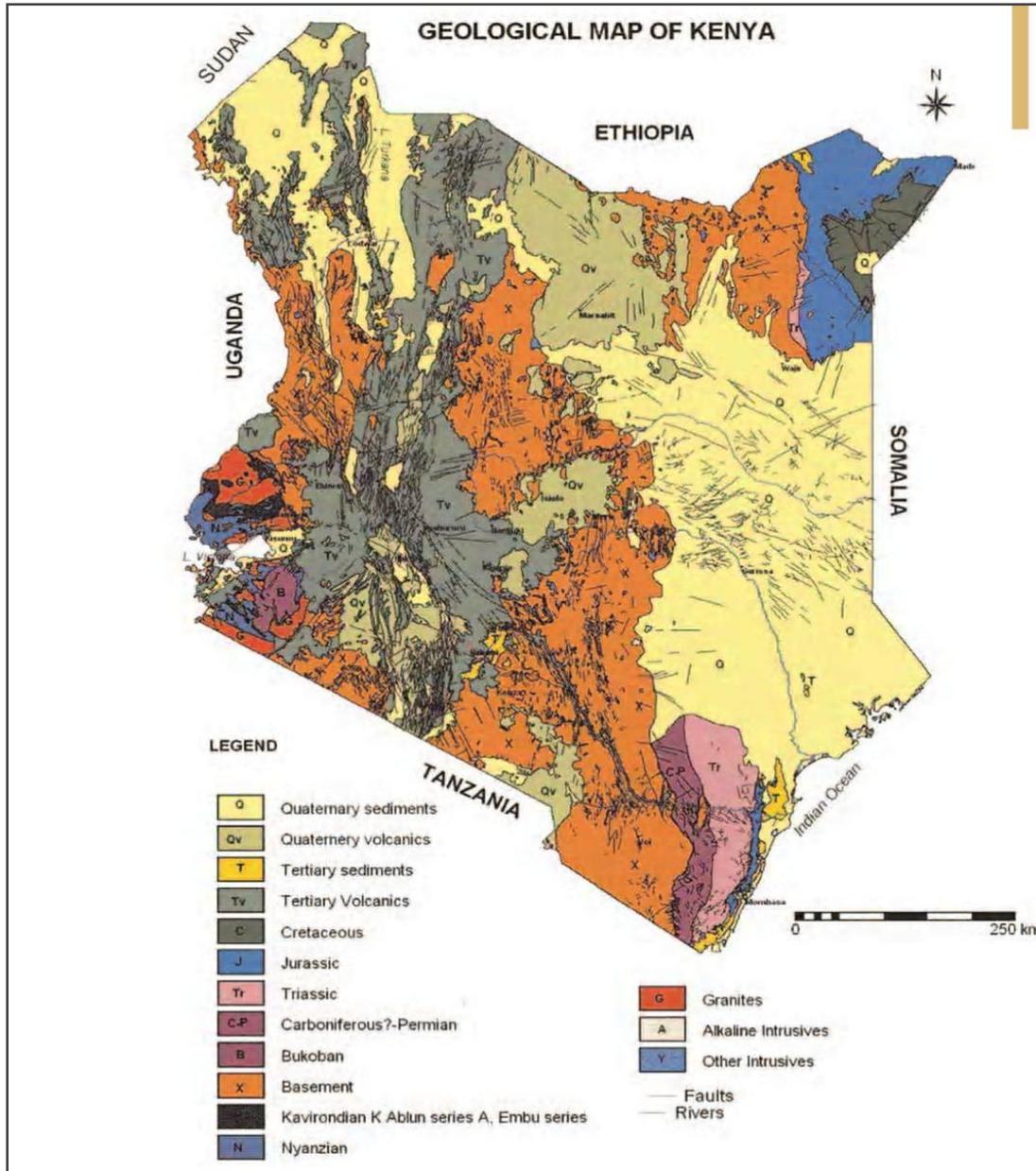


Figure 1.1: Geological Map of Kenya (SEAMIC- Southern and Eastern African Mineral Centre)

1.3 Aims and Objective

- 1) Establish the extent and occurrence of Laterites in Kenya
- 2) Establish the mineralogical composition and supergene enrichment in Laterites
- 3) Establish other significance of Laterites apart from surfacing of roads and making of bricks for building construction

1.4 Literature Review

Raychaudhuri and Mukierjee (1942) studied the mineralogical composition of Indian red soils and lateritic soils and found iron oxide, zircon, tourmaline, staurolite, chlorite, hornblende, epidote, and rutile among the heavy fractions, while in the light fractions the minerals consisted of feldspars and quartz. Roy and Landey (1962) have found the occurrence of illitic mineral with some kaolinite and quartz in the red and Laterite soils of Mand watershed in Rajgarh district in Madhya Pradesh.

Coetzee, *et al* (2003) investigated the adsorption characteristics of South African clay types and their potential as adsorbents for simple defluoridation systems. He found that not many S. African clays were useful adsorbent for fluoride but the clays consisting of substantial amounts of gibbsite or aluminium oxides showed the best overall potential as fluoride adsorbents.

Investigation of defluoridation options for rural and remote communities in the northern Territory by Dysart, (2008) found that bauxite (highly leached Laterite) appears to be a potential defluoridation media for treating drinking water and may be sourced locally, relatively economically and warrants further investigation to effectively treat water in the remote communities. It adsorbed fluoride from natural waters to lower concentrations though the process was slow.

1.5 Statement of the problem

The occurrence of Laterites in the country has only found use in surfacing of roads and making of bricks but the study of its composition and possible supergene enrichment has not been established. Therefore its study may lead to discoveries of ore deposits like the Lateritic nickel ore deposits in the country.

Ground water resources have been widely used or the most widely used resource in homes, urban centres/towns and in industries for example in Nakuru town, Kenya. Unfortunately most of the waters in the floor of the Rift Valley have high fluoride concentration that has caused dental and skeletal fluorosis among individuals living in these areas.

1.6 Research questions

1. What is the extent and occurrence of Laterites in Kenya?
2. What is the mineralogical composition of Laterites?
3. Is there supergene enrichment in Laterite deposits?
4. How can Laterites deposit be utilized as an important resource in the country?

1.5 Output

1. Map showing the occurrence and distribution of Lateritic soils in Kenya.
2. Table showing the relationship between the parent/host rock and the enrichment of oxides and trace elements
3. Graph showing relationship between fluoride concentrations and adsorption by Laterites

CHAPTER TWO

OCCURRENCE, MINERALOGICAL COMPOSITION AND SIGNIFICANCE OF LATERITES

2.1 Occurrence of Laterites in Kenya

Laterites and lateritic soils are formations peculiar to equatorial and tropical areas. There are three types of Lateritic soils that occur in Kenya: Nitisols, Ferralsols and Acrisols as shown in figure 2.1 (soil map of Kenya) below.

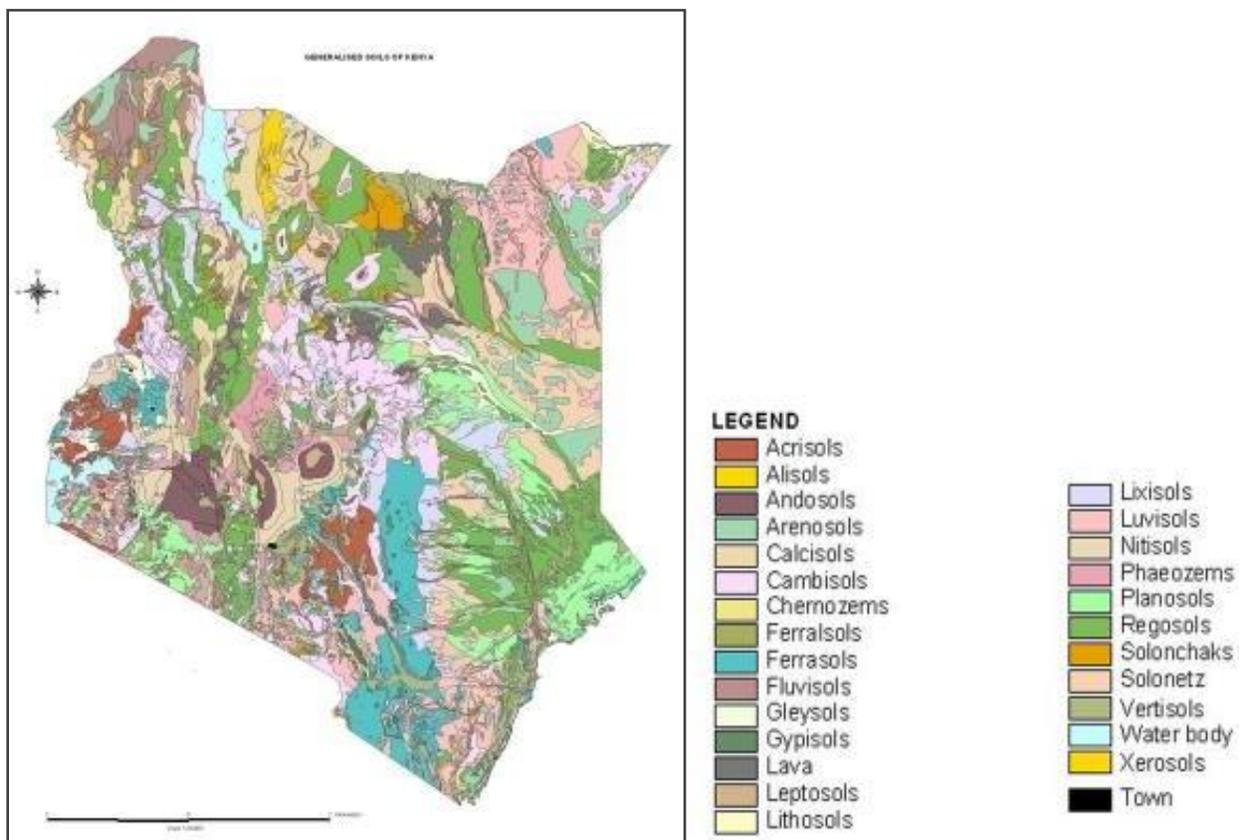


Figure 2.1: Generalized soil map of Kenya (Kenya Soil Survey)

In Kenya, Nitisols soil type of Laterite is common especially in the tropical highlands and volcanic steep slopes like Mt. Kenya. They are fertile with about 30% clay, low phosphorus and are dark red in colour. Ferralsols occur on gently undulating to undulating topography like in Tsavo. They are very old, highly weathered and leached soils, and therefore with a poor fertility, which is restricted to the top soil, as the subsoil has a low cation exchange capacity. Phosphorous (P) and Nitrogen (N) are always deficient. They are also rich in Aluminium (Al) and Iron (Fe). Acrisols soils occur in the coffee zones in the sub-humid areas, on undulating to hilly topography like Thika area.

Studies on the distribution and occurrence of Laterites in Kenya have not been widely carried. However, the studies of soil type have contributed to knowing its probable occurrence.

2.2 Mineralogical composition and Supergene Enrichment

The mineralogical and chemical compositions of Laterites are dependant on their parent rocks. Laterites consist mainly of quartz and oxides of titanium, zircon, iron, tin, aluminium and manganese, which remain during the course of weathering. Quartz is the most abundant relic mineral from the parent rock.

Laterites vary significantly according to their location, climate and depth. The main host minerals for nickel and cobalt can be Iron oxides, clay minerals or manganese oxides. Iron oxides are derived from mafic igneous rocks and other iron-rich rocks; bauxites are derived from granitic igneous rock and other iron-poor rocks. Nickel Laterites occur in zones of the earth which experienced prolonged tropical weathering of mafic/ultramafic rocks containing the ferromagnesian minerals olivine, pyroxene, and amphibole.

Moufti (2008) in his Field, Mineralogical and Geochemical Characteristics of As-Sarat Laterite Profiles of SW Saudi Arabia found that Laterites show enrichment behaviour of the major oxides and trace elements during ancient and recent weathering.

This is summarized in Table 1.1 below. This table shows diversity in ion types as being controlled by the original silicate mineralogy and the ore minerals present, particularly Fe-Ti oxides and minor sulphides.

Table 1.1: Enrichment of major oxides (as cation) and trace elements (in brackets) during Ancient and Recent weathering.

	Recent weathering		Ancient weathering			
Locality	N. Al-Wahaba	Al-Jawf	W. Al-Wahaba	Ash-Shara	Al-Qubal	Ad-Drama
Upper horizon	Si (Cr, Cu)	Si, Al, Ti, Mg (Ni, Pb)	Si, Al, Fe ⁺³ , Ca, Na	Fe ⁺³ (Ba)	Ti, Al, Fe ⁺³ , Mn, P (Cr, Cu, V)	Ti, Fe ⁺³ , Mn, P (Cr, Cu, Ni, V, S)
Transition horizon	Fe ⁺³ , Fe ⁺² , Ca, K, P (Ba, Cl)	Fe ⁺³ , Fe ⁺² , Ca, K (Cu, Ba, Cl)	Mg, K (Cr)	Al, Ca, K, P (Pb, Cl)	Fe ⁺² , Ca, K, Na (S)	Al, Ca, K, Na (Pb, Ba, Cl)
Lower horizon	Al, Fe ⁺³ , Mg, Na (Cr, Cu, V, Pb, S)	Fe ⁺³ , Na (Cr, Cu, Ni, V, Ba)	Ti, P (Cu, Pb, Cl, S)	Si, Ti, Fe ⁺² , Mg, Na (Cr, Cu, Pb, Ni, Cl)	Si (Cr, Pb, Ba, Cl)	Si, Fe ⁺² , Mg
Parent rock	Basalt	Scree-debris	Metagabbro to amphibolite	Altered olivine rock	Serpentinite	Gabbroic rock

In the table above, some transitional trace elements (namely Cr, Cu, Ni and Fe³⁺) are allied to the ferric iron in the weathered scree-debris and allied to aluminium and ferric iron in the weathered basaltic blocks. The table also indicates that enrichment of iron content occurs at the expense of Si, Al and Mg in the transition and lower horizon of the profile.

The mineralogical composition and enrichment of Laterites of the South West Saudi Arabia occurs in the Arabian-Nubian shield. The geological environment and climatic conditions is more or less similar to the Mozambique belt (MB) which according to Saggerson (1967) is part of the East African Orogen (EAO) that extends from Arabian to Nubian shield in the North.

2.3 Significance of Laterites in Kenya

Laterites have found their use in surfacing roads in almost all parts of the country. The resource has also been used for making bricks and it can also be cut into regular sized blocks while wet or moist, and then dried under a shade for slow drying and thus making blocks without cracks. No firing is required for this but in case lateritic soils are used then making of bricks would require a kiln for firing. The final product finds its use in building constructions.

Thick layer of Lateritic material is porous and slightly permeable and can therefore function as an aquifer (water bearing rock) that would be significant source of ground water. The water would be good for drinking because of the ability of Laterites to reduce fluoride concentrations by adsorption.

Laterites have therefore found minimal uses and its potential importance has not been fully established in the country. From research Laterites are important resource that may hold ore deposits of iron, nickel, cobalt and copper (Lateritic Ni ore deposit) which can be mined commercially in the country and can also be used in defluoridation of ground water with high fluoride concentrations. The latter is discussed in details in chapter three.

2.3.1 Lateritic Nickel ore deposits

These deposits are produced from two principal ore types: the nickeliferous Laterites and nickel sulphide ores. The latter is associated with mafic/ultramafic igneous rocks i.e. deposits associated with gabbroic rocks (mafic) have high Cu-Ni ratio while the ultramafic rocks have low Cu-Ni ratio.

Nickeliferous Laterites are surficial, weathered materials formed on ultramafic rocks. They comprise 73% of the continental world nickel resources and will be in the future the dominant source for the winning of nickel. Therefore nickel deposits forms by residual process which occurs by leaching of soluble elements from rocks leaving concentrations of insoluble elements in the remaining material (residue).

2.3.1.1 Genesis of nickel Laterite ore

As stated earlier the Lateritic nickel ores are formed by intensive tropical weathering of olivine-rich ultramafic rocks such as dunite, peridotite and komatiite and their serpentinitized derivatives. Serpentinite which consist largely of the magnesium silicate serpentine contains approximately 0.3% nickel. This initial nickel content is strongly enriched in the course of lateritization.

There are two types of lateritic nickel ore:

- a) **Limonite types:** Limonite type Laterites (or oxide type) are highly enriched in iron due to very strong leaching of magnesium and silica. They consist largely of goethite and contain 1-2% nickel incorporated in goethite. Limonite zone may be absent in the ore deposits due to erosion.
- b) **Silicate types:** The Silicate type (or saprolite type) nickel ore formed beneath the limonite zone. It contains generally 1.5-2.5% nickel and consists largely of Mg-depleted serpentine in which nickel is incorporated. In pockets and fissures of the serpentinite rock green garnierite (hydrated nickel magnesium silicate) can be present in minor quantities, but with high nickel contents - mostly 20-40%. It is bound in newly formed phyllosilicate minerals. All the nickel in the silicate zone is leached downwards (absolute nickel concentration) from the overlying goethite zone.

During the lateritization of such rocks, nickel passes temporarily into solution but is quickly reprecipitated either on to iron oxide minerals in the Laterite or as garnierite and other nickeliferous phyllosilicates in the weathered rock below the Laterite. Cobalt too may be concentrated, but usually it is fixed in pile. Grades of potentially economic deposits range from 1 to 3% Ni + Co and tonnages from about 10 to 100 Mt. Copper may also be recoverable, as in the Buhinda prospect, Burundi, which at a cut-off of 0.8% Ni contains 28.6 Mt running 1.62% Ni, 0.12% Co and 0.31% Cu (Derkmann & Jung 1986).

Nickel ore deposits are therefore restricted to the weathering mantle developed above ultramafic rocks. Thus, they tend to be tabular, flat and are really large, covering many square kilometres of the Earth's surface. However, at any one time the area of a deposit being worked for the nickel ore is much smaller, usually only a few hectares.

2.3.1.2 Examples of Areas with the Residual Nickel Ore Deposits

1) New Caledonia, East Australia

The area is mostly underlain by ultrabasic rocks, many of which are strongly serpentinized. The nickel occurs in both the Laterite and the weathered rock zone. In the weathered zone nickel ore deposits forms distinct masses, veins/veinlets or pockets rich in garnierite which occur around residual blocks of unweathered ultrabasic rocks and in fissures running down into the underlying rock.

The material mined is generally a mixture of the lower parts of the Laterite and the weathered rock zone. Above the nickel-rich zone there are pockets of pile containing significant quantities of cobalt. Grades of up to 10% Ni were worked in the past, but today the grade is around 3% Ni.

A typical environment of nickel mineralization and a more detailed profile is shown in Figure 3.1 and 3.2 respectively below.

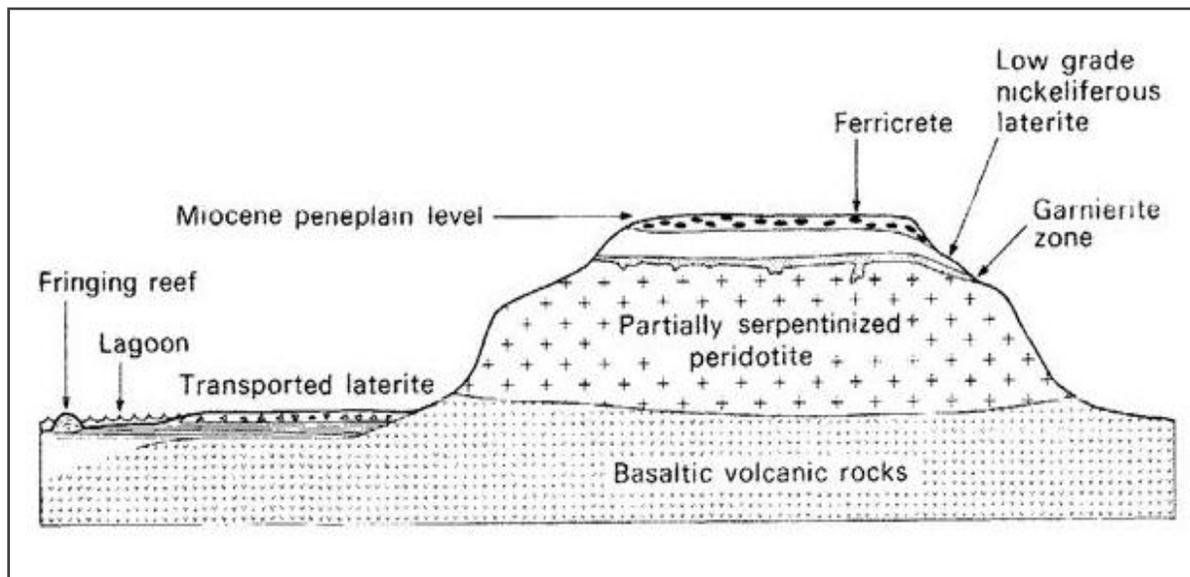


Figure 3.1: Profile of a peridotite occurrence showing development of a residual nickel deposit (after Dixon)

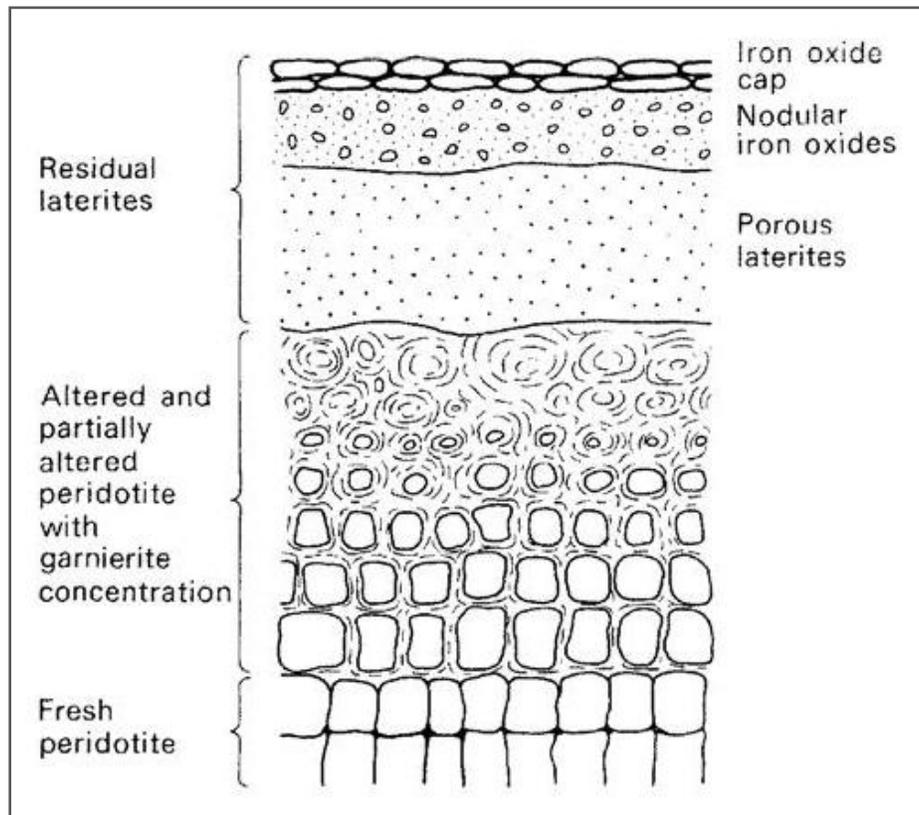


Figure 3.2: Section of Nickeliferous Laterite deposits, New Caledonia. (After Chérelat 1947)

2) The Greenvale Nickel Laterite, North Queensland - Australia

It was discovered in 1966 as a result of the comparison of the geological environment with that of New Caledonia (Fletcher & Couper 1975). The section is similar to that of the New Caledonian and the occurrences of Nickel and cobalt are concentrated to ore grade in a Laterite mantle covering about two thirds of the serpentinite. Erosion has removed the ore zone from the rest of the peridotite. Ore reserves run to 40 Mt averaging 1.57% Ni and 0.12% Co. The ore zone occurs mainly in the weathered serpentinite, often towards the top, and partially in the overlying limonitic Laterite as shown in Figure 3.3 below.

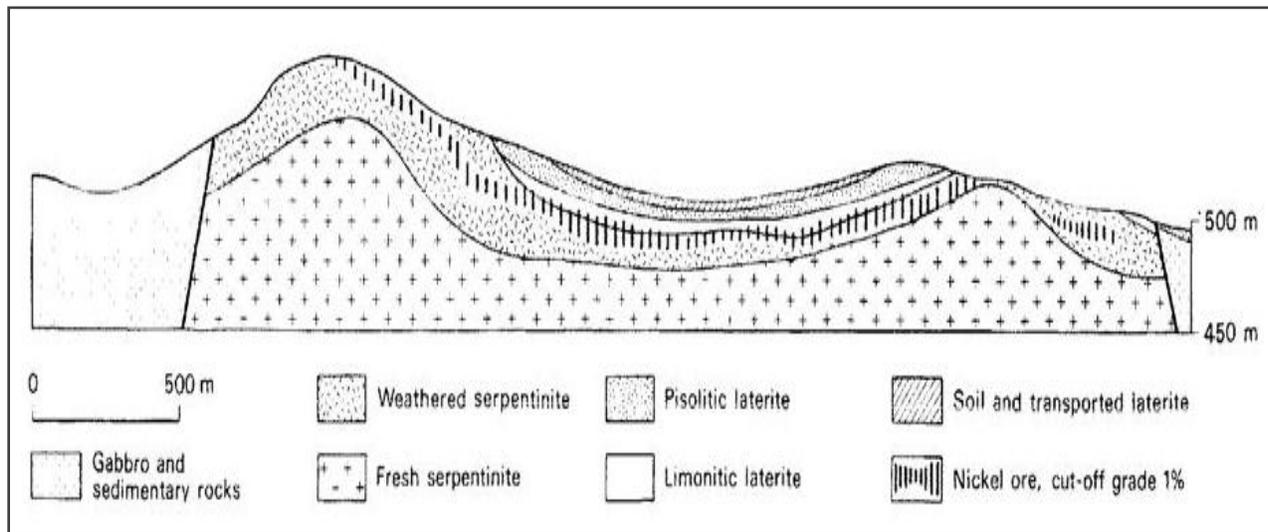


Figure 3.3: Section of the Greenvale Serpentinite, Queensland-Australia (After Fletcher & Couper 1975)

3) Acoje Area, Philippines

The ore occurs or developed in an ophiolite suite, layered mafic/ultramafic unit with Platinum (PGM)/Cr/Ni sulphide mineralization horizon in transitional dunite located between hartzburgite and gabbro layers. Lateritic ores are found at the surface generally to the western hartzburgite zones. The deposit is so rich in limonite (generally grading 47% to 59% Fe, 0.8-1.5% Ni and trace Co) that it is essentially similar to low-grade iron ore.

In 2008, the inferred lateritic ore deposit in the area is 23.5 Mt with grades of 1.18% Ni and 0.05% Co. (Rusina, Annual Report)

2.3.1.3 Exclusive Summary of Nickel Laterites

Classification	Dry Laterites	Fossil Laterites	Equatorial Laterites (‘Tropical Type’)
Locality	Australia, Southern Africa, Brazil	Balkans and Urals	Equator Regions (Cuba, New Caledonia, Phillilines)
Host Rocks	Archaean & Proterozoic	Triassic-Cretaceous	Triassic-Cretaceous but areas of highly active chemical & ground water weathering
Climate	Hot & dry conditions, periods of intense rainfall (seldom) followed by prolonged hot, dry conditions	Cool & cold conditions, periods of low seasonal rainfall, ‘higher’ latitudes	Hot & wet conditions, tropics, constant rain and humid conditions,
Topography	Low relief	Moderate- low relief	Higher relief
Clay content	High	moderate to low	Moderate - high
Moisture content	Low	Low	Very high
Leach profile	Slow	Moderate	Fast
Mineralogy	Predominantly limonite with silica and montmorillonite clays	Generally limonite- saprolite but variable	Highly variable limonite and saprolite ratios

CHAPTER THREE

METHODOLOGY

The methods used in this study involved:

1. Literature from Books.
2. Collecting data from Journals and Reports.
3. Web based material.

Based on the above methods used in research the following discoveries were made and discussed:

3.1 The use of Laterites in defluoridation of drinking water

The East African Rift Valley has high fluoride content in its ground water resources like in Nakuru, Naivasha and Gilgil areas in Kenya. Ground water is widely used domestically especially for drinking. High intake of fluoride causes fluorosis; hence there is need for simple, effective, inexpensive and socially and ethically acceptable method of defluoridation or reduction of fluoride concentrations in drinking water. This would in turn reduce or prevent fluorosis.

The use of Laterites/ Lateritic soils in this process was presented by Bjorvatn, *et al.* during the 2nd International Workshop on Fluorosis Prevention and Defluoridation of Water which took place in Nazareth, Ethiopia, November 1997. The aim of their study was:

1. To assess the fluoride binding effect of various Ethiopian soils, sampled, respectively, in mountainous and relatively low-land areas of the Rift Valley.
2. To test the possibility of using low-fired soils or soils with no previous firing for defluoridation of drinking water.
3. To study the effect of stirring.
4. To assess the fluoride binding capacity in an 'optimal' soil, Laterite from Northern Cameroon, West Africa.

3.1.1 Materials and Methods

A simple experiment was carried out as follows:

Soil samples: Ten topsoil samples (mostly red, lateritic clay) were collected in Ethiopia. Four of them, i.e. no 1 – 4, were from the mountainous areas around Addis Ababa. The six others, i.e. no 5- 10, were from the high-fluoride areas of the Rift Valley. In addition, samples of lateritic soil were collected from the high-land savannah of Adamoua, Northern Cameroon.

Pre-treatment: The Ethiopian samples were heated for about 3 hours at 250°C in an electrical furnace. Alternatively the samples were dried at 50°C for a similar period of time. Aliquots/divisions of 30-45 g were prepared from each of the soil samples. The Cameroon samples were left unheated.

Fluoride water: Fluoride solutions were prepared by dissolving 100 Mg NaF in 3.0 Litres distilled, de-ionized water, giving a fluoride concentration of approximately 15 Mg/L. Alternatively groundwater containing 7.4 Mg F/L and NaF solutions containing 8.7 mg F/L were used.

Batch kinetic experiments: Soil samples were added to plastic containers and mixed with fluoride solutions in a weight/volume ratio of 1:10. The containers were closed by tight-fitting lids and placed on an electrical shaker (50 motions/min). At given different contact times, 5 ml samples were taken and analyzed for the residual fluoride concentration in the water.

Capacity measurement: 100 g of untreated Laterite was placed in a funnel - on filter paper circles - and used for sequential filtration of 4.8 L of the 15 mg F/L NaF solution described above. The filtration was carried out successively, where 200 ml aliquots/divisions were filtered at a time to make 24 filtrates. The fluoride concentration was measured in each of the filtrate. Three parallel test series were conducted.

Fluoride measurements: The fluoride concentrations were measured by the use of an Orion combination F⁻ electrode (9600900) connected to an Orion Research microprocessor ionalyzer/900.

CHAPTER FOUR

RESULTS AND DISCUSSIONS

4.1 Results

4.1.1 The use of Laterites in defluoridation of drinking water

From the various soil samples a sharp decline in fluoride concentration was seen in all NaF solutions exposed to soils from the Ethiopian highlands. During the first hour about 50 % of the fluoride ions were removed from the water samples (Figures 4.1 and 4.2). In 24 hours the fluoride concentration was reduced to about 1 Mg/L in all the four samples.

The fluoride removal effect of the soils from the Rift Valley was very limited; the average fluoride concentration in solutions after 24 hours of exposure was 10.5 mg/L, individual samples varying from 4.85 to 15.9 mg F/L; the last soil sample actually causing an increase in the fluoride content of the NaF solution (Figure 4.3).

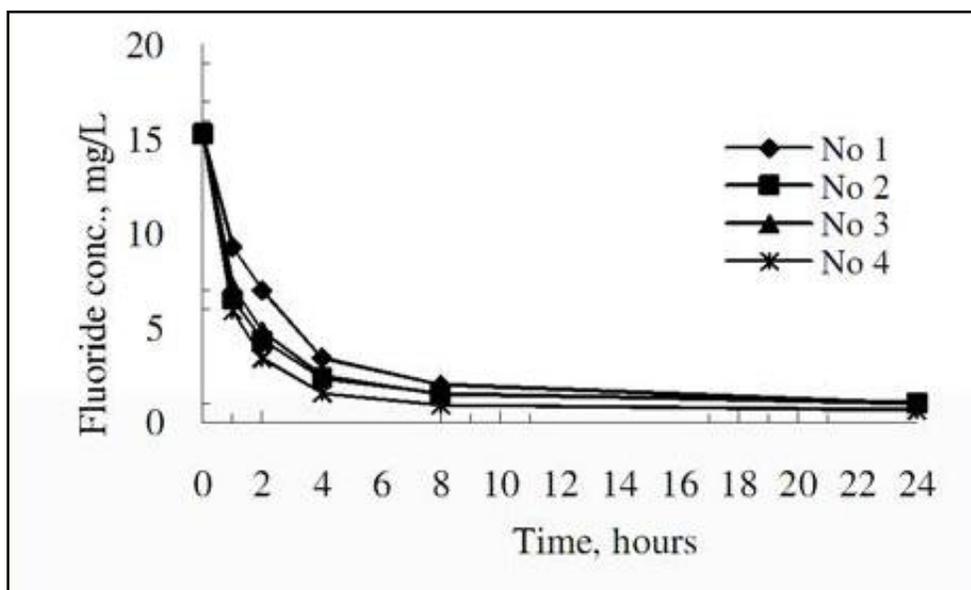


Figure 4.1: Defluoridation of water by use of soil from Ethiopian highland. (Heated at 250°C). Dosage 10g/L

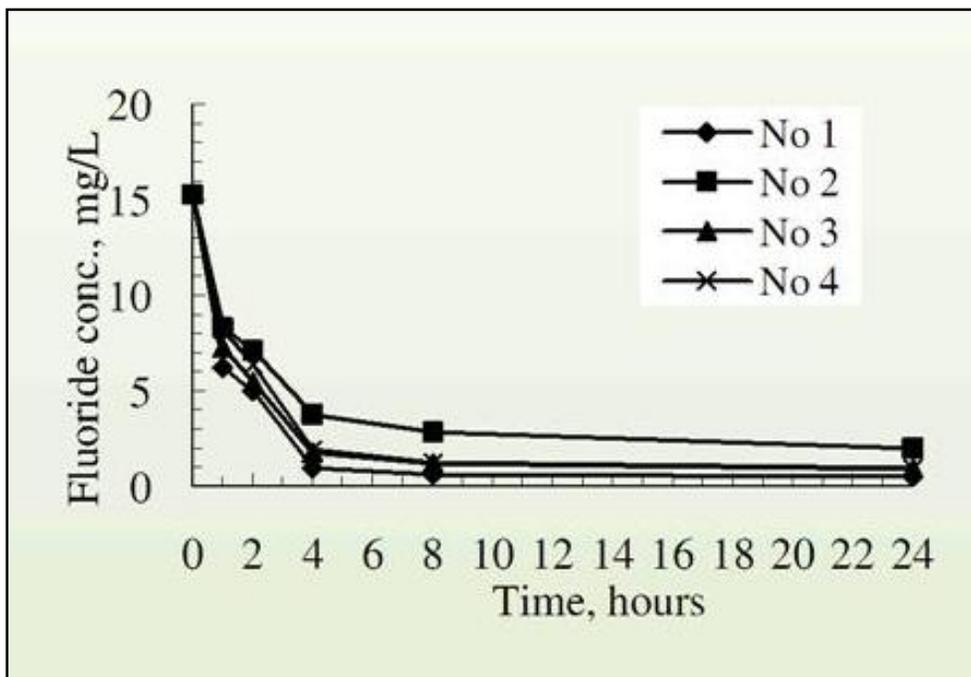


Figure 4.2: Defluoridation of water by use of soil from Ethiopian highland. (No heating). Dosage 10 g/L

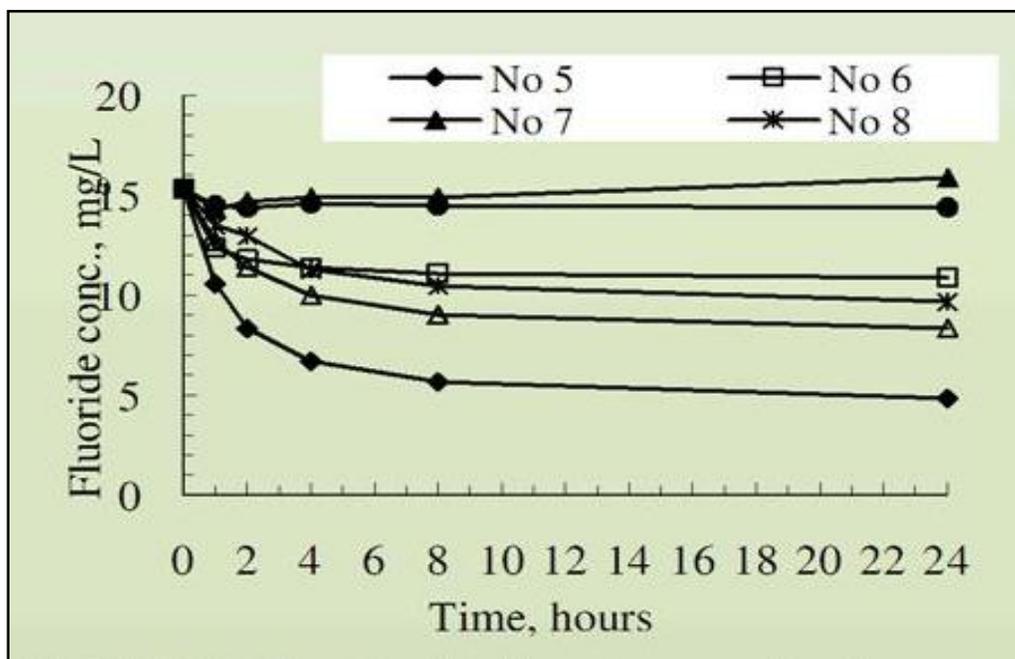


Figure 4.3: Defluoridation of water by use of soil from Ethiopian Rift Valley. (Heated at 250°C). Dosage 100g/L

Effect of stirring

Stirring speeded up the initial fluoride binding process, but did not alter the efficiency on long-time. The fluoride removing effect, given in percentage of original fluoride concentration, was similar in artificial and naturally occurring high-fluoride waters as shown in table 4.1 below.

Table 4.1: Defluoridation by the use of Laterite, in artificially made high-fluoride Concentrations of 8.7 mg F/L and naturally occurring fluoride of 7.4 mg F/L.

Type of water	Stirring	Fluoride removal in % after exposure time				
		2 hours	4 hours	8 hours	24 hours	7 days
NaF solution	Yes	48.7	64.4	77.6	87.2	94.0
NaF solution	No	19.2	25.4	40.7	65.2	95.0
Groundwater	Yes	50.3	66.8	76.4	84.2	93.0
Groundwater	No	25.9	32.7	44.1	50.0	93.0

Fluoride binding capacity

A sharp reduction in fluoride concentration was observed in water passing through the column made up of the Laterite from Cameroon. During the first few runs, the reduction was approximately 90 %. A gradual decline in the effect of filtration took place, but even after the 18th filtration, i.e. 3600-mL of water containing 14.7 Mg F/L, more than 50 % of the fluoride was removed by the Laterite.

The experiment was terminated after 24 runs. By extrapolation one should expect the Laterite filter (100 g) to be saturated by fluoride after approximately 6 more runs, i.e. after the filtration of 6000 L of fluoride solution containing 14.7 mg/L.

The average removal of fluoride in the water would then be indicated in the graph as the adsorption of the 15th aliquot, i.e. 8.5 mg/L. Thus the trend shows that 100 g Laterite may take up not less than 50 mg of fluoride, at an average removal efficiency of 58 %. The binding capacity, under such conditions would be slightly more than 0.5 mg/g.

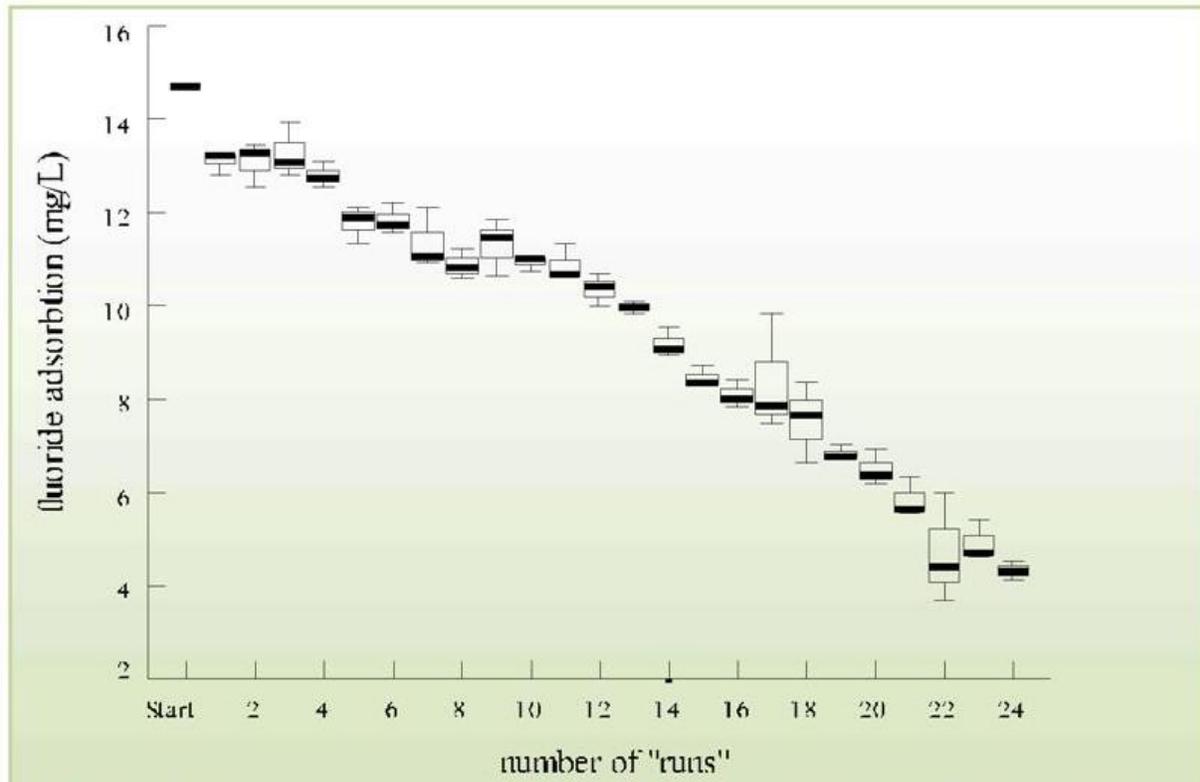


Figure 4.4: Box plot showing the gradual reduction of fluoride binding effect in a Laterite filter after repeated exposure to divisions of 14.7 Mg/L NaF solutions.

- Experiment done in triple

4.2 Discussions

The African Rift System is dominated by alkaline base-rocks; richer in Na and F than analogous rocks in other regions of the world, and high-fluoride groundwater is therefore a common phenomenon in the Rift Valley. Dental and skeletal fluorosis, consequently, are prevalent in the region and there is an acute need for simple and inexpensive methods for defluoridation of water.

Lateritic clay or soils in most places is available at practically no cost, and by the use of simple batch-type methods, drinking water with an acceptable fluoride concentration may be provided in less than 24 hours. By the use of stirring, the fluoride binding process may be speeded up.

No heating/firing of the soil is needed for defluoridation purposes thus the proposed method becomes even simpler. However, the possibility of micro-biological contamination of the soil, of the drinking water, should not be overlooked. Further studies are needed to assess this aspect.

The experiments were conducted using artificially made NaF solutions and according to the results presented in Table 4.1, NaF solutions and chemically more complicated high-fluoride groundwater, seem to follow the same pattern.

Lateritic soils are easily available in the country and the method is socially and environmentally acceptable, and implementation requires a minimum of equipment and technical skill. Even with its relatively low fluoride binding capacity, 1 kg of Laterite should - according to findings - be able to reduce the fluoride content of 100 L water from, e.g. 6 mg/L to less than 1 mg/L. Thus, the local clay or soil could possibly represent a simple and inexpensive way of improving the quality of drinking water in high-fluoride areas; at household level and at village level.

CHAPTER FIVE

CONCLUSION, LIMITATIONS AND RECOMMENDATIONS

5.1 Conclusion

Based on the research carried out the following conclusions can be drawn:

1. Laterites and lateritic soils are formations peculiar to equatorial and tropical areas and found in highlands like Mt. Kenya to gently undulating topography in areas like Tsavo.
2. Laterites consist mainly of quartz and oxides of titanium, zircon, iron, tin, aluminium and manganese. They are enriched with Cr, Ni, Fe and Cu (supergene enrichment).
3. Laterites have found use in surfacing of most roads in the country and in making of bricks for building construction. However, it has been found that they are important mineral resources that can be used in defluoridation of ground water with high fluoride concentrations. This will ultimately prevent dental and skeletal fluorosis in human.

5.2 Limitation

1. When Ground water is passed through Laterite sample it may be enriched with Iron and Aluminium in the sample. Therefore, another method for removing these constituents has to be defined e.g. Hydrogen peroxide or chlorine is used to precipitate Iron.

5.3 Recommendations

1. More studies on the occurrence and distribution of Laterites in the country.
2. Studies on mineralogical composition and supergene enrichment in Laterites in order to establish economic and viable deposits especially trace elements in the country.
3. The distribution and occurrence of Serpentinites, Komatiites and Ophiolite suites in the country to establish if it hosts important ore deposits like Fe, Ni, Cu etc.
4. More study on the properties of Laterites and the effect of Fe & Al ions contained in it in defluoridation of ground water to make the waters safe especially in the Rift Valley.

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