A WATER QUALITY, BIODIVERSITY ASSESSMENT AND COMMUNITY PERCEPTION ANALYSIS OF RUNGIRI RESERVOIR, KIKUYU, KENYA.

BY
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DECLARATION

I declare that this project report is my original work and has not been presented for examination in any other university.

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ABBREVIATIONS

BOD	- Biological Oxygen Demand
CBD	- Conservation of Biological Biodiversity
CBS	- Central Bureau of Statistics
COD	- Carbon Oxygen Demand
EIA	- Environmental Impact Assessment
EMCA	- Environmental Management and Coordination Act
EPA	- Environmental Protection Authority
DO	- Dissolved Oxygen
IUCN	- World Conservation Union
KBS	- Kenya bureau of Standards
NEMA	- National Environment Management Authority
OECD	- Organization for Economic Community and Development
ORP	- Oxidation Reduction Potential
TDS	- Total Dissolved Solids
TSS	- Total Suspended Solids
UNEP	- United Nations Environment Programme
WHO	- World Health Organization
WWF	- World Wildlife Fund For Nature

ABSTRACT

The occurrence of the Limuru Trachyte in the Kikuyu area of Kiambu District to the north west of Nairobi has led to a lot of rock excavation for building and construction of houses and graveling material for road construction. In the late 1980s, extraction was undertaken in the area during the construction of the Nairobi-Nakuru dual carriage highway, which connects Nairobi with Western Kenya and Uganda. However, due to widespread resource mismanagement associated with the previous regime, a gravel extraction site, known as Rungiri Quarry was excavated beyond the approved contract depth thereby interfering with underground water movement resulting in the development of a water body, the Rungiri Reservoir which is the subject of this research project.

The main objective of the environmental study was to assess the quality of water in the reservoir against that of nearby streams and a shallow community well in order to establish the real origin of the reservoir water. The other objective was to assess the current state of aquatic biodiversity in the reservoir in order to gauge the potential for the exploitation and multipurpose development of other natural resources. The final objective was to assess the real life community perception of the reservoir by the Rungiri residents because of their occasional animosity towards the water body due to cases of loss of human life.

Data collection involved the use of field measurements for the analysis of water quality and biodiversity and site interviews for the analysis of community perception. The project was primary data oriented and the few secondary data included site maps and rock blasting information.

The findings showed that the reservoir and community borehole did not contain good quality water for drinking purposes as provided by World Health Organization (WHO) and the Kenya Bureau of Standards (KEBS) water quality standards. The quality standards for other uses were not considered. The reservoir was found to be eutrophic and in early phase of ecological development thereby making it quite suitable for aquaculture development. It was also found to be home to two water birds namely the Little Grebe and Egyptian Goose. Two types of macrophytes, namely cattails *(Typha sp)* and the water lily (*Nymphae sp*) were found to be colonizing the waterbody although the successional progression was found to be rather slow. The residents of Rungiri did not associate the reservoir with any economic advantage. Majority of them perceived it as an environmental obstacle in their midst.

However, the analysis of Pearson's Correlation Coefficient ruled out the possibility of the reservoir being a source of disease increases in the area. This is because, even though the regression analysis showed that the relationship between the sources of water and disease outbreaks is positive, the correlation coefficient R square can only relate 0.20% of the diseases to the water sources which is not significant 99.8% being attributed to other factors not covered within the study. Besides, during the study, only four cases of typhoid were reported and no malaria cases reported meaning that the fish in the reservoir could be consuming the mosquito lava rendering the reservoir a mosquito free zone.

From the findings, it was concluded that the negative community perception towards the water body can be turned around if the community explored ways of exploiting the reservoir as a resource base that would not only be a source of income through aquaculture development but would also boost their protein based nutrition especially at household level. In this regard, it is recommended that the local communities be assisted to enable them realize the greater benefits from the reservoir. By so doing, their negative perception will change and will become instrumental in improving the poor state of the environment within and around the reservoir.

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CHAPTER ONE

INTRODUCTION

1.0 INTRODUCTION

The exploitation of construction materials especially construction rocks usually create leaves permanent marks on the ground and can completely alter the original landscape in an area. The marks are not merely scars of a quarry that are a by-product of the mining process. Surface mining also leaves a landscape of wasteland and at times hollow depressions that are often filled with garbage, wastewater or natural water. The latter can culminate in the introduction of a totally different environment in an area, which is the case for the Rungiri village.

The quarry industry in Kenya, provides building and construction material in accordance with Cap 306 of the laws of Kenya. A critical analysis of the industry provides a good example of antagonism between development and environment. The development of the industry has empowered the rural Kenyan economically without considering the environmental implications. Quarrying which utilizes simple tools such as chisels and hammer is not governed by strict mining rules. The existing legal framework does not effectively address the rehabilitation of degraded land in order to return it to its former status after the quarrying is over. There are two reasons for this state of affairs. First, is because of the non existence of a clear land use policy and second are the free hold title deeds issued by the Ministry of Lands and Settlement upon payment of the required fees for a particular parcel of land which gives authority to the private owner to do as they wish with their land. This is despite Kenya being a signatory to international treaties such as the Convention on Biological Diversity (CBD, 1992), which cautions countries against environmental degradation for conservation of biodiversity for the current and future generations.

Until December 2002, when Kenyans voted out the previous regime of government which did not seriously address and implement policies on environment, like the rehabilitation of road construction quarries, it is expected that the new National Environmental Management Act (EMCA) of 1999 will address such issues in future.

Rungiri reservoir has been in existence since 1992 and was the product of an era when Environmental Impact Assessment (EIA) was not a prerequisite for development activities with a potential for environmental transformation. A road construction company known as Fortunato-Federici/Impresit of Italy, which was responsible for the construction of a dual carriageway between Uthiru and Limuru to the northwest of Nairobi, created the reservoir through rock quarrying.

It is not known whether the water that accumulated in the rock excavation site is good for human consumption to the Rungiri community despite the obvious scarcity of fresh water in the neighbourhood. The common presence of women fetching water on their backs, men using donkey carts or their bicycles to ferry water to the village and as far as Mutego area and other women washing clothes on the shores of the Rungiri reservoir, is proof that water is scarce in the Rungiri area. The quality of water is suspect owing to its usual greenish colour, which implies eutrophication. The highly eutrophic waters are known to encourage the proliferation of cyanophytes some of which can produce toxins that may cause death if ingested in sufficient quantities by domestic animals and wildlife. They also pose a significant health risk to humans using the water, causing gastroenteritis and skin irritations, although no human deaths have so far been attributed directly to these organisms (Anon. 1990; Codd and Beattie 1991). Some toxins have been shown to be powerful tumour promoters and may therefore pose a risk to those with long-term low-level exposure. At the same time the blasting activities could have left some blasting chemicals which are toxic. These issues are very important to ascertain for the sake of long -term utilization of the reservoir as a source of water

However, the existence of algae in a waterbody could also be a positive phenomenon since eutrophication has been associated with improved fish production. Peter (Pers. Comm. 2003), using the fish buddy and together with his experience in fishing detected massive existence of *Tilapia* and Catfish in the Rungiri Reservoir. However, the population density of the fish is not yet known and requires further investigation.

The community around the reservoir is supplied with water from a shallow hand pumped borehole. However, it is known whether the shallow well which forms the source of this supply is connected to the Rungiri Reservoir which is situated only 2-5 m away. Thus, further work on this is highly recommended in order to establish the existing water quality in the reservoir and bore-well and compare with the recommended standards. One major concern is that, the blasting action was capable of tampering with the geological formation thereby transforming the hydrogeology of the area.

There is need for a clear understanding of the implication of Rungiri Reservoir to the current web of life around it especially in terms of domestic water supply, the small scale irrigation in the neighbourhood, issues of public health and the potential for additional and reservoir-centred multipurpose development including aquaculture eco-tourism. The reservoir which, is centrally located in a rural area, has a lot of potential to improve the livelihoods of the village dwellers both through improved health through diversification of the proteins and as an alternative income base. Currently, utility of the reservoir is at its lowest due to the superstition associated with the number of people who have died as a result of drowning in the reservoir who residents number up to ten. In addition, the fact that the Rungiri people are not a fish eating community by tradition, may hamper fish farming or fish consumption at household level. General complaints from Rungiri residents of a rise in the number of water borne diseases occurrence such as malaria, typhoid, dysentry and gastroentritis (stomachaches) also need to be clarified. This project was designed to address some of these environmental issues in the area

1.1: STATEMENT OF THE RESEARCH PROBLEM

In Kenya, quarrying for 'Common Minerals' as described in Cap 306 of the Laws of Kenya requires no Government license in order not to inhibit the country's economic growth. Unfortunately, due to laxity in policy implementation by the relevant government ministries, large companies usually open up the land surface for the purpose of economic development. This is often done using diesel powered machinery. Many times, the excavators usually fail to restore such disused mines to their former land use which is a requirement in the lease agreement.

The worst scenario is experienced when excavators use blasting chemicals because the force can puncture shallow water aquifers thereby discharging water into the open pit. The end result of this is the creation of a man-made waterbody which becomes a totally new and different kind of ecosystem. These events have occurred in Rungiri area following the creation of an abandoned quarry during the re-surfacing of the Uthiru-limuru section of the Kenya- Uganda highway. Despite the fact that there is enough water in the Rungiri Reservoir which was created as a result of failure by the construction company to rehabilitate the excavation pit. the utilization of the water for various uses such as consumption, irrigation and recreation has not been undertaken due to uncertainity concerning the reservoir water quality.

It is therefore, of great importance that a water quality assessment be carried out for the Rungiri reservoir to ascertain its quality especially for drinking and other uses such as fish farming and recreation. In addition, the community perception of the reservoir as the major contributing factor to an increase in water borne was investigated and then related to the problem of disease occurrence in the area. Such a study could also establish the real source of water in the reservoir in the absence of a permanent stream draining into the reservoir.

The research questions that were addressed in this project were as follows:

1. What is the source of water for the Rungiri reservoir?
2. Is the quality of water in the reservoir suitable for human consumption?
3. How rich is the Rungiri Reservoir ecosystem in terms of Aquatic biodiversity?
4. What are the chances of undertaking multipurpose development in the reservoir especially in form of aquaculture. recreation and eco-tourism?
5. How do the local communities view the reservoir environment?

2.0: LITERATURE REVIEW

Environment in any place is usually regarded as the interaction between physical, biological and the social environment (Muthoka, Rego and Rimbui, 1998, Figure 1). The physical environment constitutes the material base for any form of economic development. The physical environment acts as a support element for the biological and social components. Unfortunately, the ideological effect of capitalism and lack of environmental consciousness often results in a breakdown of the total environment network. This is worsened by the fact that environmental cost is not included in the final pricing of the goods and services extracted from the environment. This has lead into the current dilapidation of sites which are turned into wasteland like the disused quarry pits of road construction projects.

The sustainable development movement emerged out of public pressure during international environmental-oriented meetings. The 1972 Stockholm conference, and 1992 Earth summit, marked the evolution of the new term "sustainable development" as a public outcry to the governments to address the growing environmental crises. Sustainable development as defined by the Brundtland Commission 1987 report, ***Our Common Future*** called for a balance to be struck in the pursuit of human welfare:

"Sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs. It contains within it two key concepts:

- ✓ *The concept of "needs", especially to the worlds, to whom priority should be given.*
- ✓ *The idea of limitations imposed by the state of technology and the social organization on the environment's ability to meet present and future needs".*

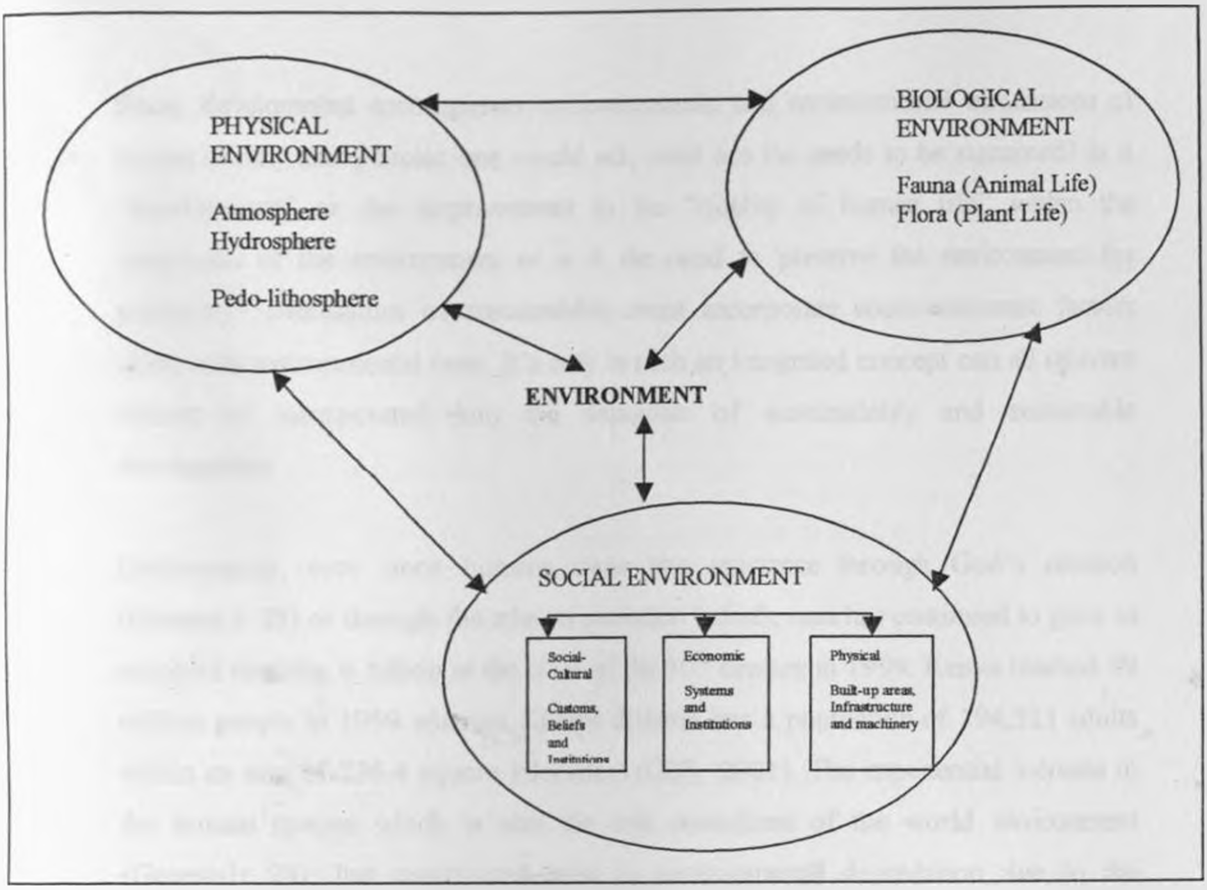


Figure 1.01- The interaction between physical, biological and the social environment **(Source: Modified from Muthoka, Rego, and Rimbui, 1998).**

The World Wildlife Fund For Nature (WWF), in collaboration with the World Conservation Union (IUCN) and the United Nations Environmental Programme (UNEP), further developed the notion of balance in the document *Caring for the Earth*, defining sustainable development as "improving the quality of life within the carrying capacity of supporting ecosystem. This notion of balance finds its way between the lines of Brundtland Commission's definition of sustainable development - the balance between human needs and the environment's ability to meet these needs, between the needs of the present and future generations and between the rich and the poor. Therefore, the concept of sustainable development must be discussed within a broad socio-economic as well as environmental context.

Since, development encompasses socio-economic and environmental dimensions of human society and policies one would ask, what are the needs to be sustained? Is it "development" or the improvement in the "quality of human life" within the constraints of the environment or is it the need to preserve the environment for prosperity? Discussions of sustainability must incorporate socio-economic factors along with environmental ones. It's only in such an integrated concept can all relevant factors be incorporated into the definition of sustainability and sustainable development.

Unfortunately, ever since humans came into existence through God's creation (Genesis 1: 28) or through the atheists evolution beliefs, man has continued to grow in numbers reaching 6 billion at the close of the 20th century in 1999. Kenya reached 29 million people in 1999 whereas Kikuyu division has a population of 194,521 adults within an area of 236.4 square kilometers (CBS, 2001). The exponential increase in the human species which is also the sole custodians of the world environment (Genesis1: 28), has contributed most to environmental degradation due to the continued unsustainable exploitation of both non-renewable and the renewable natural resources. No substitutes have been found for such resources and it seems that sufficient time is not given for their regeneration and recuperation.

The result of the above scenario is that humans have become the victim of degraded environments such as polluted aquatic ecosystems through widespread water borne diseases like cholera and typhoid and also through lack of supply of goods and services associated to such environments. The poor are usually the first victims of a degraded environment since they do not have money to buy alternatives such as bottled water or even foodstuffs from elsewhere They continue overworking the dilapidated environment thus worsening the already bad situation and the poverty cycle continues.

The failure of many world governments to enact environmental laws and policies, has also contributed to the unsustainable management of the different ecosystems. This is worsened by the fact, that such management is usually sectoral and not an integrated holistic approach. The worst bit is when the political will of governments to change for the better management is often lacking making some scholars like Rensburg & O'Donoghue (1995) to include political will as a major element in the environment system (Figure1.02).

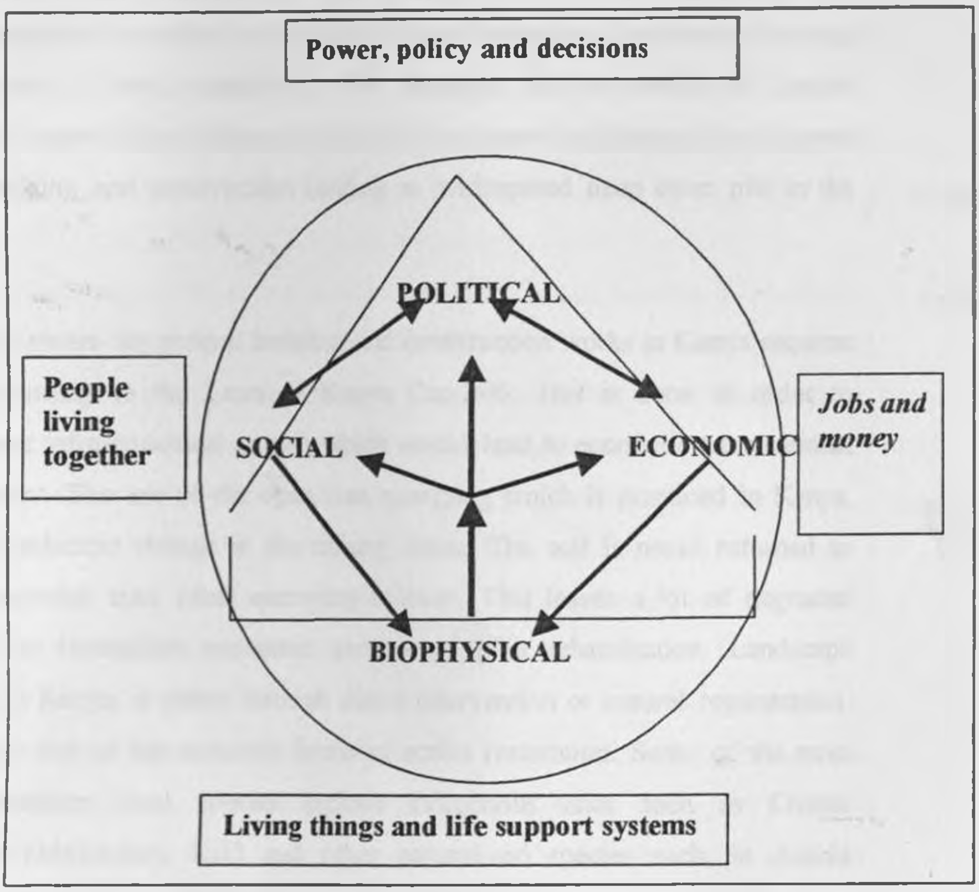


Figure1.02: A broader picture of the environment. Janse Van Rensburg & O'Donoghue (1995)

The world distribution of mining activities is not necessarily that of the distribution of resources but of the exploitation of some of those resources reflecting the needs of the societies that are carrying out the exploitation. The distribution reflects three elements as follows:

1) The presence of the minerals themselves which at times are widely scattered and are rarely very extensive reflecting geological factors,
2) The need for the minerals and the need to quarry or mine them,
3) The technical ability to abstract and exploit the minerals.

The above elements means that the distribution of mining activity at any one time reflects the culture, economic infrastructural growth and other economic needs of the society exploiting mineral resources. The type, ease of exploitation and the end use of the mineral resources occurring at a particular area determines the extent of mining and general level of land degradation. For example, the occurrence of Limuru Trachytes and Quartz in the Kikuyu area has led to general exploration for its good quality for building and construction leading to widespread deep open pits in the landscape.

Exploitation of stones for general building and construction works in Kenya requires no permit according to the Laws of Kenya Cap.306. This is done in order to encourage faster infra-structural growth which would lead to economic advancement and development. The use of the open cast quarrying which is practiced in Kenya, causes great landscape change in the mining areas. The soil is never returned to restore the degraded sites when quarrying is over. This leaves a lot of degraded wasteland of no immediate economic use except after rehabilitation. Landscape rehabilitation in Kenya, is either through direct intervention or natural regeneration. Afforestation is one of the common forms of active restoration. Some of the most common restoration plant species include indigenous ones such as ***Croton megalocarpus*** (Mukinduri, Kik) and other naturalized species such as ***Acacia mearnsii*** (Muthanduku) and ***Eucalyptus sp.*** (Mubao or muringamu). At times thickets of the common shrub ***Lantana camara*** (Kamucomoro) deter any chances of any woody growth thus inhibiting any future chances of woody harvests even if only for firewood if not for any commercial value.

The distribution of wasteland in Kikuyu division, is widespread, in almost all privately owned land, by virtue of possession of a free hold title deed that guarantees the owners authority to quarrying activities. The distribution pattern seems to follow the main Kikuyu–Waithaka Road. The high population density of 823 people per square kilometer, is the highest in Kiambu district according to the 1999, population census (CBS 2001). This could be the reason for the overexploitation of the building stones coupled with the fact that proximity of Kikuyu division to Nairobi makes it easy to exploit the stones and market them for the ever growing building and road construction industry in the region. The fact that Kikuyu Division has no cash crops like tea and coffee could also leave quarry mining as the only alternative for the ever growing population of school-leavers or drop outs to earn an income if at all they are to avoid criminal activities which are also prevalent in the area. Some of the worst scenarios in the quarrying sector include the following:

(1) The target stones do not occur on the surface of the soil but have to be dug out from a depth of about 2-3 metres deep while using simple tools or up to 10-14 metres while using diesel powered equipment thus destroying the landscape.

(2) When the quarrying activities are over, the deep open pits left behind are not restored to their former status either because; (a) the soil was sold out hence lack of materials to fill up, or (b) ignorance and lack of knowledge on issues pertaining to sustainable development and hence lack of concern on the need to restore for the sake of the future generation.

A feature of most natural waters is that they contain a wide variety of microorganisms like algae, bacteria and viruses forming a balanced ecological system. However, due to misuse and direct deposition of human waste into the surface fresh water systems, the ecological balance gets destabilized and the proliferation of undesirable bacterial colonies like *Escherichia coli* makes such water unsuitable for public use out of the fear of the spread of water borne diseases such as typhoid and cholera which are very common in the developing world. On the other hand bacteria form the bases for the decomposition of the organic matter and thus ensure the circulation of the elements in the aquatic ecosystem. The nutrients so released especially if they are nitrates and phosphates form the nutrient base for the proliferation of algae. Depending on the continous supply of the nitrates and the phosphates, the algae may form blooms leading to the eutrophication of the aquatic ecosystem.

More often than not, the open pit quarries which develop as a result of abandoned quarries become filled up with water either from surface runoff or sub-surface inflow. This water can suffer from organic water pollution as a result of clogging up by different forms of organic waste matter. This situation can cause the problems, which are often associated with eutrophication. One of the key indicators of eutrophication build-up is the frequent occurrence of cyanobacteria or simply cyanophytes, which is a form of blue-green algae. Some good examples include *Microcystis, Anabaena Oscillatoria* and *Aphanizomenon*. Various studies have associated the occurrence of eutrophication with the sporadic growth of cyanobacteria (Welch, 1952; Sawyer, 1966; Fruh *et al.*, 1966; Lee, 1971; Golterman 1975 and OECD 1982). Their presence in water is known to increase the risk of waterborne diseases to humans, livestock and wildlife depending on the levels of cyanotoxins. A recent study done in various water bodies in Kenya (Bengtsson & Mosen, 2003) reviewed that the levels of the toxins vary in Kenya. Kahuru in Kinangop recording the highest levels outside the Rift valley and Lakes Elementaita and Naivasha in the Rift valley recording high levels. A disease outbreak in Embu that killed more than a hundred people with symptoms resembling those of Malaria was also reported (Daily Nation, 2001). Water samples tested revealed high levels of algae toxins 5ug microcystin/ L far beyond the 1 ug/L Tolerable Daily Intake (TDI) as provided by WHO.

3.0: RESEARCH OBJECTIVES

The aim of the project was to address the following set of research objectives:

1. To assess the physical, biological and the chemical qualities of water in the Rungiri reservoir,
2. To assess the variety of the biodiversity in the aquatic ecosystem,
3. To assess the effects of the reservoir on community health and get also a general perception from the community.

4.0: HYPOTHESES

The following null hypotheses were identified in order to deal in part with the research objectives, which have been listed above:

1. Rungiri Reservoir water does not conform to the acceptable drinking water standards,

2. The water quality in the reservoir is not different from that drawn from the communities water pump and the irrigation wells.

3. Rungiri Reservoir does not negatively affect the health of the community.

5.0: JUSTIFICATION AND SIGNIFICANCE OF RESEARCH PROJECT

Various kinds of baseline information are required or desired by resource managers, policy makers and planners in order to undertake their work. At the same time, many human activities affect different ecosystems in different intensities due to differences in susceptibility of ecosystems to various environmental hazards. Not all ecosystems like the Rungiri Reservoir have been valued as equally significant for society whether it be for their life supporting functions or for their natural functions. Thus, a total assessment based on the various ecosystem components is a desirable process. A surface water quality assessment for diverse uses like public water supply, fish farming and recreation would significantly increase the value attributed to it by society with respect to it's present and future uses and overall reduce the number of deaths attributed to the reservoir.

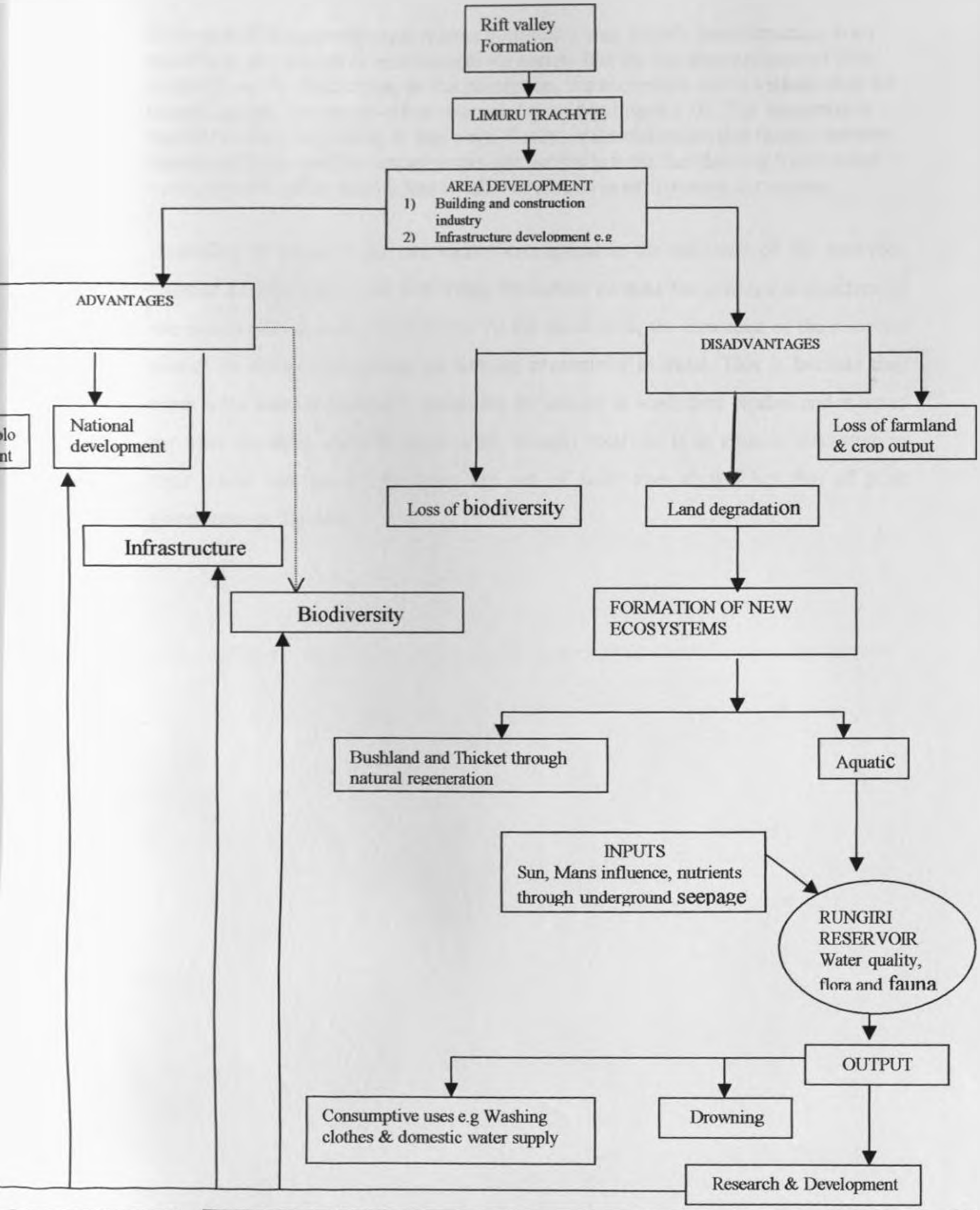
Water is a scarce resource in the Rungiri area due to absence of piped water. This forces the people to use the reservoir water for washing clothes. The dangers of human contact with water whose quality is unknown, range from outbreak of water borne diseases like cholera and typhoid to insect-spread diseases like malaria whose negative effect to a society whose economy is small would be highly significant. There is need to assess the current ecosystem status in terms of the water quality and the biodiversity in order to promote public awareness for sustainable management of neighbourhood ecosystems.

This research project was undertaken in an attempt to address some of the above important concerns of the environment. The scarcity of scientific investigations on the characteristics and environmental implications of abandoned quarries, many of which are considered as wastelands, particularly prompted it. However, the recent rehabilitation of abandoned limestone quarries in the Bamburi Cement Company into a world famous urban park has demonstrated how such areas can be transformed from being eye sores into important sources of income and environmental conservation.

6.0: THEORETICAL FRAMEWORK

This project was configured around the ecosystem concept, which can be considered as underlying the operations of any environmental site especially when the integration of biophysical and socio-economic elements is desired. Ecosystems can be defined in various ways and can either include or exclude humans as a central factor in the overall structure. Most of the times, one cannot however restrict the ecosystem concept to exclude humans since through their actions, they can destroy the ecosystems from where they derive various goods and services.

Many ecologists have described an ecosystem as a system of structurally related abiotic and biotic components that are functionally related by physical, chemical and biological processes. Ecosystems are considered to be in a dynamic equilibrium with their inputs and surrounding. When one of the inputs is changed, the ecosystem will readjust to a new equilibrium. The food chain or food web is the avenue by which energy is transferred through the ecosystem. The ingestion of a smaller consumer by a larger one establishes a trophic level with the producers at the lowest level. For example the ***Typha*** species is the highest-level producer in terms of species numbers currently in occurrence in the Rungiri reservoir and is good in the cycling of excess nutrients like nitrogen and phosphorus in the aquatic ecosystem. On the other hand, the exponential growth of the algae in the Rungiri reservoir, is a response to the increase in the nutrients especially nitrogen and phosphorus. The nutrients most often are pumped into the system from point and non-point sources. A good example is as a result of excessive use of the same by humans in their endevour to improve on and or sustain his lifestyle through intensive agriculture on already extensively demarcated and reduced land sizes like is the case in Rungiri village. Figure 1.03 shows the conceptualization of the Rungiri Reservoir within the wider environment as envisaged in this project.



Key:
Direct Relationship
Indirect Relationship

Figure 1.03: The Project Conceptual Model Reflecting the Linkages in Society and the Ecosystem Relation to society (Source: Researcher 2003).

The result of the ecosystem to human destruction may include transformation from suitable to less attractive environment for society like the bio-accumulation of toxic materials via the food chain. In this perception, the ecosystem can be visualized as the central module in a cause-effect chain as depicted in Figure 1.03. The ecosystem is therefore related to society in two ways. Firstly, is the realization that human activities influence the ecosystem characteristics and secondly is the fact that any transformed ecosystem can either form a less suitable or attractive environment for society.

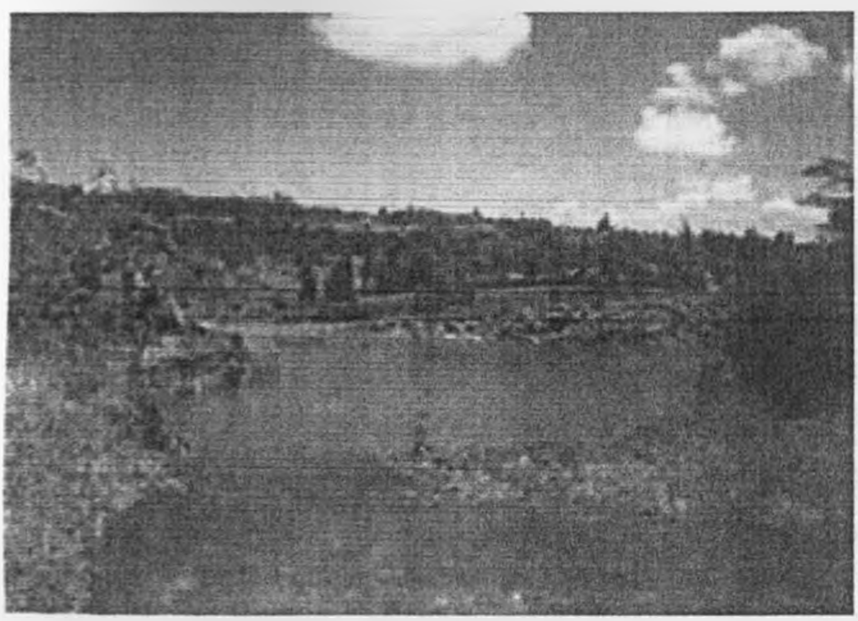
According to Figure 1.03 one cannot conceptualize the existence of the reservoir, without thinking about the Rift Valley formation because the geological structure of the area is related to the Rift Valley. At the same time, the existence of the reservoir cannot be discussed without the Rungiri community in mind. This is because they draw water from it especially during the dry season to wash their clothes and at times for their domestic animals. Most of all, Rungiri reservoir is an aquatic ecosystem in their midst that came into being not out of their own choice but that of poor governance at the time.

CHAPTER TWO
THE STUDY AREA

2.0: INTRODUCTION

Rungiri reservoir (Plate 1) below is a man made waterbody located in Rungiri village in Gitaru sub-location of Kikuyu Division lying between $36^{0}40'$E and 1^{0} 15'S (Figure2.02). It is situated at the point where the local residents used to fetch water from a spring called Githima Kia Njiiru in the local Kikuyu language, which translates to Njiiru Springs. It is irregular in its size as well as its depth and covers an approximately area of 4.21 acres (Peter, Pers. Com., 2003). Its depth varies from 4.97 meters in its shallow parts to 12.35 meters in the deepest parts. Peter, a fishing expert has measured a depth of up to 14.335metres. The reservoir is located about 2.5 kilometers from Kikuyu town from where it is clearly visible. It borders the Kenyan – Ugandan railway on the eastern side and the Kia Njiiru stream on the western end. Human settlements are concentrated on the northern direction whereas irrigation farming is concentrated in its southern end.

Plate 1: Rungiri reservoir as seen from the southern end.



Rungiri reservoir came into being when water through underground seepage and runoff filled the disused quarry in the early 1990's. Notice how green the water is. **(Source: Researcher 2003)**.

2.1: TOPOGRAPHY AND GEOLOGY

Kikuyu Division is located in the Lower Highland Zone (LH1-LH5) agro-ecological zones of Kiambu District. It is part of the four main topographic zones, others being Limuru, Gatundu and Githunguri. Hills and undulating plateaus characterize the area. The soils are developed on undifferentiated tertiary volcanic and basic igneous rocks. They are well-drained, very deep, dark grey to black in colour, with calcareous, a slightly saline sub-soil. The presence and distribution of Trachytes and Quartz, in the area provides various kinds of stone for building and construction that makes mining an attractive income generating occupation for the unemployed.

The geology of the reservoir area is associated with the formation of the Rift valley. The area is well covered by the Limuru trachytes and Quartz formed during the last phase of the Rift Valley formation (Figure 2.03). This kind of stone is good for building and construction of either roads or houses and it is recognized by the materials branch of the Ministry of Works for its suitability as a building stone (Jourbert, 1969). This explains why exploitation for the stone is of such high magnitude.

The Limuru Trachyte which occurs in the area is heavier and considered not to be as good as the Nairobi Trachyte although it has a fairly high crushing strength and excellent pick up and absorption character. Limuru Trachyte has been crushed and used in the past as an aggregate both in road foundations and as a surfacing material. After weathering, the Limuru Trachyte becomes somewhat softer and lighter in colour and is then easily trimmed. The soft quality like the Nairobi Trachyte yields an aggregate, which compacts well in solid road foundation and has been used extensively for that purpose in the Limuru - Uplands area where it is abundantly exposed and easily accessible. Although no results of tests are available, the materials branch of the Ministry of Works considers the aggregate yielded by the Limuru Trachyte to be of standard comparable to Nairobi trachyte in many ways. Some of the advantages of the Limuru Trachyte over the other kinds of construction stones include the following:

1) It can easily be cut with simple equipment,

2) The rock is beautiful in physical appearance because of the high amount of silica,
3) It is soft but not friable to maintain good quality for building and construction purposes.

2.2: HYDROLOGY AND DRAINAGE

During the formation of the rift valley there was movement of the earth's surface and major faults were formed. This is evidenced by a wide valley bottom against interlocking spurs that characterize other highland places like Murang'a District. Figure 2.01 shows the general characteristic of the area and it is clear that there is a depression or fault in the area where the Rungiri reservoir and the river are located.

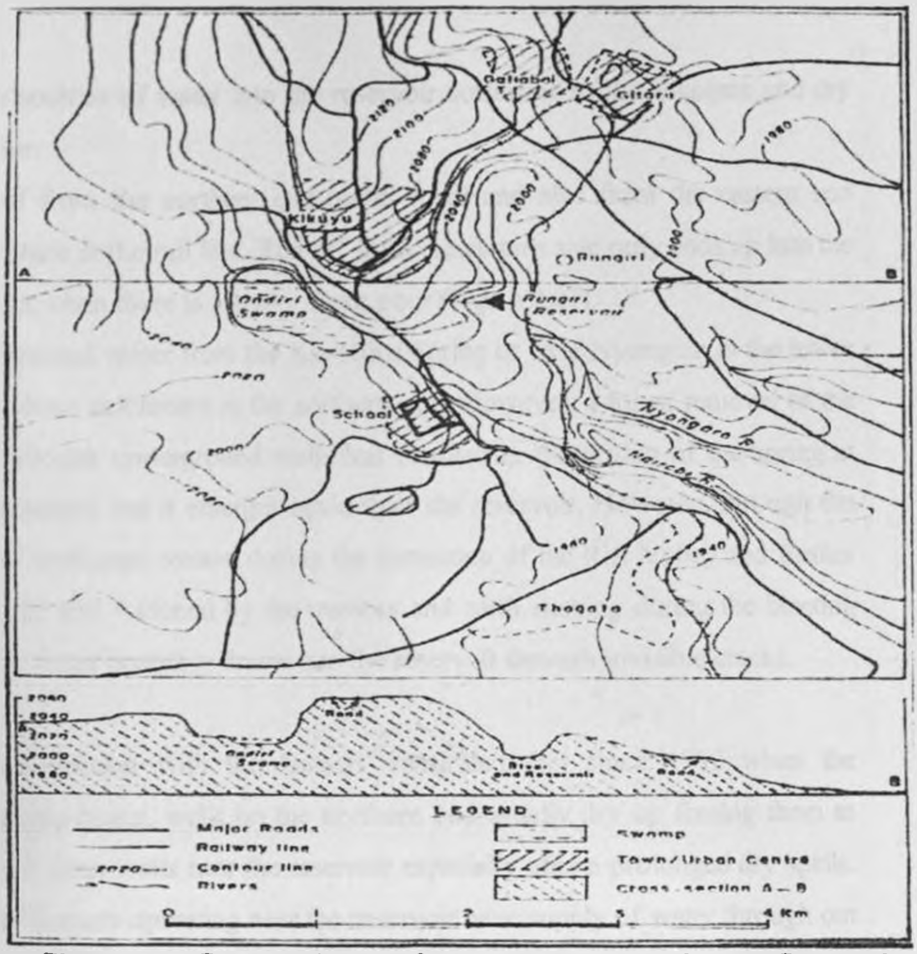


Figure Topography and Drainage pattern at Rungiri Reservoir.

igure 2.01: HYDROLOGY AND DRAINAGE OF RUNGIRI RESERVOIR AREA

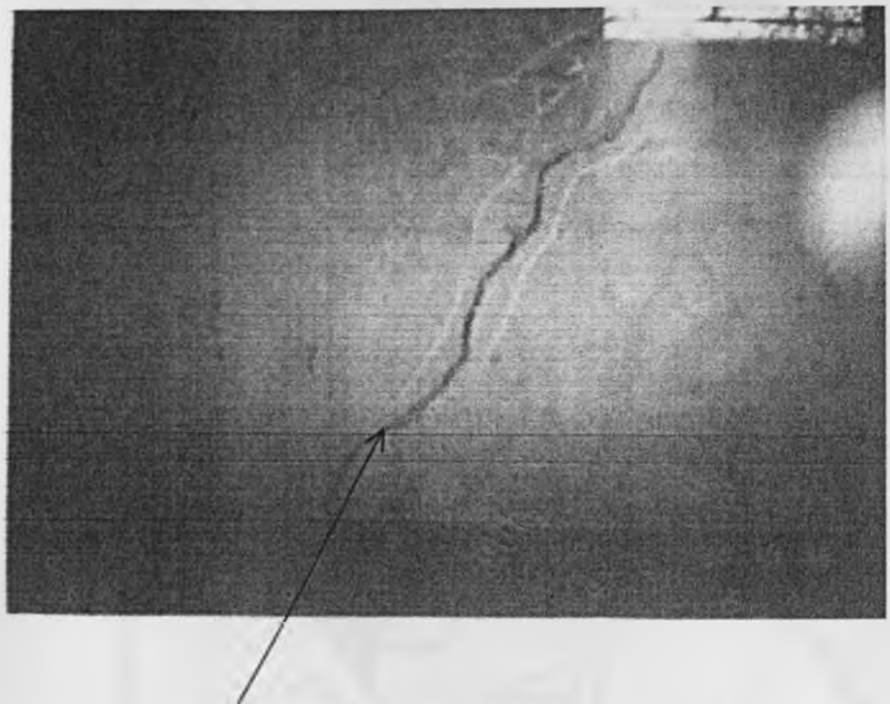
ource: SOK, Topograghical sheets 148/3 & 148/1. 1967.

There are two sources of water into the reservoir according to the villagers and my own observation:

1) Run-off from the northern end (earth road) and also from the eastern end where there is the rail line. Run off from the eastern side only ends up into the reservoir when there is a heavy down pour (Figure 2.01).
2) Underground water from the Kia-Njiru Spring or river Nyongara in the lower basin whose catchment is the northern end. However, a lot of removal of the water through underground wells has resulted in the drying of the spring at the catchment but it emerges again near the reservoir. However, through the lines of weakness created during the formation of the Rift Valley and further weakened and widened by the tremors and earth shaking during the blasting process, water probably drains into the reservoir through invisible cracks.

Personal communication with the farmers confirmed that since 1992 when the reservoir came into being, wells on the northern end usually dry up forcing them to pump water back from wells near the reservoir especially after a prolonged dry spells. However, those farmers operating near the reservoir have supply of water through out the year and it even becomes a nuisance during the wet season when farming is delayed until the dry spell (Mwangi, per. Comm.). Evidence that new lines of weakness were formed and probably old ones expanded, is visible through massive cracking of floors within the vicinity of the reservoir (Plate 2).

Plate 2: Cracks formed in the houses as a result of blasting during rock exploration for road construction.



This is one of the many cracks that appear on the walls in many of the stone houses in Rungiri village within the vicinity of the Reservoir created as a result of the stress wave that was created during the open blasting process **(Source: Researcher 2003).**

2.3: POPULATION

Kikuyu Division had 96,417 males and 98,104 females giving a total population of 194,521 adults in 1999. Gitaru Sub-Division had a total population of 9,599 with 4696 males and 4903 females in an area of 5.3 square kilometers giving a population density of 1.811 persons per square kilometer according to the 1999 Census.

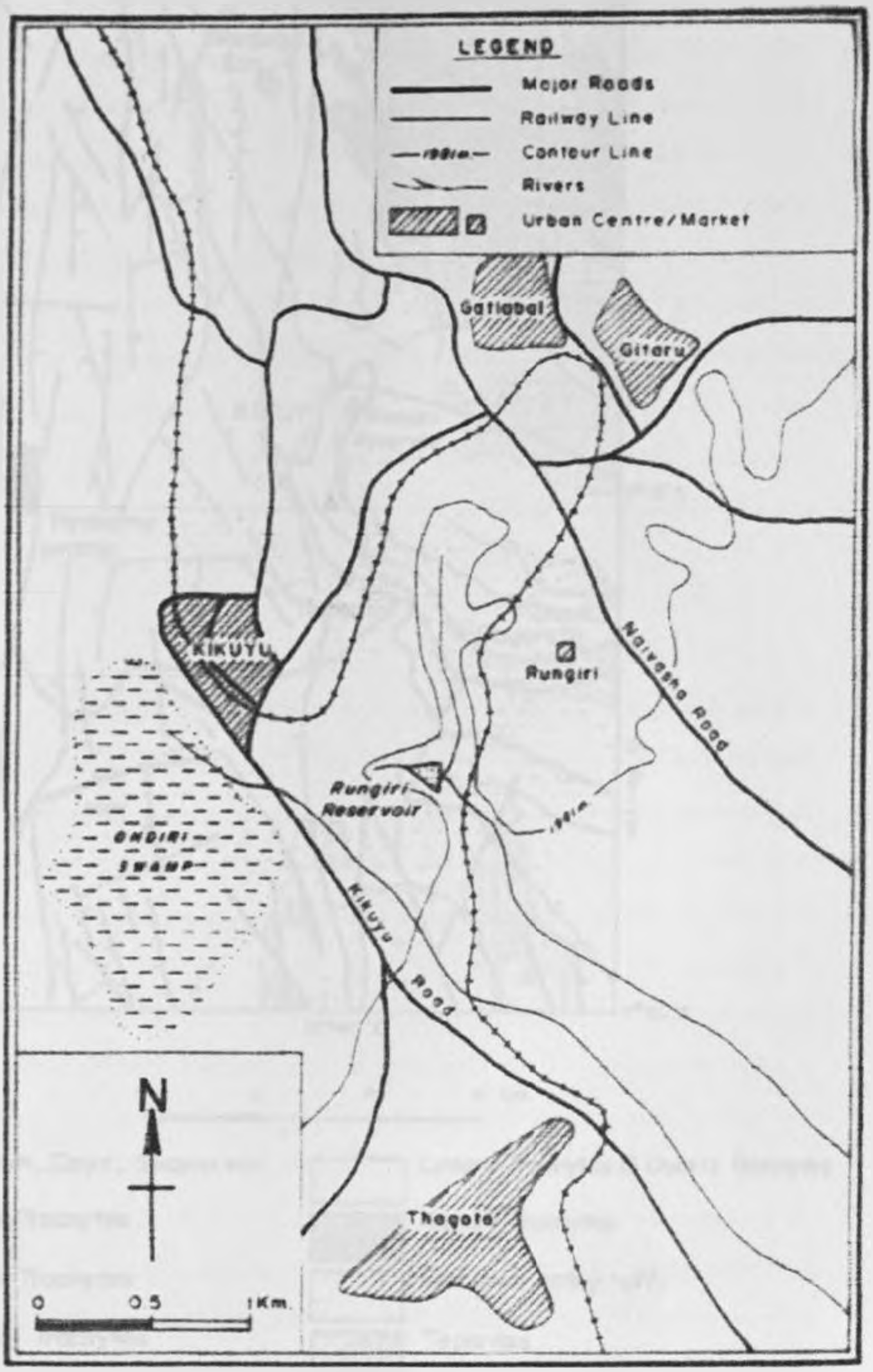


Figure I Location of Rungiri Reservoir

Figure 2.02: The Location of Rungiri Reservoir Source: Sok, 1967

Figure 2.03: The Geology of Rungiri Area (Source: Saggerson, 1971)

2.4: URBANIZATION

Settlement in Kikuyu Division is influenced by such industries as steel rolling, milk and garment making factories, which are based within the town council, which offer employment and other business opportunities. Proximity to Nairobi coupled with cheaper housing and efficient transport services has also led to the fast growth of Kikuyu town. Urbanization has attracted development activities especially Jua Kali activities, manufacturing and sale of both industrial and agricultural commodities which are on high demand. This has not only created employment in the town but also in the catchment area including vegetable farming through irrigation near the reservoir. Besides Kikuyu town, there are other small towns in the fringes like Gitaru or Mutego that are growing faster than Kikuyu Town Council can supply important social amenities like water or recreation facilities. This lives the residents with no choice but to seek water from boreholes or the Rungiri Reservoir.

2.5 MINING

Due to the fast growth of the Kikuyu town and its environs, there has been a continuous demand for stones and ballast to satisfy the fast growing building and construction industry either for commercial or residential purposes. The presence of Trachytes and Quartz makes quarrying an alternative source of income in the area. The extraction of quarry stones can be described as extensive and efforts to intervene or regulate the activity is hampered by the fact that most quarries are on privately owned land through ownership of a free title deed. This gives the land- owners a right to carry on all activities on their land without interference. The greatest problem is when the quarrying sites are left open without any restoration activities because the soil was removed, sold or dumped elsewhere. The result of this has been increased invasion by climbers and low value tree species besides being a danger because of the steep cliffs and loss of agricultural land. Mining through open cast blasting achieves the results like that of creation of Rungiri Reservoir. There are many explosives used during the blasting of rocks but the most commonly used one in Kenya is Ammonium Nitrate.

The blasting procedure adopted during rock quarrying depends on the expected end results. Thus, to get bolders for building or for crushing the following actions are necessary;

1) Drilling a hole about 40 feet into the target stone,

2) Adding Ammonium nitrate (*Priteledi*) plus diesel in the ratio 96:4 in the drilled hole. In the case of Rungiri reservoir, many holes were drilled with a distance of about 15 feet between holes as shown in Figure 2.04 and

3) Detonation of the mixture with some current.

The result of the above action is the creation of a stress wave that is responsible for the breaking up of the rock with some flying as far as 1km away. The movement of the wave is dependent on the a number of factors including the following among others:

- Type of explosives,
- Type of rock. The wave moves faster in the hard rock than in soft rock,
- Length of the explosive column in relation to hole diameter,
- Distance from the hole,
- Number of priming points,
- Relationship of detonation velocity to wave propagation velocity of the rock.

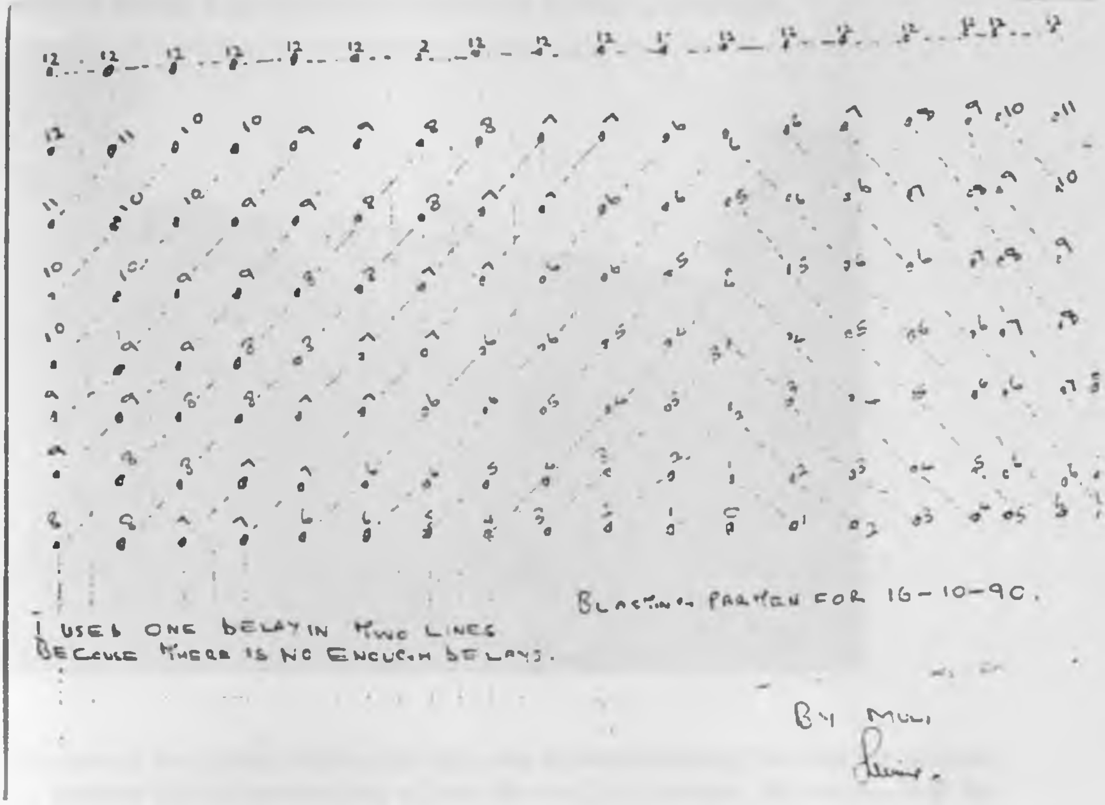


Figure 2.04: Example of a pattern used during the blasting process

Source: Mines and Geology department, Ministry of Environment and natural Resources

PLATE 3: ROOF TOP DESTRUCTION BY FLYING STONES

This is one of the houses whose roof tops was destroyed during the blasting process. Many patches like this are evident all over the roof. It is located 200 metres from the Rungiri Reservoir in the eastern direction. However, even though the owner would like to renovate the house, she cannot do so because she will be destroying the only evidence that qualifies the house for compensation, eleven years after quarrying **(Source: Researcher 2003).**

Plate 4: THE ABANDONED HOUSE AT RUNGIRI RESERVOIR

This house 5 metres away from the Rungiri reservoir and in the northern direction was near completion when the blasting process began. Unfortunately, there was no EIA done to recommend that the residents be moved away temporarily and be compensated for any damages accrued as a result of the blasting. The owner is yet to receive compensation for the damage. Until then, this house remains as evidence as to how poor governance and failure to implement rules and regulations can slow down development (**Source: Researcher 2003**).

The most common environmental hazards during the blasting action includes dust production, noise and vibrations. The blasting also results in the discharge of flying rocks. At Rungiri, the dust was a problem during the crashing process whereas the fly rocks damaged rooftops as shown in Plate 3. This causes them to leak during the wet season. The vibrations also caused cracking of house floors as well as the walls (Plate 2). Plate 4 shows a picture of a house located 5 meters from the Rungiri Reservoir that was abandoned as a result of the tremors. The owner is yet to receive any compensation eleven years later, the tragedy.

2.6 AGRICULTURE

Agricultural practices like zero grazing and intensive vegetable farming are the main income generating activities. The use of nitrogen, phosphorus and potassium (NPK) based fertilizers in addition to manure from zero grazing units on farms contributes both directly and indirectly to enrichment and pollution of water sources like Rungiri reservoir through underground seepage. The fertilizers and manure contribute greatly to the nitrogen and phosphorus ratios that are the basis for the mushrooming of algae in the reservoir that forms the basis for the primary production.

CHAPTER THREE

METHODOLOGY

3.0: INTRODUCTION

This section discusses the materials and methods used during the acquisition and analysis of data in this study. The procedures included the designing of a suitable site sampling strategy within which the collection of data was configured. The project mainly utilized primary data that was acquired through the following avenues: water sampling and analysis, biodiversity sampling and analysis and environmental perception studies.

3.1: SAMPLING STRATEGY

In order to identify different sampling sites in the reservoir, the qualities considered included: general shape of the reservoir, sources of run off, unique features such as bare stone or soil cliffs, vegetation distribution, human activities and general wind direction. Using the above features or qualities five sampling sites were identified and were as follows (Figure3.01):

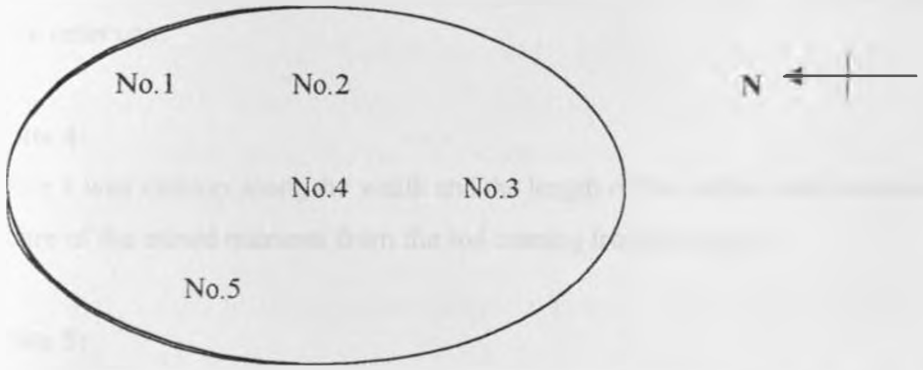


Figure 3.01: Rough sketch of the distribution of the sampling points

Site 1:

Site 1 had the unique feature in that any run off from the surrounding upper northern farmlands of the Rungiri village comes in through this point. The input has a possibility of having nitrates, phosphates or even cow dung from the zero grazing. Cow dung is the main fertilizing ingredients in newly constructed fish ponds as recommended by the Fisheries Department in Kenya whereas the nitrates and phosphates are the main ingredients that promote algae growth with phosphates being the limiting ingredient. A ratio of 16N: 1P has been seen to give optimal growth.

Site 2:

Site 2 had the unique feature in that it is located next to a stone cliff. The site was characterized by water lilies (*Nymphae)*. This site occurs midway along the greater axis of the eclipsed shape of the reservoir along the eastern end.

Site 3:

Site 3 was located at the southern end of the tip of the reservoir. It was characterized by the presence of cattails or *Typha* vegetation which is drying. The cliff was therefore bare due to continous disturbance by young men trying to look for the Limuru Trachyte to make quarry chips. The soil was loose and could easily release sediments into the reservoir thereby forming a source of nutrients for algae growth in the reservoir.

Site 4:

Site 4 was midway along the width and the length of the eclipse and hence could take care of the mixed nutrients from the soil coming from the south.

Site 5:

Site 5 had the unique feature in that at the time of sampling in January. the wind direction was from east to west and hence the water currents forming as a result could easily mix the water column thereby transforming the water quality. It was also the zone where major human activities like washing clothes, fetching of water for household use and for livestock. The launching of the rubber dinghy was undertaken from this point.

3.2: WATER QUALITY SAMPLING AND ANALYSIS

Water is probably the most important natural resource in the world since without it life cannot exist and industries cannot operate. It is known that, of all the natural resources, it has no known substitute in its uses. Only about 1% of world water is available through the hydrologic cycle for all uses including industrial, agricultural and domestic uses. Any degradation of water quality can escalate problems of water scarcity. Water quality characteristics range from physical characteristics, chemical characteristics to biological characteristics and different uses like industrial, agriculture or even domestic uses consume water of different standard qualities dictated by World Health Organization (WHO) and specific country standards. The Kenya Bureau of Standards (KEBS) determines the Kenyan standards.

3.2.1: Methods of water sampling and assessment

The following materials were used during the water sampling. This also included a general assessment of the general reservoir morphometry; a rubber dinghy, a nylon string and a fish buddy. In order to measure the water depth, a nylon string was tied to the boat anchor and slowly lowered until it anchored at the bottom. This depth was marked with a waterproof pen to be measured at the shore using carpenters measuring tape. In order to distinguish the different sampling points, the mark would coincide with the number of the sampling point. For example if measurement was for site 1 the depth mark on the rope would just be a single line and site two would have two lines. The procedure was repeated for the rest of the sites.

The fishing buddy whose structure is shown in Plate 4 was attached to the boat for the detection or sensing of the presence of fish. It also registered the depth of the water. In order to use the equipment, a few runs were made within the reservoir.

In-situ measurement of water transparency was undertaken using a Secchi Disk. which allows the measurement of Secchi disc visibility at various sites. Secchi depth is an important measurement for the determination of the depth at which at least 5 per cent of the solar radiation reaches the surface. When siltation or clay causes turbidity, the system tends to be rated as unproductive but when turbidity in a system is the result of microorganisms, then that system is said to be productive. At the Rungiri reservoir, the Secchi depth transparency was measured using improvised equipment due to lack of the standard Secchi disk. The improvising procedure was as follows:

1. A stone heavy enough to sink in a whitish paper was tied to a nylon string of known diameter but firm enough to support the stone in the paper bag.
2. The stone was sunk in water and the point at which the paper disappears and appears was marked on the string length.
3. The total length of the string from the marked point to the tip of the stone in the paper bag was marked. This is recorded as the secchi depth.

The collection of water samples for laboratory analysis was undertaken using 1 liter sampling bottles and a scooping spoon or 1 liter jug. At each sampling site a one liter sampling bottle was filled to the brim by just lowering the bottle into the water and the samples were refrigerated to keep them fresh since the sampling was done during the weekend. Sampling was done once during a dry day in January. The determination of the chemical parameters was undertaken at the Water Quality and Pollution Monitoring Laboratory in Nairobi. The only exceptions were pH, water temperature, dissolved oxygen and oxidation and reduction potential, which were measured on site using portable oxygen and pH meters. The laboratory analysis was undertaken within a week after sample collection.

3.2.2: Water quality parameters

The physico-chemical water quality parameters considered in this research project were as follows:

1. Temperature

Though easy to measure using a simple thermometer, it is very significant because it affects other properties like solubility and chemical reactions. Temparature was measured on site using a portable meter.

2. Taste and odor

Taste and odour emanate from dissolved impurities. Although judgment may be subjective, drinking water should be odorless and colorless according to WHO Standards. Taste was determined orally.

3. Color

Pure water has a pale green-blue tint while in large volumes and thus it is important to differentiate between color due to suspended or dissolved material in solution. Water color was determined gravimetrically in the Laboratory.

4. Turbidity

Turbidity emanates from colloidal solids in water either from the soil or discharges of sewage or industrial wastes, which give water a cloudy appearance that is aesthetically unattractive and may even be harmful. Turbidity was determined gravimetrically in the lab.

5. Solids

These may be present in suspension as suspended solids (SS) or in solution form as total dissolved solids (TDS). Suspended solids can easily be estimated through filtering a sample through fine paper whereas TDS can be estimated from electrical conductivity measurements since conductivity of a solution is directly related to the quantity of dissolved salts.

6. Electrical conductivity

Conductivity of any solution is dependent upon the amount of dissolved salts and thus, it is directly related to TDS. It was determined titrimetrically in the laboratory.

7. pH

Water pH is defined simply as the negative logarithm of the hydrogen ion concentration. pH values range from 0-14 with 7 as the neutrality point, below 7 being acid and above 7 being alkaline. Many chemical reactions are controlled by pH and biological activities are restricted to a fairly narrow pH range of 6-8. Thus, water being too acidic or too alkaline will be undesirable because of corrosion hazards and possible difficulties in treatment. Water pH was determined calorimetrically in the laboratory

8. Alkalinity

It is useful in waters and wastes in that it provides buffering to resist changes in pH and it is due to the presence of bicarbonate (HCO_3^-) and hydroxide (OH^-) ions. Alkalinity was determined titrimetrically in the laboratory.

9. Acidity

This is expressed in terms of $CaCO_3$ because most natural waters are buffered by a CO_2-HCO_3^- system. It was determined titrimetrically in the laboratory.

10. Hardness

This is the property that reduces lather formation with soap and is mainly due to the presence of Calcium (Ca^{2+}) and Magnesium (Mg^{2+}) ions. It was determined titrimetrically in the laboratory.

11. Biological Oxygen Demand (BOD)

This is a measure of the oxygen required by micro-organism whilst breaking down organic matter. It was measured titrimetrically in the laboratory.

12. Dissolved Oxygen (DO)

Aquatic life forms like fish are dependent on the amount of oxygen available in the water for their survival. Hence, a measure of the oxygen depleting substances like organic matter would be detrimental to the oxygen demanding life forms and would render an ecosystem being referred to as being dead. DO was measured on site using a portable meter.

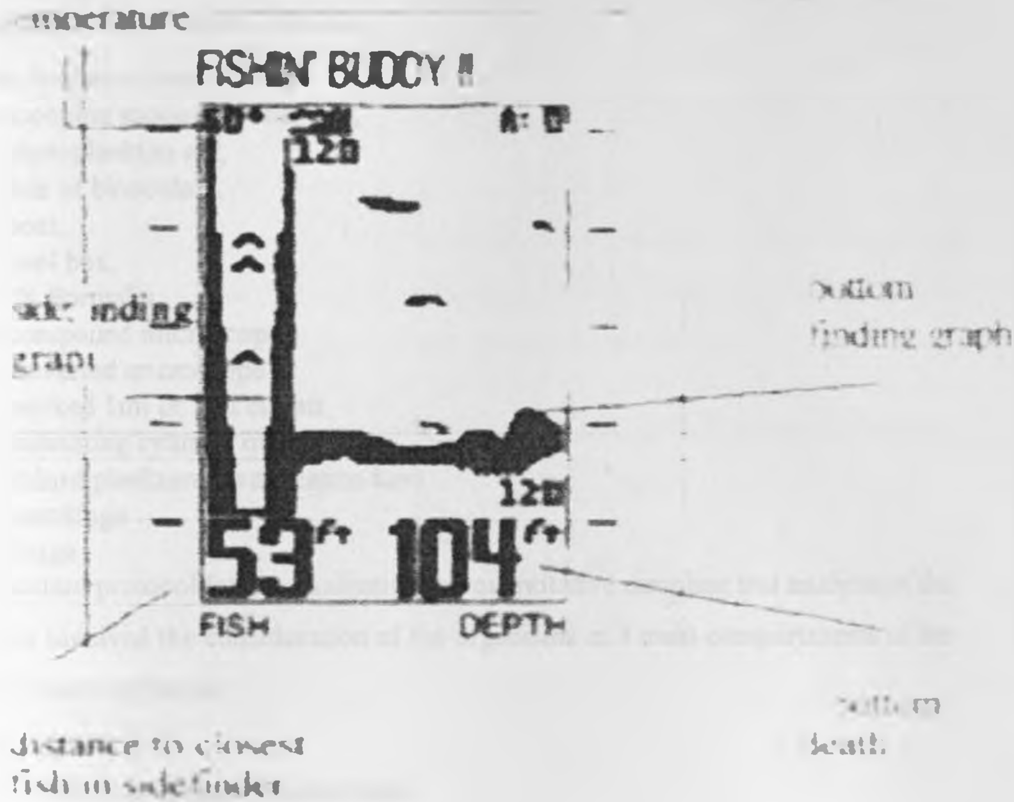
13. Nitrogen

This is an important element since biological reactions can only proceed in the presence of sufficient nitrogen and exists in four main forms which are organic nitrogen, ammonia nitrogen, nitrite nitrogen and nitrate nitrogen. Only nitrates and nitrites were measured spectroscopically in the laboratory.

14. Chloride

Chloride in water is often responsible for brackish taste in water and is an indicator of sewage pollution in water because of the chloride content of urine. Chloride was measured spectroscopically in the laboratory.

Plate 5: The Structure of a Fish Buddy



3.3: BIODIVERSITY SAMPLING AND ANALYSIS

The biological parameters considered in the study included phytoplankton. Zooplankton and water birds. The materials used for sampling, identification and quantification included the following:

- One liter sampling bottles.
- A scooping spoon or 1 liter jug.
- A phytoplankton net,
- A pair of binoculars,
- A boat.
- A cool box.
- 40 % Formalin.
- A compound microscope
- An inverted microscope
- A marked 1ml or 5ml cuvett
- A measuring cylinder or a pipette
- Standard plankton identification keys
- A centrifuge
- A fridge

The standard protocol for the qualitative and quantitative sampling and analysis of the plankton involved the consideration of the organisms at 3 main compartments of the water column as follows:

1. Surface level,
2. Vertical integrated 1meter depth,
3. Vertical integrated 2 meter depth.

Surface level samples (0 metres)

1. While the boat is moving, a Zooplankton net was trawled along the surface of the water for about one and half meters in the same directions and all the Zooplankton correct in the bottle attached to the bottom of the net.

2. The contents were emptied into another labeled container of equal dimension and then safely kept in the cool box to be transferred into the refrigerator after completion of the exercise.

Vertical integrated samples (1 or 2 metre depth)

1. A scooping spoon was sunk to a depth of a metre to scoop the contents at that level and empty them into a labeled container. The procedure was repeated at 2 metre depth. This method plus the surface trawl ensured the knowledge of what aquatic organisms there are and at what levels they were found in the water column.

2. The contents were later transferred into the refrigerator for safe keeping and depending on the distance from the field could be diluted with 5% formalin in order to fix the zooplankton to avoid their decomposition.

The phytoplankton were mainly sampled using the surface bottling method as follows:

1. While the boat was anchored, one liter bottles were directly filled from the surface of the water and cocked tightly.

2. The bottle was also labeled and placed in a cool box for transfer to the laboratory.

The above methods were found to be appropriate for the Rungiri reservoir since it is young and the population density of the planktons is still low.

Plankton Identification and quantitative analysis

The identification and quantification of the lifeforms was undertaken using the following equipment: a compound microscope, microscope slides and cover slips, a pipette, and plankton identification keys.

The method was as follows:

1. At each sampling site, one litre of the reservoir water was filtered through a plankton net ten or five times. This methodology of sampling assumes that through filtering ten or five litres of the water, all representative zooplanktons

and the phytoplankton will have been captured in the receiving container which has the capacity of about one litre.

2. The contents were transferred into a container of a capacity not less than one litre and dilute 40% formalin added to fix the zooplanktons in order to avoid decomposition of the benthic inverterbrates and the zooplankton. The alternative of using the formalin was place in the cool box for transfer to the laboratory without delay.
3. In the laboratory, a drop of the sampled water was placed on a slide using a pipette.
4. The slide was transferred on to a compound microscope.
5. With the help of different magnifications. identification of the algae, zooplanktons or even the benthic invertebrates was done against the identification keys,
6. This procedure was repeated for all the other samples collected from the field and records of all identified species were made in a separate notebook.

The materials used during the counting process included the following: a graduated 1ml or 5ml Cuvett, a graduated pipette or measuring cylinder, an inverted microscope, identification keys, and a centrifuge.

The procedure used was as follows:

1. Using a pipette and considering the holding capacity of the cuvette, measure the required volume of the sampled water was measured.
2. The contents were thoroughly centrifuged.
3. The contents were then transferred into a cuvette (5ml cuvette having four transects was used).
4. Counting of the micro-organism was started from one transect and then to the second transect as shown in the sketch on figure 9.

5. Assuming that the whole volume of the sample has an equivalent number of the micro-organisms, the number was counted on the two transects.

6. The number was recorded to be the representative of the micro-organism population of the total sample.

7. The procedure was repeated for all other samples.

8. A good record was made for all the population from different sites.

Figure 3.02 shows the general pathways examined under the inverted microscope to enable the estimation of plankton numbers in the water samples.

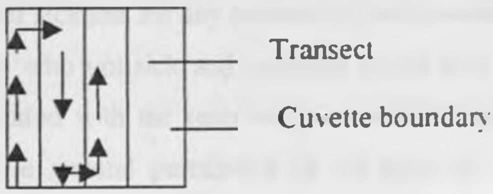


Figure 3.02: General view of the cuvette through an inverted microscope (The arrow direction showing how counting was done).

A numerical count of the existing birds was made with the help of the binoculars and a checklist of the common birds in the area. Details of the existing macrophytes was made during site selection and their records made.

3.4: COMMUNITY HEALTH AND ENVIRONMENTAL PERCEPTION ANALYSIS

A two -stage data collection procedure was adopted as follows for evaluation of the community health and environmental perception analysis.

Stage one

A standard questionnaire was designed to establish the diseases the Rungiri community has suffered which they associate with the existence of the reservoir. The hospitals or private clinics they attend and the costs they have incurred per year were also to be estimated. The study population or Rungiri community included those people living around the reservoir but not outside a 2 kilometers radius. Whereas the respondents are the heads of the family, in Rungiri, the woman was preferred since she is the one who is responsible for all the house hold chores like fetching water or washing clothes and in case of sickness for any member of her household, she will be in a better position to know who got sick and possibly where they were taken for treatment. Other uses associated with the reservoir were established in addition to capturing and quantifying the general perception of the reservoir by the Rungiri community. The standard questionnaire on Appendix 1 was used for the interviews.

Systematic sampling where every tenth household head was interviewed was adopted for this purpose in order to get the frequency of hospital visitations, kind of disease suffered and the approximate cost of the treatment. Systematic sampling procedure was adopted because the Rungiri community problems and way of life is so related and unique to them that this procedure would bring out the issues out clearly. This also helped in acquiring the data for stage two data collection. A population survey using a questionnaire was conducted to cover the area under study but in-depth interviews with the doctors and leaders were also conducted.

Stage two

Having established from stage one results where the majority of the Rungiri community go for treatment (hospitals and private clinics) then hospital records from those institutions were collated in order to get the water borne disease occurrence at least two years before and after reservoir was created and compare the frequency of occurrence. This would confirm beyond reasonable doubt whether the reservoir has been a health hazard.

3.5: DATA ANALYSIS

Several methods were utilized so as to have concrete but well summarized work. For instance the water quality results were organized into histograms with the use of MS - Excel spreadsheets. Biodiversity results were organized in tables formats whereas the community perception analysis was done using regression analysis and correlation coefficient analysis. tools with the help of computer aided SPSS programme.

Bivariate regression analysis gives the relationship between two variables. However. the functional relationship between two variables may be too complicated to be described in simple terms leading to use of simple mathematical expression. It is assumed that a certain type of linear relationship exists between two variables and parameters are unknown. The unknown parameters are estimated with the help of available data and a fitted equation is obtained which can be evaluated in terms of its significance. The strength of the relationship was obtained by using the correlation coefficient.

SPSS was used in the correlation analysis to analyse the data on community perception. The correlation coefficient analytical tool indicates the variation in y, which is explained by the independent variable x. The goodness with correlation coefficient. is that it measures the strength of the relationship between x and y.

Statistical charts utilized for presentation of data included histograms in water quality data presentation and pie charts to display a particular distribution like occupation of Rungiri residents. Histograms were preferred because they easily show a difference in either increase or decrease of particular comparative parameters under investigation.

CHAPTER FOUR

RESULTS

4.0: INTRODUCTION

This chapter presents the results generated from the analysis of the data collected in the field. The results are organized in separate sections, which deal separately with reservoir morphometry, water quality and biodiversity. The water quality part is organized in terms of both physical and chemical aspects while biodiversity results are presented according to the various lifeforms considered in this project.

4.1: MORPHOMETRY AND PHYSICAL WATER QUALITY

The morphometric and physical quality aspects examined included water depth, water temperature, water transparency, turbidity, water colour and suspended sediments.

4.1.1: Water depth

Table 4.01 shows the water depth characteristics as reflected by the measurements taken at different sampling sites. The results show that the general range of water depth is between 5 and 12 m. The deepest section is at the outlet section which also the most actively utilized part of the reservoir (Table 4.01 and Appendix 2). This signifies great public hazard due to the risk of drowning especially in the case of the numerous children who visit the area.

Table 4.01: Rungiri Reservoir depth characteristics

Sampling point	Location	Depth (m)
Site 1	Run-off point	4.97
Site 2	Rocky point	5.59
Site 3	South tip	7.60
Site 4	Middle part	8.70
Site 5	Outlet section	12.25

Source: Researcher 2003

4.1.2: Water temperature

Table 4.02 shows the results of water temperature measurements, were ranging between 23 and 25°C and mean temperature of 24.55°C. Site one was cooler than the others and there was a systematic drop in water temperature by depth.

Table 4.02: Rungiri Reservoir water temperature characteristics

Sampling point	Location	0°C (Surface)	0°C (80 cm)
Site 1	Run-off point	24.5	24.1
Site 2	Rocky point	23.6	23.0
Site 3	South tip	25.2	24.9
Site 4	Middle part	25.2	24.9
Site 5	Outlet section	25.3	24.8

Source: Researcher 2003

4.1.3: Water transparency and turbidity

The Secchi disk depths in the reservoir were 93 cm at the shoreline and 115 cm inside the reservoir. These records were very high by tropical standards. Most aquatic environments in the region are characterized by a high intake of soil which lowers the water transparency.

The water in the reservoir had a mean of 8.4 NTU far beyond the recommended WHO and KEBS standard of 5 NTU. However, the turbidity levels in the bore-well was well within the standards and appears to have reduced significantly from 16 NTU in 1995 following reservoir establishment to 2 NTU in 2003. This transformation can be accounted to the sedimentation process, which occurred following the completion of earthworks in the area.

4.1.4: Total suspended solids

The TSS values are all below the WHO recommended value of 30mg/l except for seepage 2 which has TSS of 43 mg/l as even compared to seepage 1 that has a TSS value of 2 mg/l. However, Njiiru stream has a TSS value of 29 mg/l a value close to the maximum recommended by WHO. The TSS concentration pattern is as shown in figure 4.01.

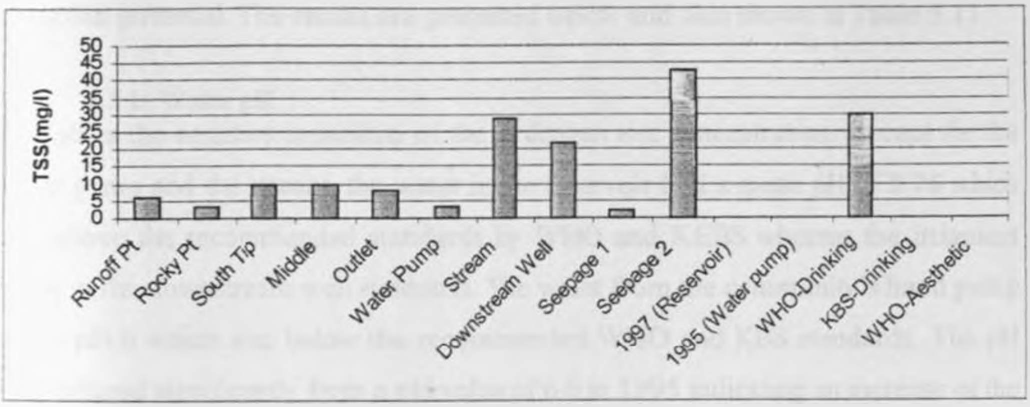


Figure 4.01: Total suspended solids concentration pattern Source: Researcher 2003

4.1.5 Water colour

The colour of the water in the reservoir, the water pump, the stream and the first seepage was found to be suitable for human consumption as recommended by WHO and KEBS. The colour of the water in the community's hand pumped supply was 65 mgPt/l in 1995 but has significantly reduced to 5 mgPt/l in 2003. Details of the concentration pattern are as shown in figure 4.02.

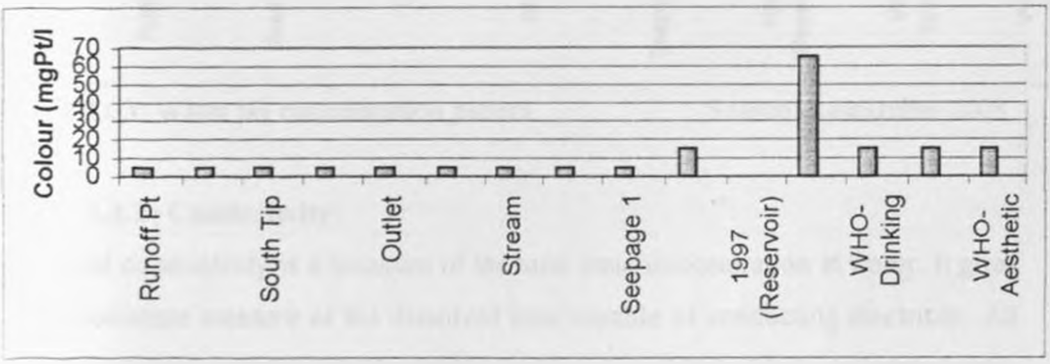


Figure 4.02: Water colour concentration pattern Source: Researcher 2003

4.2: RESERVOIR WATER CHEMISTRY

The chemical quality parameters considered in the project included water pH, electrical conductivity, iron, manganese, calcium, magnesium, sodium, potassium, total hardness, total alkalinity, chloride, fluoride, nitrates, nitrites, sulphates and orthophosphates. Free carbon dioxide, dissolved solids, BOD, COD and oxidation-reduction potential. The results are presented below and also shown in Table 5.11

4.2.1: Water pH

The pH is the negative logarithm of the hydrogen ion concentration. Except for the water pump and the stream, the water in the reservoir had a mean pH of 8.76 which was above the recommended standards by WHO and KEBS whereas the irrigation water in the downstream well is neutral. The water from the community's hand pump had a pH 6 which was below the recommended WHO and KBS standards. The pH had reduced significantly from a pH value of 6.6 in 1995 indicating an increase of the hydrogen ions in the water over the years (Figure 4.03). The stream and the two seepage's had the pH within the recommended range of 6.5- 8.5 according to WHO and KEBS Standards.

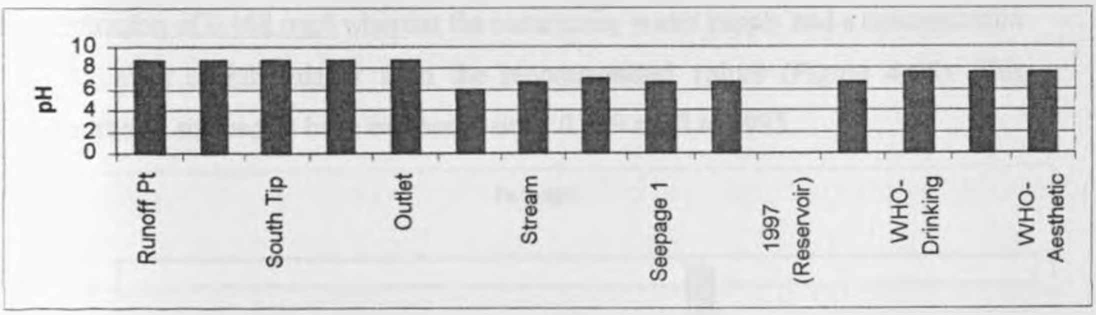


Figure 4.03: Water pH concentration pattern Source: Researcher 2003

4.2.2: Conductivity

Electrical conductivity is a measure of the total ionic concentration in water. It gives an approximate measure of the dissolved ions capable of conducting electricity. All the water from the reservoir had a mean conductivity of 286 μS/cm, the water pump, the Njiiru stream, the downstream irrigation well and the two seepage's from the reservoir had conductivity far below the recommended values by WHO and KEBS of 1000 μS/cm as shown in figure 4.04. The conductivity in the community water supply pump had increased from 269 μS/cm in 1995 to 292 μS/cm.

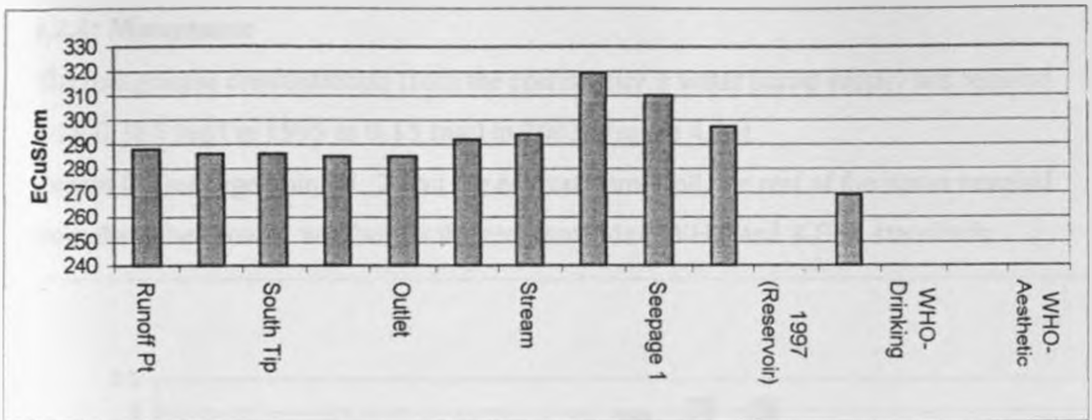


Figure 4.04: Water conductivity concentration pattern Source: Researcher 2003

4 2.3: Iron

All sampled water had iron concentration above the recommended WHO and KBS concentrations of 0.3 mg/l with reservoir water seepage having the highest amount of iron concentration measuring up to 3.3mg/l. The reservoir had a mean iron concentration of 0.468 mg/l whereas the community water supply had a concentration of 0.35 mg/l slightly higher than the recommended values (Figure 4.05). This concentration seemed to have increased since 0.169 mg/l in 1995.

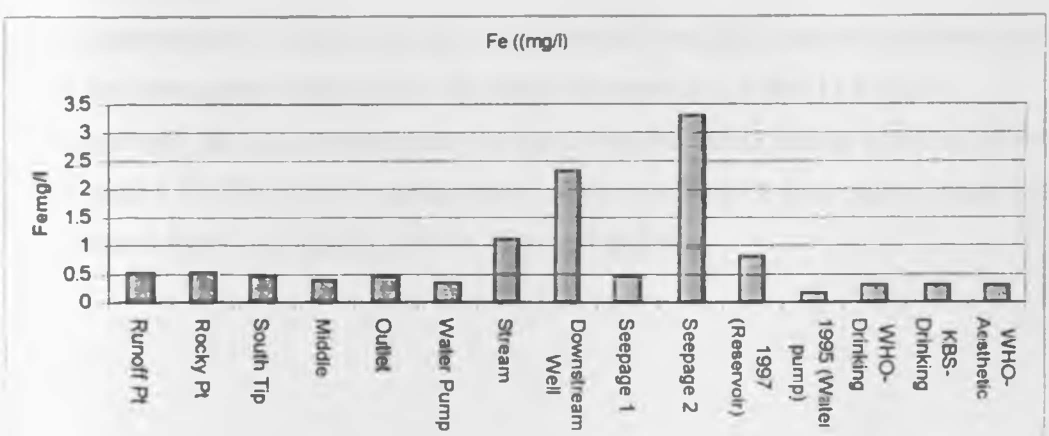


Figure 4.05: Iron concentration pattern Source: Researcher 2003

4.2.4: Manganese

The manganese concentration from the community's water pump supply has reduced from 0.386 mg/l in 1995 to 0.15 mg/l in 2003 (Figure 4.06).

Except for seepage points 1, 2 and the downstream well, the rest of the water sampled from the other points, was below the recommended WHO and KEBS standards.

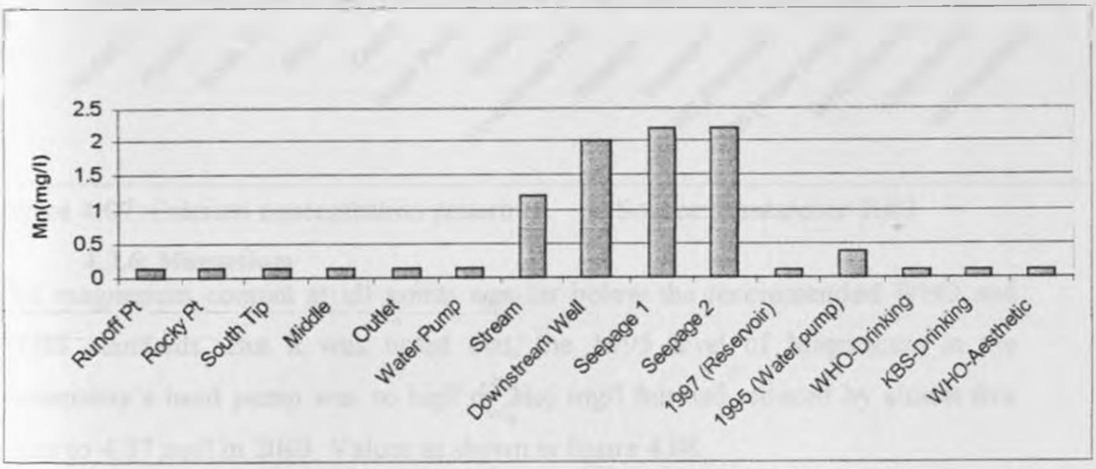


Figure 4.06: Manganese concentration pattern Source: Researcher 2003

4.2.5: Calcium

The concentration of calcium in the water sampled from the outlet within the reservoir and the community water pump was almost the same at12.5 and 12.8 mg/l respectively. All values were below the recommended WHO critical levels as shown in Figure 4.07. The calcium concentration in the community's water pump supply had decreased from 18.4 mg/l in 1995 to 12.8 mg/l in 2003.

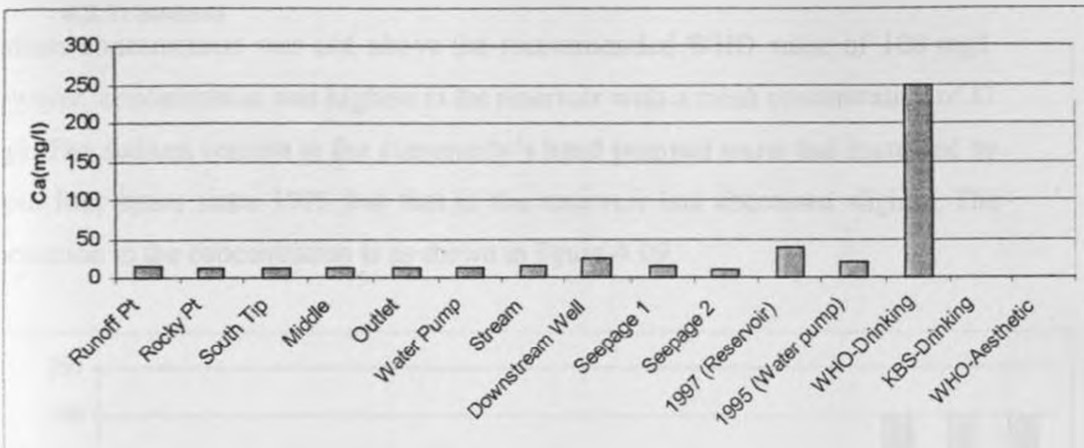


Figure 4.07: Calcium concentration pattern Source: Researcher 2003

4.2.6: Magnesium

The magnesium content at all points was far below the recommended WHO and KEBS standards. But it was noted that, the 1995 level of Magnesium in the community's hand pump was so high of 21.6 mg/l but had reduced by almost five times to 4.37 mg/l in 2003. Values as shown in figure 4.08.

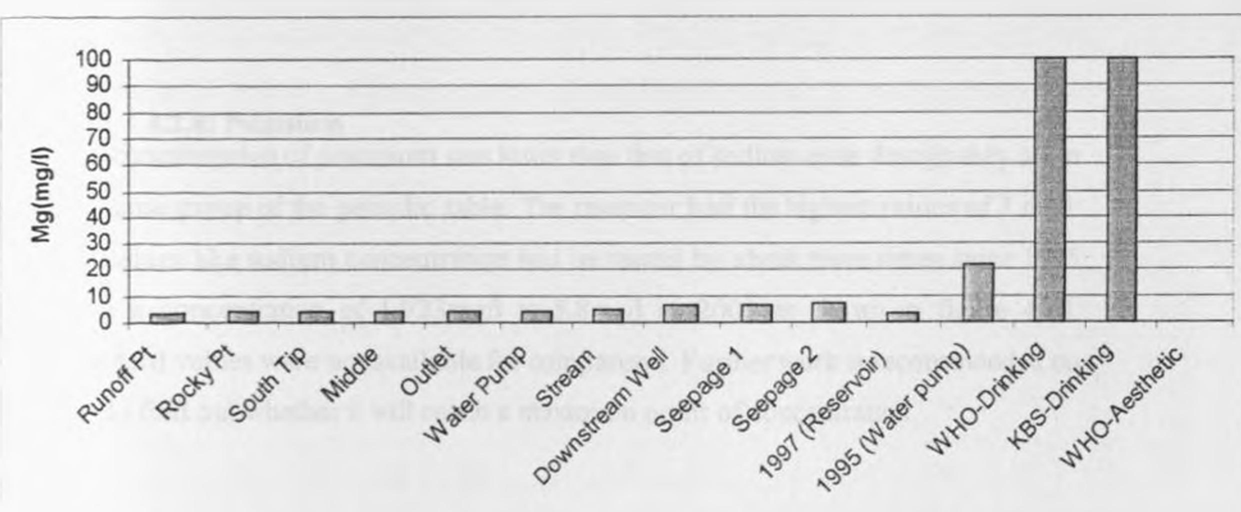


Figure 4.08: Magnesium concentration pattern Source: Researcher 2003

4.2.7: Sodium

Sodium concentration was not above the recommended WHO value of 100 mg/l. However, concentration was highest in the reservoir with a mean concentration of 37 mg/l. The sodium content in the community's hand pumped water had increased by about four times since 1995 but that in the reservoir had decreased slightly. The fluctuation in the concentration is as shown in figure 4.09

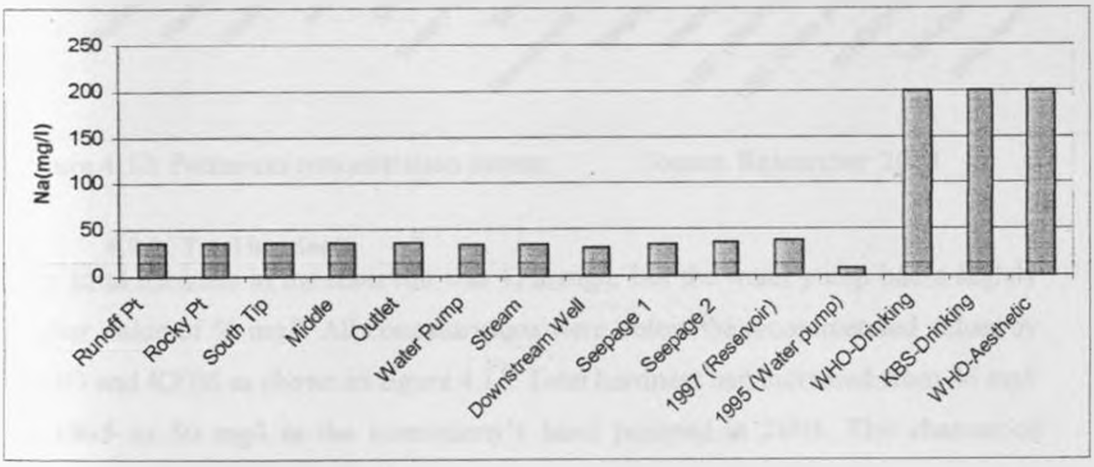


Figure 4.09: Sodium concentration pattern Source: Researcher 2003

4.2.8: Potassium

The concentration of potassium was lower than that of sodium even though they are in the same group of the periodic table. The reservoir had the highest values of 7 mg/l. Potassium like sodium concentration had increased by about three times since 1995 from a concentration of 1.923mg/l to 5.8mg/l in 2003 as shown in figure 4.10. Standard values were not available for comparison. Further work is recommended on this to find out whether it will reach a maximum point of concentration.

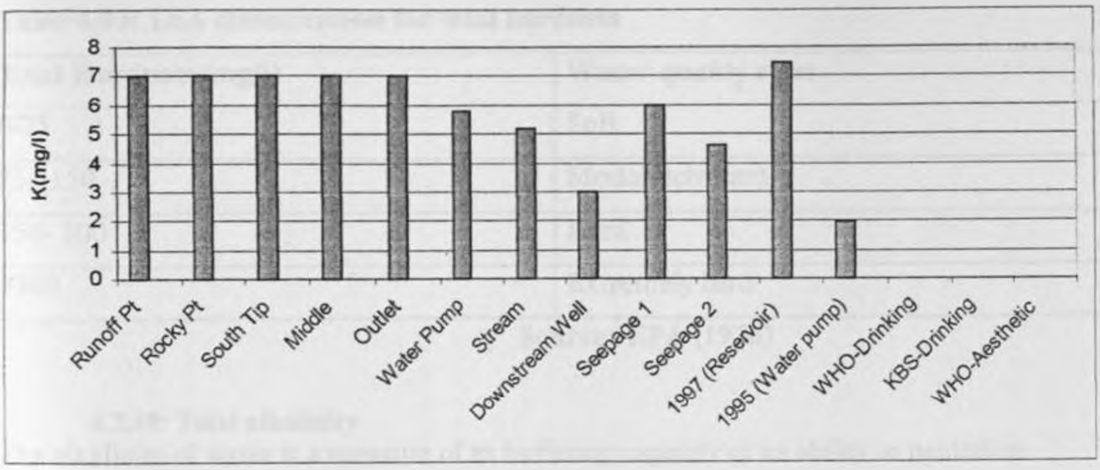


Figure 4.10: Pottasium concentration pattern Source: Researcher 2003

4.2.9: Total hardness

The total hardness in the reservoir was 47.2 mg/l. but the water pump had a slightly higher value of 50 mg/l. All concentrations were below the recommended values by WHO and KEBS as shown in figure 4.11. Total hardness had increased from 46 mg/l in 1995 to 50 mg/l in the community's hand pumped in 2003. The chances of continued increase in hardness cannot be ruled out and continuos assessment is therefore recommended. Table 4.03 shows the USA classification of water according to the total hardness. According to this classification the state of water in Rungiri can be considered to be soft.

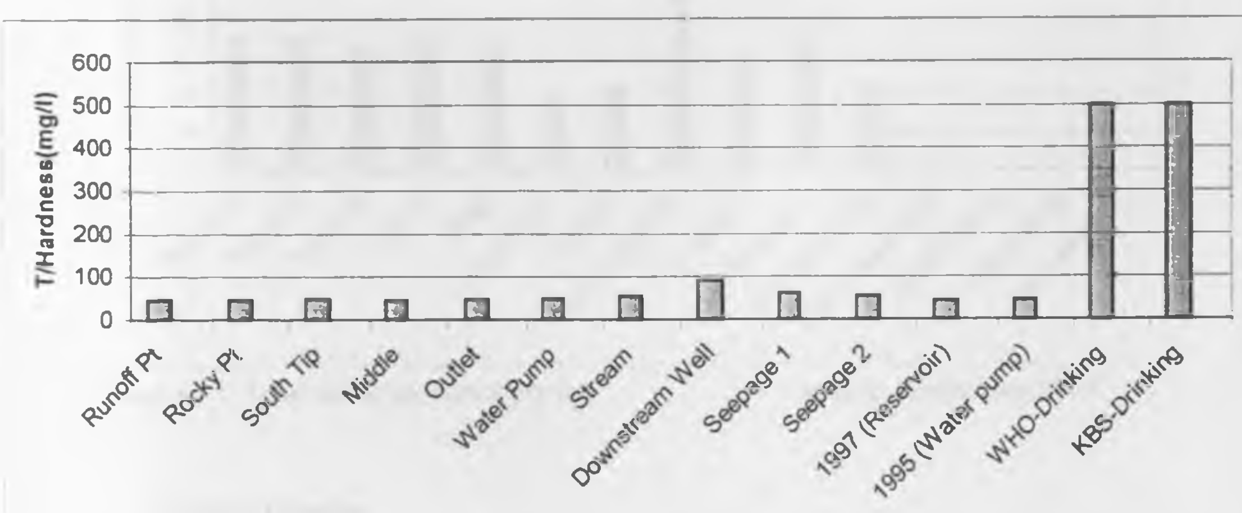


Figure 4.11: Total water hardness concentration Source: Researcher 2003

Table 4.03: USA classification for total hardness

Total Hardness (mg/l)	Water quality class
0-75	Soft
75 –150	Moderately hard
150- 300	Hard
>300	Extremely hard

Source: EPA (1976)

4.2.10: Total alkalinity

The alkalinity of water is a measure of its buffering capacity or its ability to neutralize acids and bases and could even be correctly defined as the sum total of all the carbonates (CO_3^-), the hydroxyl (OH^-) and the bicarbonate (HCO_3^-) ion. The downstream well had the highest alkaline values of 98 mg/l. Alkalinity in the reservoir had increased from a value of 44mg/l in 1997 to a mean value of 68.8mg/l in 2003. The total alkalinity in the water pump had also increased from zero in 1995 to current levels of 36 mg/l as shown in figure 4.12. Standard WHO and KEBS values were not available for comparison.

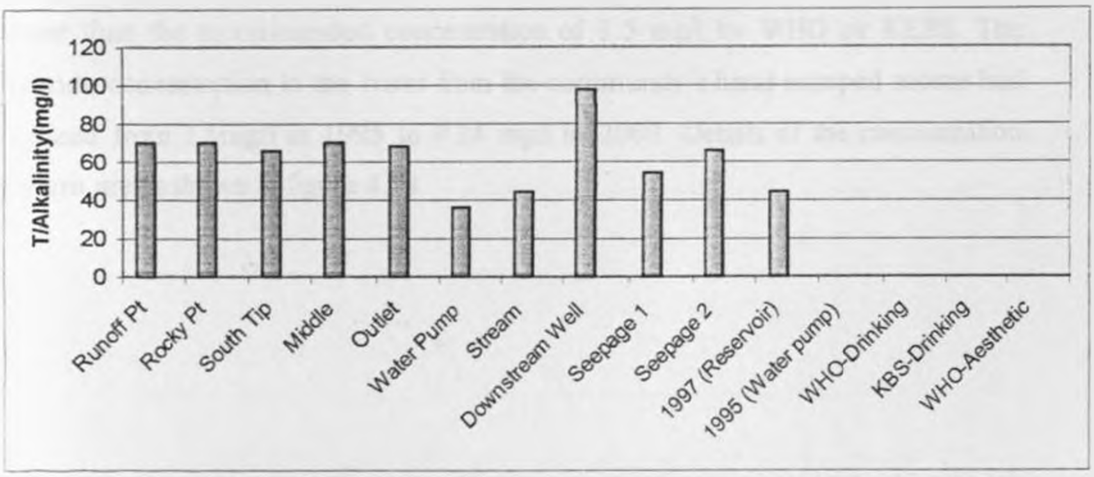


Figure 4.12: Total alkalinity concentration Source: Researcher 2003

4.2.11: Chloride

The reservoir had a mean chloride concentration of 41.8 mg/l whereas the community's hand pumped water had remained constant at 43 mg/l between 1995 and

2003. The values are far beyond the recommended 0.2-0.5 mg/l WHO level or the 0.1mg/l KEBS standards for drinking water. Details of the concentration pattern are as shown in figure 4.13.

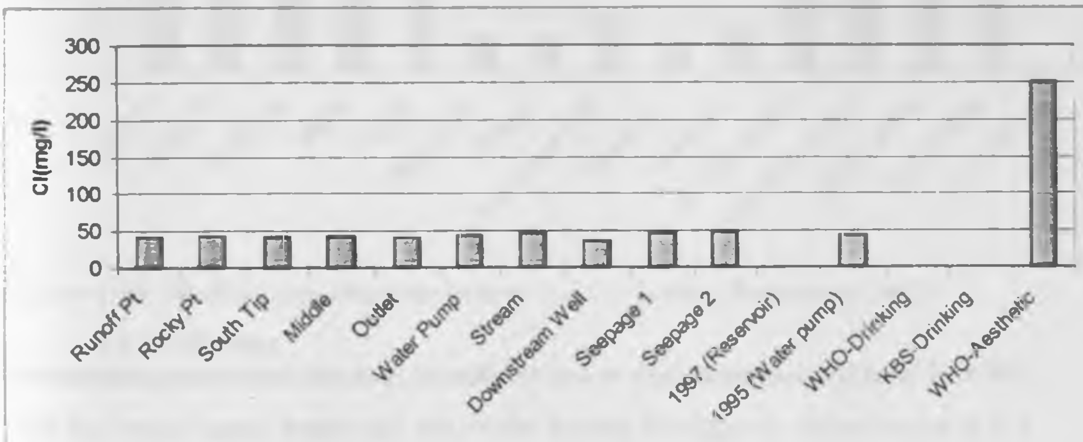


Figure 4.13: Chloride concentration Pattern Source: Researcher 2003

4.2.12: Fluoride

All the fluoride values were below the recommended WHO and KEBS values even though the reservoir had the highest concentration of 1.3 mg/l, which was slightly lower than the recommended concentration of 1.5 mg/l by WHO or KEBS. The fluoride concentration in the water from the community's hand pumped source had reduced from 1.5mg/l in 1995 to 0.24 mg/l in 2003. Details of the concentration pattern are as shown in figure 4.14.

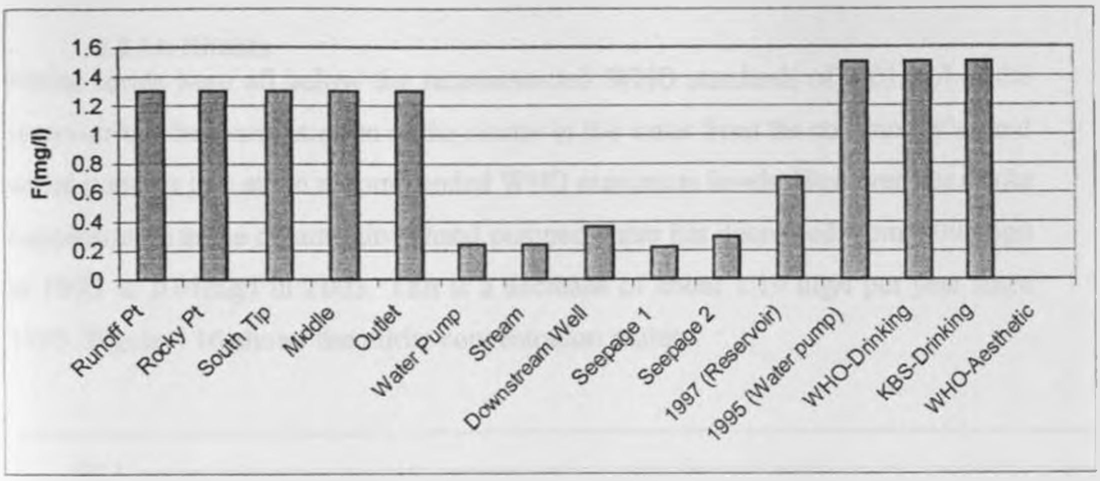


Figure 4.14: Fluoride concentration pattern Source: Researcher 2003

4.2.13: Nitrates

All sampling points had nitrate concentration below that recommended level by WHO with the water pump water and the stream having the highest concentration of 6.4 mg/l. There was a big difference in concentration between the nitrate levels in seepage points 1 and 2 at 5.8 mg/l and 0.82 mg/l respectively. Seepage 1 had almost four times the amount of nitrates in seepage point 2. The concentration of nitrates in the reservoir had decreased significantly from 4.4 mg/l in 1997 to a mean value of 1.16 mg/l in 2003. This was equivalent to about 0.62 mg/l of nitrate decline per year in the last six years. Figure 4.15 shows the nitrate concentration pattern.

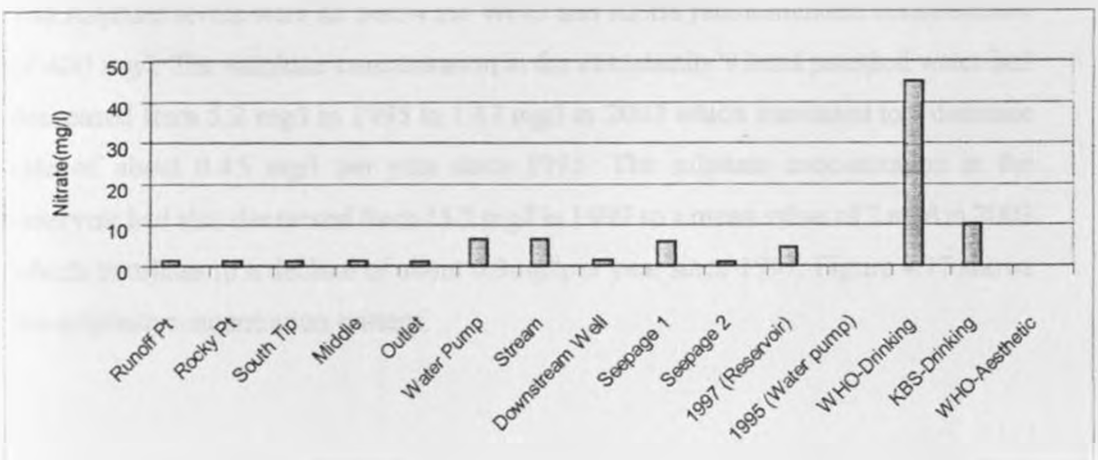


Figure 4.15: Nitrate concentration pattern Source: Researcher 2003

4.2.14: Nitrites

Nitrite levels were all below the recommended WHO standards of 0.01mg/l in the reservoir but the concentration of the nitrites in the water from the community's hand water pump is just at the recommended WHO maximum levels. However, the nitrite concentration in the community's hand pumped water has decreased from 0.095mg/l in 1995 to 0.01mg/l in 2003. This is a decrease of about 1.19 mg/l per year since 1995. Figure 4.16 shows the nitrite concentration pattern.

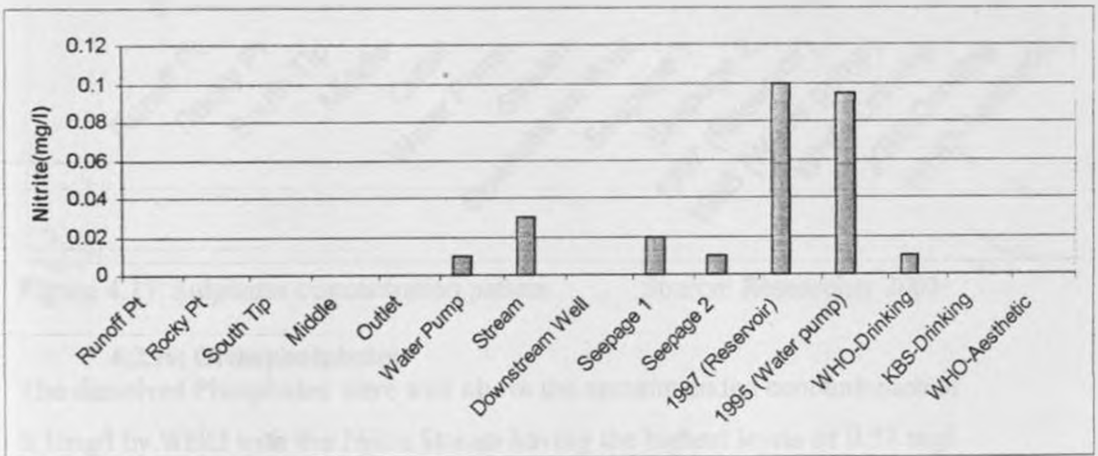


Figure 4.16: Nitrite concentration pattern Source: Researcher 2003

4.2.15: Sulphates

The sulphate levels were all below the WHO and KEBS recommended concentration of 400 mg/l. The sulphate concentration in the community's hand pumped water had decreased from 5.2 mg/l in 1995 to 1.43 mg/l in 2003 which translated to a decrease rate of about 0.45 mg/l per year since 1995. The sulphate concentration in the reservoir had also decreased from 15.2 mg/l in 1997 to a mean value of 2 mg/l in 2003 which translates to a decline of about 0.3mg/lper year since 1997. Figure 4.17 shows the sulphate concentration pattern.

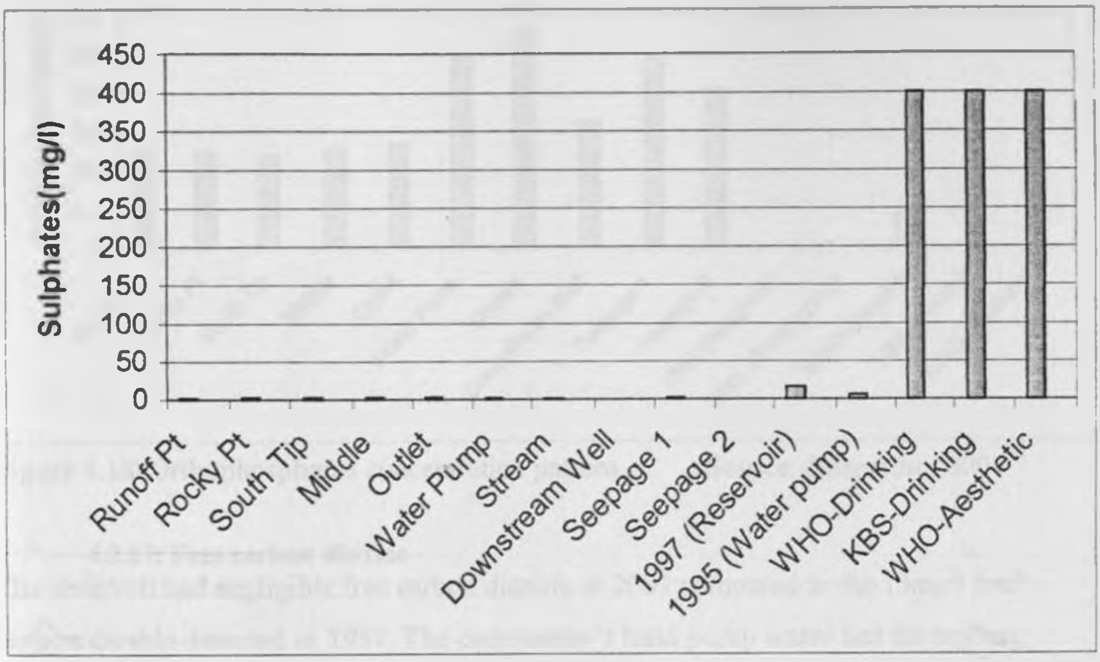


Figure 4.17: Sulphates concentration pattern Source: Researcher 2003

4.2.16: Orthophosphates

The dissolved Phosphates were well above the recommended concentration of 0.1mg/l by WHO with the Njiiru Stream having the highest levels of 0.57 mg/l followed by the pump water which had a concentration of 0.51 mg/l as shown in figure 4.18. The reservoir had a mean orthophosphate level of 0.26 mg/l with the outlet having the highest value of 0.27 mg/l. Phosphorus concentration between 0.01 and 0.1 mg/l is sufficient to promote accelerated growth of aquatic life especially algae.

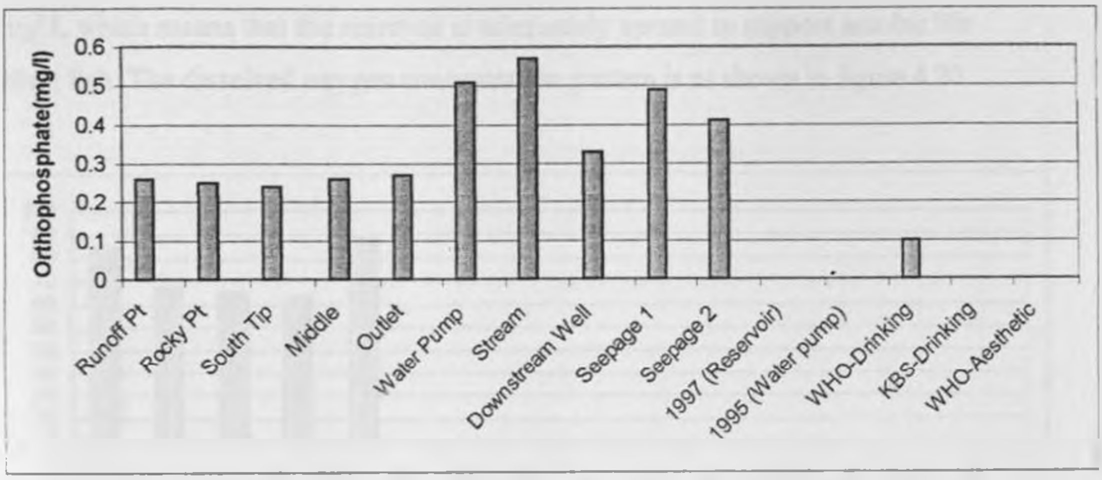


Figure 4.18: Orthophosphates concentration pattern Source: Researcher 2003

4.2.17: Free carbon dioxide

The reservoir had negligible free carbon dioxide in 2003 compared to the 13mg/l free carbon dioxide detected in 1997. The community's hand pump water had the highest free carbon dioxide of 32 mg/l against recommended WHO concentrations of 4 mg/l. The concentration pattern for the free carbon dioxide is as shown in figure 4.19.

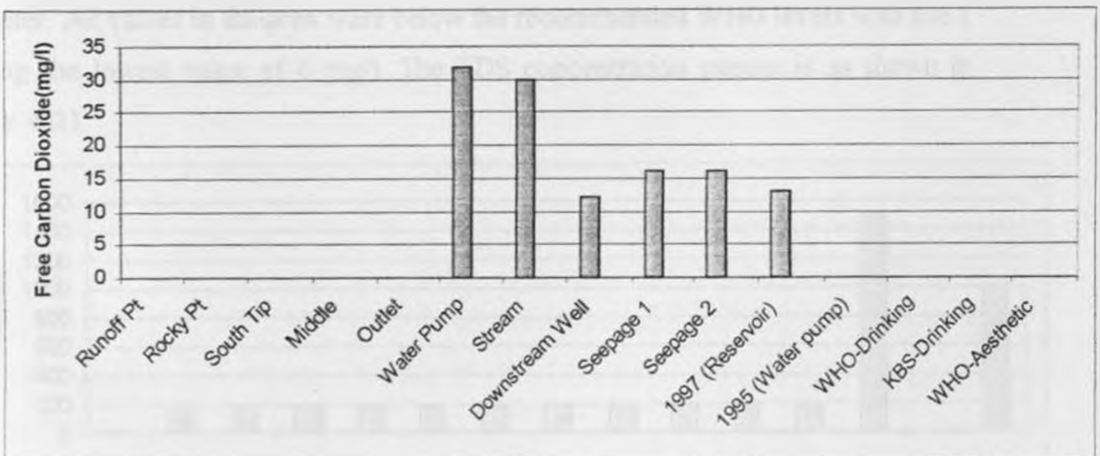


Figure 4.19: Free Carbon dioxide concentration pattern Source: Researcher 2003

4.2.18: Dissolved oxygen

The DO available to the life forms in the reservoir is about 73.8% at a mean water temperature of 24.55° C. At 24° C, the saturation concentration of oxygen in water has been found to be 8.5 mg/l. The critical threshold of DO for aquatic lifeforms is about

4mg o_2/ L which means that the reservoir is adequately aerated to support aerobic life including fish. The dissolved oxygen concentration pattern is as shown in figure 4.20.

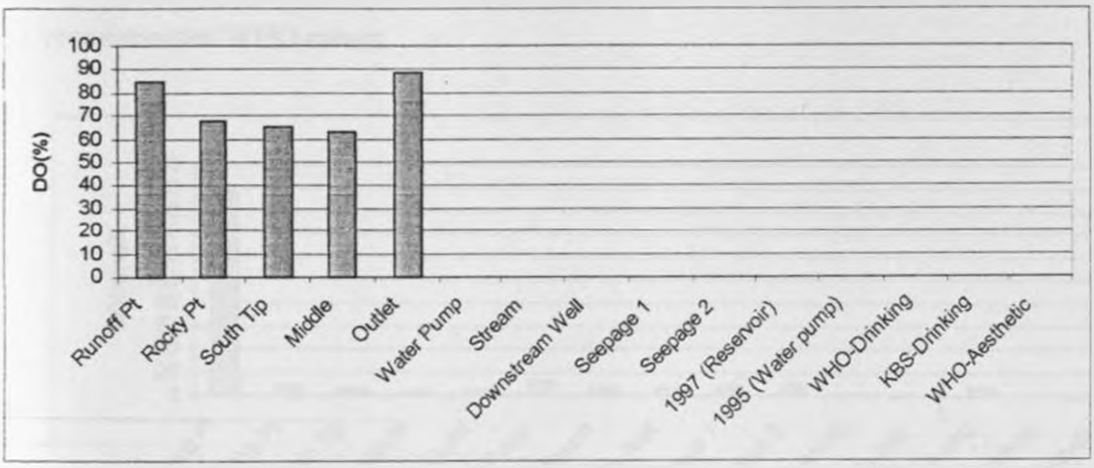


Figure 4.20: DO concentration pattern Source: Researcher 2003

4.2.19: Total dissolved solids

TDS give the conductance of electricity and reflect on the total concentration of ions in water. All values in the area were below the recommended WHO levels with site 1 having the lowest value of 6 mg/l. The TDS concentration pattern is as shown in figure 4.21.

Figure 4.21: Total Dissolved Solids concentration pattern Source:Researcher 2003

4.2.20: Biological oxygen demand

The BOD at site 1was very high with a value of 177 mg/l as compared to the rest of the sampling points as shown in figure 4.22. However, it is only at the southern tip, the middle and the reservoir outlet points that had BOD levels below the recommended WHO values.

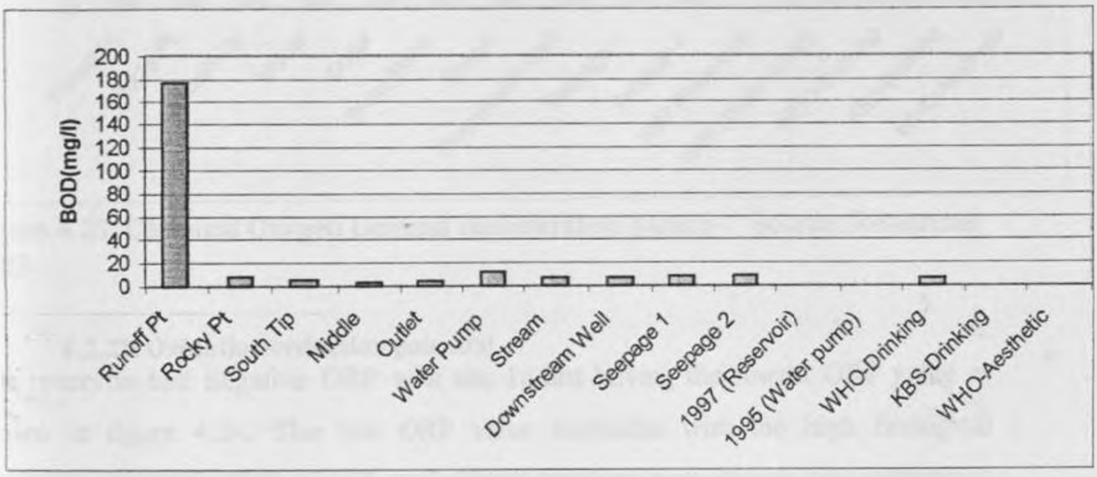


Figure 4.22: Biological Oxygen Demand concentration pattern Source: Researcher 2003

4.2.21: Chemical oxygen demand

All points except seepage point 2 had chemical oxygen demand values above the recommended WHO value of 10 mg/l. The community's hand pumped water has the highest concentration of 105 mg/l, which incidentally was only 8.4 mg/l in 1995 as shown in figure 4.23. This probably occurred as a result of increment of such elements such as iron and chloride even though values of calcium, magnesium were not initially measured in 1995 or 1996 to compare with the 2003 values for judgement.

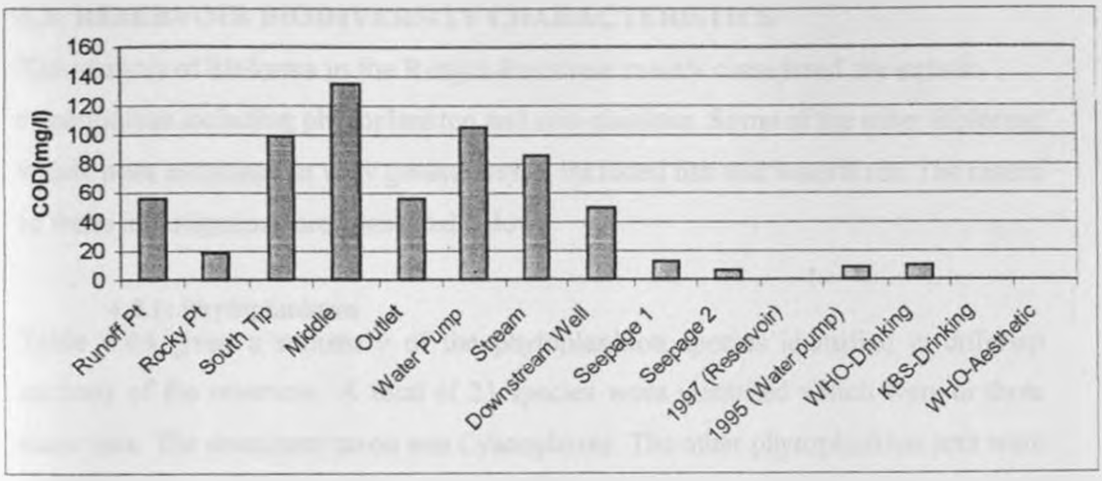


Figure 4.23: Chemical Oxygen Demand concentration pattern Source: Researcher 2003

4.2.22: Oxidation-reduction potential

The reservoir had negative ORP with site 1point having the lowest ORP value as shown in figure 4.24. The low ORP value coincides with the high Biological Oxidation Demand value of 177 mg/l. There were no past records for comparison purposes hence continuos monitoring is essential.

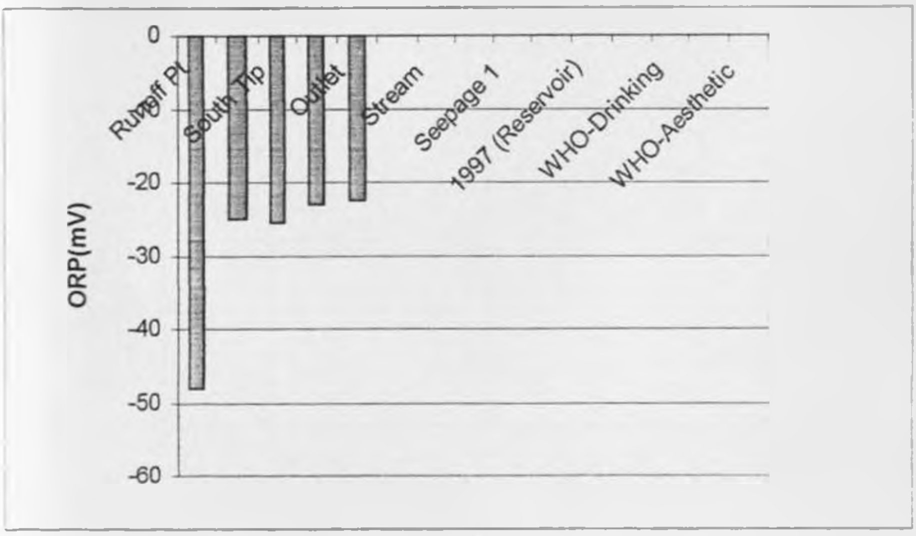


Figure 4.24: Oxygen Reduction Potential concentration pattern Source: Researcher 2003

4.3: RESERVOIR BIODIVERSITY CHARACTERISTICS

The analysis of lifeforms in the Rungiri Reservoir mainly considered the aquatic communities including phytoplankton and zoo-plankton. Some of the other lifeforms. which were examined in very general terms. included fish and waterbirds. The results of these investigations are presented below:

4.3.1: Phytoplankton

Table 4.04 gives a summary of the phytoplankton species identified in different sections of the reservoir. A total of 21 species were identified which were in three main taxa. The dominant taxon was Cyanophytes. The other phytoplankton taxa were Bacillariophyta and Chlolophyta. Table 4.04 and 4.05 shows the characteristics and distribution of the phytoplankton within the water column.

Table 4.05 below, shows that there were eleven cyanophycean species whereas the Bacillariophytes and the Chlorophytes had six and four species respectively. ***Microcystis aeruginosa*** a Cyanophyte is the most dorminant of all the species with a mean of fifty six. ***Asterionella Formosa*** and ***Haematococcus pluvialis*** dominated in the Bacillariophytes and Chlorophytes with means of 16.8 and 20.4 respectively. A summary of the main phytoplankton groups is given in Table 4.06.

Table 4.04: The characteristics of the reservoir phytoplankton

SPECIES LIST	FAMILY	SITE COUNTS (In DIS /5ml)					MEAN
		Run off Point	Rocky Point	Southern tip	Middle Point	Outlet	
1. *Microcystis aeruginosa*	**Cyanophyceae**	100	38	6	16	120	56
2. *Microcystis wesenbergii*	-do-	24	28	4	-	50	21.2
3. *Microcystis viridis*	-do-	-	14	-	-	-	2.8
4. *Microcystis botrys*	-do-	-	-	-	-	4	0.8
5. *Anabaena viguieri*	-do-	-	-	-	-	2	0.4
6. *Anabaena sp.*	-do-	20	6	64	4	-	18.8
7. *Planktothrix agardii*	-do-	38	-	-	-	60	19.6
8. *Snowella septentrionalis*	-do-	-	-	-	-	92	18.4
9. *Groetrichia echinulata*	-do-	-	-	-	-	12	2.4
10. *Aphanizomenon gracile*	-do-	-	-	-	-	8	1.6
11. *Chroococcus limneticus*	-do-	-	-	-	-	4	0.8
1. *Asterionella Formosa*	**Bacillariophyceae**	-	-	84	-	-	16.8
2. *Planklyngbya limnetica*	-do-	-	-	-	6	20	5.2
3. *Gymnodium species*	-do-	-	-	-	-	24	4.8
4. *Dinobryon divergens*	-do-	-	-	-	-	32	6.4
5. *Cyclotela sp.*	-do-	-	-	-	-	8	1.6
6. *Cryptomonas sp.*	-do-	-	-	-	-	4	0.8
1. *Haematococcus pluvialis*	**Chlorophyceae**	-	20	-	-	82	20.4
2. *Botryococcus pluvialis*	-do-	-	-	2	-	-	0.4
3. *Botrycoccus braunii*	-do-	-	14	3	8	-	5
4. *Botryococcus terribilis*	-do-	-	14	2	-	-	3.2

Source: Researcher, 2003.

Table 4.05 shows that, the Cyanophytes were mainly distributed at the surface of the reservoir, Chlophytes at 1 metre depth, Bacillariophytes at both the surface and the 2 meters depths but not at the 1meters depth. *Haematococcus pluvialis*, a Chlorophyte was observed at all levels of the reservoir whereas *Microcystis aeruginosa*, *a* Cyanophyte and *Asterionella Formosa*, a Bacillariophyte were both observed at the surface and at the 2 metres depth.

Table 4.05:The distribution of reservoir phytoplankton by depth

SPECIES	FAMILY	DEPTH		
		SURFACE TRAWL	1 METER	2 METER
1)*Microcystis aeruginosa*	**CYANOPHYCEAE**	✓	X	✓
2) *Microcystis wesenbergii*	-do-	✓	X	X
3)*Microcystis viridis*	-do-	✓	X	X
4) *Anabaena flos aquae*	-do-	✓	X	X
5) *Chroococcus limneticus*	-do-	✓	X	X
6) *Aphanizomenon gracile*	-do-	✓	X	X
7) *Aphanocapsa holsatica*	-do-	✓	X	X
8) *Oscillatoria cf princeps*	-do-	✓	X	X
9)*Gloetrichia echinulata*	-do-	✓	X	X
10) *Radiocystis germinata*	-do-	✓	X	X
11) *Planktothrix agardii*	-do-	X	X	✓
1) *Haematococcus pluvialis*	**CHLOROPHYCEAE**	✓	✓	✓
2) *Botryococcus terribilis*	-do-	✓	X	X
3) *Botryococcus braunii*	-do-	X	✓	X
4) *Micrasterias furcata*	-do-	X	✓	X
5) *Scenedesmus ecornis*	-do-	X	✓	X
6) *V.groebladii*	-do-	X	✓	X
7) *Coelastrum reticulatum*	-do-	X	✓	X
8) *Volvox aureus*	-do-	X	✓	X
9) *Asterionella Formosa*	**BACILLARIOPHYCEAE**	✓	X	✓
10) *Dinobryon bavaricum*	-do-	X	X	✓
11) *Mallomonas puntifera*	-do-	X	X	✓
12) *lanktolyngbyalimnetica*	-do-	✓	X	X
13) *Gymnodium sp.*	-do-	✓	X	X

KEY: √ =OBSERVED; X = NOT OBSERVED Source: Researcher, 2003

Table 4.06: The main phytoplankton groups in the Rungiri Reservoir

GROUP	SITES					MEAN
	Run off point	**Rocky point**	**Southern point**	**Middle point**	**Outlet**	
Cyanophyceae	182	86	74	20	352	142.8
Bacillariophyceae	-	-	84	6	88	35.6
Chlorophyceae	-	48	7	8	82	29.0
TOTAL	182	134	165	34	522	207.4

Source: Researcher, 2003

The results showed that except for the Southern Point where the Bacillariophyte count outpaced the Cyanophytes by ten, Cyanophyceae family was the most dorminant group in both species richness and density. The group exceeded the second group in species richness by fourfold. Even though Bacillariophytes were more than the Chlorophytes, the latter were more evenly distributed over the reservoir since it is only at the run off point where they were not observed. Another key observation was that the outlet was the richest in all groups attributed by the number of species that were identified and counted followed by the Runoff point. The middle-point as was observed, has the least number of species representing the three major groups resulting in a low count even though all the families were represented.

4.3.2: Zooplankton

Table 4.07 shows the composition of zooplankton within the reservoir while Table 4.08 shows their distribution within the water column. Table 4.09 shows the main zooplankton taxa within the reservoir. Only a total of 8 species were identified which belonged to two taxa namely Rotifera and Copepoda. Generally the zooplankton were very few compared to the phytoplankton. ***Trichocerca porcellus***, a rotifer was the most dorminant species. Most of the zooplankton were concentrated at the outlet with rotifers being the majority. The run off point, the southern tip and the middle had no zooplankton while the copepods were only observed at the outlet. A major observation is that majority of the species in all groups were feeding from different surfaces of the reservoir. The copepods were common at 1meter depth and rotifers at the surface.

Table 4.07: Characteristics of the Rungiri Reservoir zooplankton community

SPECIES IDENTIFIED AND COUNTED	FAMILY	SITES COUNTS (In distribution /5ml)					MEAN
		Run off point	Rocky point	Southern tip	Middle	Outlet	
1. *Keratella testudo*	Rotifer	-	1	-	-	-	0.2
2. *Keratella cochlearis*	-do-	-	-	-	-	2	0.4
3. *Trichocerca porcellus*	-do-	-	-	-	-	10	2
4. *Gastropus stylifer*	-do-	-	-	-	-	2	0.4
1. *Bosmina longirostria*	Copepod	-	-	-	-	2	0.4
2. *Alona sp.*							
3. *Cyclopoid copepod*							
4. *Diaphasoma brachirum*							

Source: Researcher, 2003

Table 4.08: The distribution of reservoir zooplankton by depth

SPECIES	FAMILY	DEPTH		
		SURFACE TRAWL	1 METER	2 METER
1) *Kellicotia longispina*	ROTIFERS	X		X
2) *Gastrtopus stylifer*	-do-	✓		X
3) *Keratella cochlearis*	-do-	✓	✓	X
4) *Hearthra mira*	-do-	✓		X
5)*Cori cochilus hippocrepis*	-do-	✓	X	X
6) *Synchaeta sp.*	-do-	X	✓	X
1) *Bosmina longirustris*	COPEPODS	X	✓	X
2) *Alona sp.*	-do-	X	✓	X
3) *Cyclopoid copepod*	-do-	X	✓	X
4)*Diaphasoma brachirum*	-do-	X	✓	X

KEY: √ =OBSERVED; X = NOT OBSERVED

Source: Researcher, 2003

Table 4.09: The main zooplankton groups in the Rungiri Reservoir

GROUP	SITES					MEAN
	Run off point	Rocky point	Southern tip	Middle	Outlet	
ROTATORIA	-	1	-	-	14	3
COPEPODA	-	-	-	-	2	0.4
TOTAL	-	1	-	-	16	3.4

Source: Researcher, 2003

4.3.3: Reservoir macrophytes fish and waterbirds

Table 4.10 shows the characteristics of the reservoir environment with regard to macrophytes, fish and birds. The only prominent macrophytes was cattail *Typha* of the genera which was dominant at the outlet even though there was also a drying population of the same at the Southern tip. The only other significant plant was *Nymphae caerulea* or water lilly, a rooted macrophyte with floating leaves which was observed growing at the rocky point but the distribution was not extensive.

The fish and bird fauna was also quite low. The highest population of the *Oreochromis niloticus* (Tilapia) and *Clarias gariepinus* (catfish) were detected at the outlet using the fish buddy even though they were also available in the other parts of the reservoir. The population density is not known and requires further investigation.

The only Egyptian goose sighted had no permanent location and swam between the outlet and the run off point as compared to the Hottenttot teal that used the *Typha* area as its permanent dwelling base at the outlet and can be described as a shy swimmer because it hade within the *Typha* macrophytes. Initially it was only a pair but later was sighted with four chicks. A few Little Grebe were also seen in the open water.

Table 4.10: The distribution of macrophytes, fish and waterbirds in Rungiri Reservoir

	Run off Point	Rocky Point	Southern tip	Middle Point	Outlet
FLORA					
1. Nymphaea	X	✓	X	X	X
2. Typha	X	X	✓	X	✓
FAUNA					
Fish 1. *Oreochromis niloticus* (Tilapia)	✓	✓	✓	✓	✓
2. *Clarias gariepinus* (catfish)	✓	✓	✓	✓	✓
Birds 1 Little Grebe	X	X	X	X	✓
2 Egyptian Geese	✓ X	X	X	X	X

KEY:
✓ Available
X Not available
✓ X Not permanent

Source: Researcher, 2003

4.4: RESERVOIR USES AND HUMAN PERCEPTIONS

The results of community health and reservoir perception were tabulated after receiving views from the Rungiri community through the use of a standard questionnaire (Appendix 1). The questionnaire was administered in the area for a period of two weeks. A total of 43 people were interviewed and their composition was as follows:

1. 67.5 % of the residents had lived in Rungiri for more than eleven years.
2. The remaining 32.5 % was comprised of the young children born in 1989 and the people whose spouses mostly men had rented houses to either work in Kikuyu or to Nairobi or engaged in casual jobs within Kikuyu area living their wives indoors.

The 10.7% of the men interviewed had ages distributed between 21 and 70 years of age whereas the women were in the age blanket between 18 and 70 years. 14.3 % of the women were in that category are 35 years which was the highest category. 31.4% of the women who were housewives are also farmers as compared to the 30.8 of the men who are farmers and 9.3 % were drivers.

4.4.1: Population structure, distribution and settlements

The average household comprised of a father, mother and an average of seven children. During the interviews, the women was preferred as the head of the family since they were better positioned to know about sources of water and other family details. Most of them also could spare the time to sufficiently respond to questions.

One very important personal observation made was that, most of the older sons were married and had their own families though most had put up their houses in the same compound as their parents and they all shared a common pit latrine. However, the depth of the toilets and the general mode of human waste disposal was not established even though it could be a good source of nitrogen into the reservoir through underground seepage considering that 55.8 % of the Rungiri residents live in iron sheet (Mabati) houses and 53.5 % live within a distance of one kilometer and in the northern end from the reservoir (fig 11). The type of houses was a reflection of the income levels. 18% of the people interviewed were farmers but if zero grazing is included, then the total percentage of the farmers would be 25.6 % followed by drivers which takes the next big percentage of 9 % (fig 4.6).

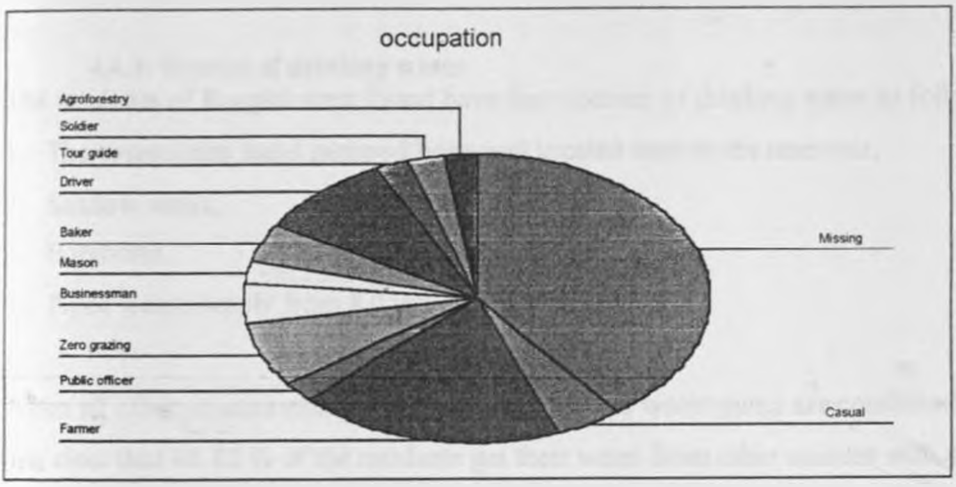


Fig 4.25: Categories of occupation of Rungiri residents

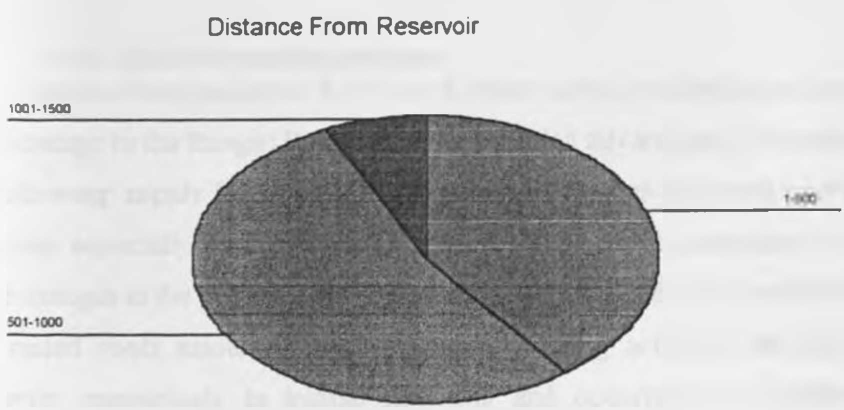


Fig 4.26: Location and distribution of Rungiri homesteads

The findings also reviewed that 62.2 % of the residents have lived in their current homesteads for more than 11 years with 69.8 being self-employed. The northern section was on a higher ground with respect to the reservoir thus any flow into the reservoir from the houses would come in mostly as run off or through underground seepage (Fig 2.01). It was observed that run off gets into the reservoir through one point on the upper or eastern end. The main road to the reservoir was a source of the soil sediments.

4.4.3: Sources of drinking water

The residents of Rungiri were found have four sources of drinking water as follows:

1. The community hand pumped bore-well located next to the reservoir.
2. Shallow wells.
3. Boreholes.
4. Piped water supply from Kikuyu Town Council.

When all other sources except the community's hand water pump are combined, then it is clear that 65.12 % of the residents get their water from other sources with 44.2% of the Rungiri residents getting their water from boreholes as compared to the 34.88 % getting it from the community's hand pump. Only about 53.5 of the residents boiled water before drinking.

4.4.4.: Reservoir benefits and costs

Only a total of nine people or 20.9% of the interviewed residents associated any sort of advantage to the Rungiri Reservoir. The recorded advantages of the reservoir were the following: supply for various uses like washing clothes and small scale household irrigation especially during the dry season. The residents associated a number of disadvantages to the presence of the reservoir. These ranged from cracks in the houses and rusted roofs associated with the initial blasting activities and rock crashing processes respectively to human drowning and occurrence of diseases both at household levels and community levels.

4.4.5: Analysis of common diseases

Only four people out of the forty-three interviewed indicated that they had suffered from typhoid. The reason for this low number was probably the fact that about half of the people boiled water before drinking. Tables 4.20 to 4.23 show the results of the regression analysis of reservoir water and the occurrence of water borne diseases

Table 4.11: Results of regression analysis between use of reservoir water and the occurrence of Typhoid, Bilharzia, Dysentery and Malaria

Model Summary[b]

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.045[a]	.002	-.023	.51

a. Predictors: (Constant), Sources of Drinking Water

b. Dependent Variable: Has anyone suffered from Typhoid, Bilharzia, Dysentry or Malaria?

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	1.387	.166		8.336	.000
	Sources of Drinking Water	1.605E-02	.057	.045	.284	.778

a. Dependent Variable: Has anyone suffered from Typhoid, Bilharzia, Dysentry or Malaria?

Table 4.12: Results of regression analysis between use of unboiled water and suffering from Typhoid, Bilharzia, Dysentery and Malaria

Model Summary[b]

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.114[a]	.013	-.019	.51

a. Predictors: (Constant), Do you boil your water?

b. Dependent Variable: Has anyone suffered from Typhoid, Bilharzia, Dysentry or Malaria?

ANOVA[b]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	.107	1	.107	.411	.526[a]
	Residual	8.075	31	.260		
	Total	8.182	32			

a. Predictors: (Constant), Do you boil your water?

b. Dependent Variable: Has anyone suffered from Typhoid, Bilharzia, Dysentry or Malaria?

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	1.312	.240		5.470	.000
	Do you boil your water?	.107	.167	.114	.641	.526

a. Dependent Variable: Has anyone suffered from Typhoid, Bilharzia, Dysentry or Malaria?

Table 4.13: Results of regression analysis between direction of household location in respect to reservoir and suffering from Typhoid, Bilharzia, Dysentery and Malaria

Model Summary[b]

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.213[a]	.045	.020	.49

a. Predictors: (Constant), General direction from reservoir

b. Dependent Variable: Has anyone suffered from Typhoid, Bilharzia, Dysentry or Malaria?

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	1.255	.141		8.890	.000
	General direction from reservoir	7.660E-02	.058	.213	1.326	.193

a. Dependent Variable: Has anyone suffered from Typhoid, Bilharzia, Dysentry or Malaria?

Table 4.14: Regression analysis between distance of households and advantages associated with the reservoir.

Model Summary[b]

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.099[a]	.010	-.017	.43

a. Predictors: (Constant), Household distance from reservoir (in Metres)

b. Dependent Variable: Advantages associated with Rungiri Dam to household

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	1.656	.200		8.295	.000
	Household distance from reservoir (in Metres)	6.818E-02	.112	.099	.607	.548

a. Dependent Variable: Advantages associated with Rungiri Dam to household

The results did not indicate the reservoir as a major source of diseases like Typhoid nor is it a source of any major advantages to households regardless of the distance. The diseases can also spread through the washing of foods especially vegetables with contaminated water. A more intensive investigation is necessary to establish whether the occurrence of toxin producing algae species like *Microcystis* are affecting human health in the area.

CHAPTER FIVE
DISCUSSION

5.0: INTRODUCTION

This chapter provides a general discussion of the findings presented in Chapter 4 against the existing knowledge for the subject under investigation as reflected in available literature. The discussion is organized in three sections according to the key aspects of water quality, biodiversity, reservoir utilization and human perception.

5.1: WATER QUALITY

Rungiri reservoir was established as a result of reluctance and failure by the government of the day to inspect and follow the rules as they were laid down in a development contract and failure to fulfill the governments mandate to be the custodian of its citizens environmental resources especially the non-renewable ones. This resulted in the creation of an aquatic ecosystem with its unique water quality and diverse biodiversity of fauna and flora that local residents are not accustomed to. 46.5 % of the respondents interviewed in this study claim that the dam is extremely disturbing and only five residents said that it had some little value. 67.5% of the residents associated the reservoir with the problem of drowning at community level.

Rungiri aquatic ecosystem is functionally related to the physical, chemical and biological processes because most of the chemical properties seem to be highly influenced by the chemical composition of the Limuru Trachyte that has been found to have the chemical composition as shown in Table 5.10.

Table 5.01: Chemical composition of Limuru Trachyte and Quartz

Chemical Composition	Chemists			
	1	2	3	
SiO_2	65.99	62.54	64.45	
Al_2O_3	14.42	15.85	15.79	
Fe_2O_3	2.85	3.66	3.81	
FeO	2.89	2.69	2.66	
MgO	0.18	0.36	Trace	
CaO	0.49	1.46	0.77	
Na_2O	5.57	6.12	5.16	
K_2O	5.28	5.07	5.51	
H_2O^+	0.59	0.59	1.06	
H_2O^-	0.39	0.45	0.68	
TiO_2	0.72	1.07	0 71	
P_2O_5	0.10	0.13	Trace	
Cl	0.01	0.04	-	
F	0.23	-	-	
MnO	0.23	-	0.20	
S	0.01	-	-	
So_3	-	0.01	-	
Less O equivalent	99.95	100.03	100.80	

Key:

1. Quartz Trachyte, 2 miles West of Ngong scarp
2. Phonolitic Trachyte, Kikuyu Escarpment
3. Trachyolites, kedong scarp.

It can be seen from Table 5.01 that most of the chemical constituents of the water are being dissolved from the Limuru Trachyte whose origin is volcanic action in the final outpourings of lava during formation of the Rift valley. They were derived by eruptions along fault zones connected with rift faulting. The lava is alkaline in nature which explains why the water in the reservoir is slightly alkaline even though the community hand pumped water is acidic in nature. It seems that both waters are from underground sources because of the presence of free carbon dioxide, which is a common phenomenon with underground water sources. However, due to the large volume of the water available in the Rungiri reservoir, then there is a great possibility that the free carbon dioxide is dissolved to form either Calcium or magnesium carbonate according to the following chemical equations:

$CO_{2\,(g)} + H_2O_{(L)} \longrightarrow CO_3^-{}_{(aq)} + H_{2\,(g)}$ --------------(1) or

$CO_{2\,(g)} + H_2O_{(L)} \longrightarrow HCO_3^-{}_{(aq)} + H^+{}_{(aq)}$ ___________(2)

The by-products from the above reactions, hydrogen gas (equation 1) escapes into the atmosphere and the hydrogen ion could be neutralized by the hydroxyl ions (OH^-) from the alkaline water in the reservoir. The other bi-products the carbonate ($CO_3^{=}$) or the bicarbonate (HCO_3^-) ions react with either magnesium or calcium carbonate in the equation:

$$Mg_{(aq)} + CO_3^{=}{}_{(aq)} \longrightarrow MgCO_{3\,(aq)} \text{ -----------(3)} \quad \text{or}$$

$$Ca_{(aq)} + CO_3^{=}{}_{(aq)} \longrightarrow Ca\,CO_{3\,(aq)} \text{ -----------(4)}$$

The formation of the calcium carbonates could especially explain the decrease in the calcium concentration in the water and the increase in the total hardness and possibly even the total alkalinity in the reservoir. On the other hand the general increase of the ions such as manganese, sodium, potassium and magnesium contribute towards the increase in conductivity especially in the community's hand pumped water. However, since conductivity in the reservoir had not been measured earlier, it is hard to conclusively say whether conductivity has gone upwards or has declined even though the suspicion is that it has increased following the increase in the concentration of the above mentioned ions since conductivity is directly proportional to the dissolved ion concentration and both sources of water are in the same drainage basin and rock type The only difference is that, the reservoir is an open water mass with a lot of influence from direct human activities, the atmosphere and the soil type through run off. This argument is strengthened by the increase in the levels of chemical oxygen demand especially with the community's hand pumped water that has increased almost thirteen times since 1995.

The findings indicated that iron in the reservoir had a decreasing trend since 1997 even though it was still above the WHO or KEBS standards but it had increased in the community's hand pumped water. The excess amount could be of negative consequence to the users since it could cause staining to ceramic ware as well as textile clothing or materials. The excess chloride in the reservoir could be as a result of the ions dissolving from the rock and their continuous monitoring could be the solution since in excess they make the water be condemned as blackish water. The reservoir on the overall seems to be closely related to the hand pumped water. Statistical testing to compare the two was not possible owing to the different nature of the parameters and also that sampling has not been done for a long time to generate sufficient data for comparative analysis. The study therefore accepts the second hypothesis that the reservoir water was not different from the community hand pumped water. Table 5.02 shows the reservoir water quality against the WHO and KEBS standards for drinking water.

Table 5.02: A summary of Rungiri Reservoir water quality against the WHO and KBES standards

PARAMETER	UNIT	RESERVOIR WATER	HAND PUMP WATER	WHO/ KBES	COMMENT
pH	-	8.76	6	6. 5-8.5	The pH of the water from the community hand pump and the reservoir do not comply with the WHO or KBES drinking standards. The hydrogen ion concentration is in both extremes acidic and alkaline respectively.
Colour	MgPt/l	5	5	15	The colour of both sources of water is within the recommended WHO and KBES values.
Turbidity	NTU	8.4	2	5	The reservoir water is turbid and not good for drinking as far as the recommended standards are concerned but the community's hand pumped water is okay.
Conductivity	uS/cm	286	292	1000	Both sources of water have good water for drinking
Iron	mg/l	0.468	0.35	0.3	Both sources of water have excess Iron and therefore not good
Manganese	mg/l	0.15	0.15	0.1	Both water supply sources have excess manganese and hence water is not good for drinking.
Calcium	mg/l	12.58	12.8	0.5	Both sources of water have excess Calcium and hence water is not good for drinking.
Magnesium	mg/l	3.792	4.37	100	Magnesium concentrations are below recommended levels and hence both sources of water are good
Sodium	mg/l	37	34	200	Water from both sources is good for drinking.
Potassium	mg/l	7	5.8	-	Cannot recommend because the standard values were not available. However, since Potassium and Sodium are in the same group one of the periodic table, then Potassium

Table 5 cont'd

					concentrations are low and hence the water is good for drinking.
Total hardness	mg/l	47.2	50	500	Water is good for drinking
Total alkalinity	mg/l	68.8	36	-	Cannot recommend because the WHO/KBS alkalinity values were not available.
Chloride	mg/l	41.8	43	0.2-0.5 (WHO) 0.1 (KEBS)	Water is not good for drinking
Fluoride	mg/l	1.3	0.24	1.5	Water is okay for drinking
Nitrates	mg/l	1.16	6.4	45	Water is good for drinking
Nitrites	mg/l	1.16	0.01	0.01	The nitrite levels are high as far as the reservoir is concerned but the community hand pumped water is good for drinking.
Sulphates	mg/l	2	1.43	400	Water is good for drinking
Orthophosphate	mg/l	0.26	0.51	0.1	Water is not good for drinking
Total Suspended Solids	mg/l	7.4	3	30	Water is good for drinking
Free Carbon Dioxide	mg/l	0	32	-	Cannot comment
Total Dissolved solids	mg/l	141.2	179	1500	Water is good for drinking
Biological Oxygen demand	mg/l	39.4	12	6	Water is not good for drinking
Chemical oxygen demand	mg/l	72.56	105	10	Water is not good for drinking

The nitrites and the nitrates in the reservoir water could have originated from the surrounding soil and drainage basin through run off and underground seepage from the pit latrines. The orthophosphates seem to be a direct consequence of the rock type even though detergents used by the community while washing cannot be ignored since they discharge waste water back into the reservoir especially during the dry season when the demand for the water is at its highest.

From the above assessment, the reservoir water had 11 parameters out of the 23 within the WHO and KEBS standards. In other words, the reservoir water was 47.83 % suitable and hence is not good for drinking. The community's hand pumped water had 13 parameters within the standards meaning that the water was 56.52 % good and hence marginally suitable for human consumption.

Since the first objective of the study was to confirm whether the reservoir water adheres to the WHO or KEBS standards for drinking water, it is important to emphasize that, only 11 out of the 23 parameters in the reservoir and 13 out of 23 parameters in the community's hand pumped water conformed with the WHO or KEBS standards for drinking water.

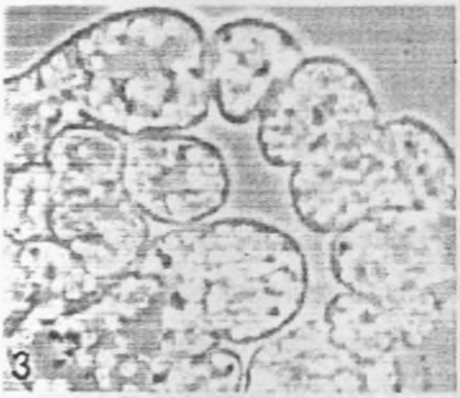
5.2: BIODIVERSITY

Rungiri Reservoir was found to have poorly developed biological communities across the board. This was attributed to the young age of the waterbody, which means that the ecosystem is still at its initial successional phase. This is bound to change with time and is already being reflected through the development of the littoral macrophyte canopy. The cattail macrophyte, which is growing quite well at the outlet point of the reservoir, acts as the pump of the nutrients from the organic state in the sediments and possibly even from the rock to the soluble state which makes nutrients available to the algae. It is interesting to note that the nitrates and the nitrites whose sum total gives the total nitrogen have decreased tremendously in the reservoir since 1997. This is because, together with phosphorus that is abundant and even exceeding the recommended concentration especially in the community's hand pumped water, they have acted as the source of nutrition for the algae especially from the cyanophyceae that has grown in abundance in the reservoir.

Ecologists give the proportions 1P: 16N: 100C as the amounts required for the proliferation of algae. Although this is the case with most lakes and other reservoirs, cases have been reported where there has been excess phosphorus but no algae blooms or other cases whereby there are very small amounts of phosphorus but have led to excessive growth of algae. In rare cases nitrogen, has been shown to be the limiting factor especially in blackish water. The cyanophytes were found to be dominating at the Rungiri reservoir, both in terms of abundance and species diversity. The fact that *Microcystis*, *Anabaena*, *Aphanizomenon*, and *Oscillatoria* as well as diatoms such as *Asterionella* (Plate 5) were present, at Rungiri Reservoir means that the reservoir is probably in the eutrophic state (Welch, 1952; Sawyer, 1966; Fruh et al; 1966; Lee, 1971; Golterman, 1975; OECD, 1982). This is confirmed by the presence of zooplankton such as *Bosmina longistris*. The success of the blue-green algae in many eutrophic aquatic ecosystems is well documented. They are known to occur in waterbodies with a stable water column, reduced grazing by large herbivores, low ratios of nitrogen to phosphorus (N: P), high nutrient levels, high pH and high temperatures above 20^0C. All these conditions, were fulfilled at the Rungiri reservoir especially at the outlet where *Typha* is thriving well making the water calm towards this end. The limited turbulence and mixing of the water column seems to encourage the deposition of materials including nutrients.

The P: N ratios in the reservoir was quite low at 0.256:1.1695 converting closely to one part of phosphorus to four parts of nitrogen while the mean temperature recorded at the reservoir was 24.55°C. The other thing about the man-made reservoir was that it does not empty its waters out at high speed making the water stagnant even though two small seepage's that drain the water to the Kia Njiiru Stream were spotted. All the conditions being right, especially the low water turbulence which meant that the blue-green algae were easily buoyed to the surface with the help of the entrapped oxygen to take advantage of optimal nutrient and light conditions. The water looked very green especially due to the occurrence of the cyanophytes and cholorophytes (Plate1). The domination of the reservoir by cyanophytes also indicated a high possibility of eutrophication. This could emanate from the flushing and sweeping of soil and dead matter from the surrounding into the waterbody through the northeast end. These materials although entering the reservoir on occasional basis are capable of causing eutrophication due to the lack of a direct surface outflow.

Plate 6: ***Microcystis aeruginosa*** **and** ***Asterionella formosa*** as seen under a Microscope



Microcystis aeruginosa ***Asterionella formosa***

Source: Jenny Bengtsson (1991)

The surface scums which formed at the surface made the water turbid as recorded by Secchi disk and turbidity measurements. Identifying the different algae species at different depths proved the fact that surface scums were mainly formed by the blue-green algae. The excess growth of the blue-algae especially at the surface seems to utilize a lot of oxygen especially at the northern end as reflected by the BOD readings. The runoff which came in to the reservoir made other types of algae and zooplanktons hard to survive in some parts of the reservoir (Figures 2.01-2.03). This seems to be complemented by shallowness at this northern end. Excess oxygen consumption was also confirmed by the negative oxidation-reduction potential (ORP).

The richest biodiversity site within the reservoir seemed to be the outlet owing partly to the presence of macrophytes of the genus *Typha* that besides acting as the nutrient pump from the sediments also offers good and safe habitat for other species like spiders and birds to thrive. The Little Grebe, lived within the macrophytes. Most fish were detected at this location using the fish buddy and almost all species of the plankton are represented here. Thus, even though the reservoir water may be condemned for drinking purposes partly as a result of the algae community leading to the acceptance of the null hypothesis that the reservoir water does not conform to the

WHO/KEBS standards, the aquatic ecosystem was found to be an important habitat for both terrestrial and water birds like the Little Grebe or the Egyptian goose respectively. The water lilies (*Nymphae caerulae*) on the other hand were colonizing the rocky end of the reservoir which was good for the growing ecosystem since it's undersurface acts as a pad providing a convenient resting places for egg deposition by insects. All organisms form a food web with the algae acting as the principal primary producers unique to this ecosystem that requires further studies.

5.3: RESERVOIR UTILIZATION AND COMMUNITY PERCEPTION

Humans act as the most important biotic factor in the environment. This is because, a human was made to blast out the Limuru Trachyte which dominates the physical environment in the area in order to generate raw material to build a good road for the quick transport of goods and services so that people can improve on their well being. In so doing, mistakes were done and hence the creation of an aquatic ecosystem (Rungiri reservoir). The preceding discussion has indicated that the reservoir owes it permanency to underground seepage.

Regression analysis and correlation coefficient done on the relationship between the sources of water and disease outbreaks showed that, even though the relationship was a positive, one can only relate 0.20% of the diseases to the water sources which was not significant 99.8% being attributed to other factors not covered within the study. Besides, during the study, only four cases of typhoid were reported and no malaria cases were reported meaning that the fish in the reservoir could be consuming the mosquito lava rendering the reservoir a mosquito free zone.

The medical reports and personal interview with Dr Kung'u indicated that, the water borne diseases recorded in the area could be related to spouses traveling to malaria laden areas considering that driving as an occupation is the second income earner next to farming with 9.3%. Considering also that, Rungiri village is a small village with a high population density, transmission of malaria becomes a high possibility. The results lead to the acceptance that of the null hypothesis that the reservoir was not a health hazard. However, the earlier parts of the discussion on biodiversity indicated that the cyanophytes or the blue-green algae are the majority species in the Rungiri Reservoir and are caused by the eutrophication of the reservoir. Studies have shown that cyanobacteria produce toxins that may cause death if ingested in large quantities by domestic animals and wildlife. They also pose significant health risk to humans, causing gastroenteritis and skin irritations (Anon. 1990; Codd and Beattie 1991; Hunter 1991). Some toxins have also been shown to be tumour promoters and may therefore pose a risk to those with long term low level exposure. In Kenya, a study by Helene Annadotter of University of Lund, Sweden indicated that there was presence of high levels of endotoxin and microcystin in water samples collected in Embu where people had died of a disease displaying symptoms like those of malaria and typhoid (Daily Nation, 2001). At Rungiri however, this is not likely to happen since 44.2% get their drinking water from the boreholes compared to 34.9 % that get it from the community's hand pump and none getting their supply from the reservoir.

Regression analysis showed that advantages at household were positively related to the distance from the reservoir. The Rungiri residents, out of whom 46.5% lived in the northern direction and within one kilometer from the reservoir, stand to benefit more from the aquatic ecosystem if properly managed. This is because eutrophic conditions are generally associated with high levels of fish production. The people could either explore chances of fishing as a sport or fishing to supply the market with the high fish protein. Tilapia for example has a high consumer demand in the market and fetches good returns in terms of money and this could go along way in poverty eradication. The demand for cat-fish is also available in the market. Besides selling the fish, consumption at household level would supplement the proteins for the whole family. A healthy family is more productive than a hungry and an unhealthy one and probably this would generate income to the government besides creating employment for the majority of the Rungiri residents in the fish industry. This opportunity can be expanded through eco-tourism development for sport fishing and bird watching among others.

Depending on the use in which the Rungiri residents want to put the reservoir into, for the current and probably the future generation, fish farming is a way of reducing the nutrient levels from the reservoir even though it is not as efficient as the sustainable harvesting of the macrophytes. The macrophytes could be harvested to make compost manure for the use by the residents since they take up a lot of the nutrients from the sediments. Some people use the macrophytes to make their salt for home use (personal communication). Alternatively, if the residents prefer to do fish farming to diversify their income base, then the macrophytes need not be harvested since they are a source of nutrients into the water for the growth of algae that acts as fish food. Further studies to establish the fish population density is required if the Rungiri community will have to establish sustainable harvesting pattern either by considering weights or fish numbers.

CHAPTER SIX

SUMMARY OF FINDINGS, CONCLUSIONS AND RECOMMENDATIONS

6.0: INTRODUCTION

This chapter presents a summary of the key findings that emerged from this project. The findings were used to draw a number of conclusions, which are also presented here. The final part of the chapter presents the recommendations made from the findings in this investigation towards various areas of the future management of the Rungiri Reservoir.

6.1: SUMMARY OF FINDINGS

6.1.1: Reservoir water quality

Owing generally to the chemical constitution of the Limuru Trachyte, the water quality of both the reservoir and the community well manifested some parameters with concentrations well above the recommended values by WHO and KEBS for drinking water. These parameters included turbidity, Iron chloride and phosphorus. The BOD and COD levels were above recommended standards and indicated an element of pollution.

6.1.2: Reservoir biodiversity

The low nitrogen to phosphorus ratio in the reservoir caused rapid growth of the algae especially cyanobacteria that was found to be dominating making the water turbid due to eutrophication build up. Eutrophication could however improve existence of catfish and the tilapia as detected using the fish buddy. They could eventually attract more birds than the two species of water birds, the Little Grebe and the Egyptian goose which were recorded. Macrophytes of the genera *Typha* grow freely at the mouth in addition to the water lilies.

6.1.3: Reservoir utilization and community perception

Despite the good potential of the reservoir for fish farming or its development as an eco-tourism site, the Rungiri residents view the reservoir as a very disturbing phenomenon within their midst especially when associated with deaths as a result drowning of family members. The only uses of the reservoir include washing because domestic water supply is provided in a near by community well.

6.2: CONCLUSIONS

The basic questions in this study were as follows:

1. What is the condition of the water in the reservoir in terms of the quality in relation to the known drinking standards?

2. How rich is the Rungiri reservoir ecosystem in terms of water birds. phytoplankton, zoo- plankton in order to explore new avenues for other uses such as fish farming and recreation?

3. How do the Rungiri village residents view the reservoir? Has its occurrence since 1992 been of any advantage or disadvantage to them or has it been a health hazard?

The results showed that the Rungiri reservoir and the community well contain water that is not completely fit for human consumption. The two sources of water have comparative water chemistry owing mainly to the geology of the area and also the possible influence of underground seepage. The contribution of the soil sediments through run off to the addition of nutrient to the reservoir was not studied.

It was found that the phosphorus to nitrogen ratio in Rungiri reservoir was 1:4.56. which together with conducive water temperatures and calmness have greatly contributed to the mushrooming of cyanobacteria species such as *Microcystis*. *Anabaena*. *Aphanizomenon*. and *Oscillatoria* in addition to diatoms such as *Asterinella Formosa*. The main zooplankton species was *Bosmina Longistris*. The reservoir was considered to be heading towards a eutrophic state according to the above conditions. Despite this condition being bad as far as domestic and livestock water supply are concerned. it forms a good backyard for the development of a stable aquatic ecosystem with fish species, water birds and emergent macrophytes that cleanse the water as well as acting as a nutrient pump from the sediments

The Rungiri residents have not realized the full potential in terms of unexplored opportunities in form of fish farming or sport fishing or merely biodiversity conservation.

Initial worries by the residents, that the reservoir has contributed to the water borne disease was disapproved through the Pearsons correlation analysis which associated only 0.2 % of diseases in the area to the water body. 99.8% of the diseases were therefore accounted for by other factors not considered in the study.

The Rungiri reservoir has a lot of multipurpose potential which could elevate the income base of the local residents through sustainable management. One of the outstanding opportunities include fish farming. However this will only be realized if optimal productivity of the algae as well as the fish stocking levels are known in order to decide on appropriate harvesting patterns. Other opportunities include recreation and eco-tourism preferably through community management.

6.3: RECOMMENDATIONS

The following recommendations are proposed based on the findings and conclusions of the research project:

6.3.1: Reservoir management

1. From the research findings, it was clear that most of the water quality parameters within the reservoir and the community hand-pumped water are not stable. Hence continuous monitoring is required and more so for the community hand-pumped water so that it may not become a health hazard in the long run.

2. Educating the Rungiri residents on the findings is a necessary step towards the implementation of the results as a step towards poverty eradication strategy in the community.

3. Fencing. A stone fence is recommended throughout the reservoir as an earlier one erected using poles and barbed wire was vandalized by some residents

4. Runoff buffer strips should be constructed in order to filter incoming runoff and minimize eutrophication.

5. Fish introduction is necessary in order to expand the biodiversity network. This actually requires sufficient scientific research in order to select the right breeds for the reservoir.

6. Education and awareness campaigns is necessary to enable the local community to change their negative altitude and help in exploring the site as an eco-tourism site or exploring fishing as an income generating activity alternative.

6.3.2: Multipurpose Development

1. Community fishery development if explored could help the residents expand their income base in addition to improving the protein diet at household level.

2. Eco-tourism development would also be possible owing to the favourable location of the reservoir near the Nakuru –Nairobi dual carriage highway and only a small section of the road to the reservoir is not tarmacked. The reservoir is therefore well accessible by visitors from Nairobi, Limuru, Kikuyu and other neighbourhoods.

3. Controlled quarrying in the area could also be a good source of building materials and side employment for the local people.

6.3.3: Further Research

1. Further research on the food web in the reservoir is important as well as establishing the fish population density in order to decide on a good and sustainable harvesting pattern and Identification of available niches for fish introductions.

2. More intensive and comprehensive biological community studies to monitor upcoming patterns as ecological succession progresses.

3. Cyanobacterial blooms, cyanotoxin production and implication to human and livestock health.

4. Further research using isotopes would be recommended so as to establish the real source of water into the reservoir.

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APPENDICES

APPEDIX 1
QUESTIONARE (Rungiri Reservoir)

A WATER QUALITY, BIODIVERSITY ASSESSMENT AND COMMUNITY PERCEPTION OF RUNGIRI RESERVOIR, KIKUYU, KENYA.

To determine whether there has or there has not been an increase in diseases since the inception of the reservoir.

PART A

1. (a) What is your name?
   (b) Household code
   (c) Household distance from the reservoir
   (d) General direction from the reservoir
2. What is your husbands/wife name?
3. Number of children. Female/male/Age. Dead or alive. Cause of death.

No	Name	Relationship to household head	Age	Sex	Marital status	Occupation
1	Head					
2	Wife					
3	Child 1					
4	Child 2					
5	Child 3					
6	Child 4					
7	Child 5					
8	Child 6					
9	Child 7					
10	Niece					
11	Nephew					
12	Uncle					

4. Employed or self employed.
5. Period of residence.
6. What are your sources of
   i) Drinking water.
   a) Do you boil your water? If no why?

ii) Water for washing, bathing.
iii) Irrigation (where applicable).
iv) Domestic animals.
v) Recreation e.g. swimming.

PART B

1 Quantify the benefits of the dam/reservoir compared to the time the dam (reservoir) was not there. Advantages and Disadvantages.

Are there any advantages that are associated with Rungiri dam to this household?

If yes name them.

1________________________________
2________________________________
3________________________________
4________________________________

Are there any advantages that are associated with Rungiri dam (reservoir) to this Community?

If yes name them.

1________________________________
2________________________________
3________________________________
4________________________________

Are there any disadvantages that are associated with Rungiri dam (reservoir) to this Household?

If yes name them.

1________________________________
2________________________________
3________________________________
4________________________________

Are there any advantages that are associated with Rungiri dam (reservoir) to this Community?

If yes name them.

1________________________________
2________________________________
3________________________________
4________________________________

You say the Reservoir came to being in 1992. Have you or anyone in your household ever suffered from the following diseases:

a) **Typhoid**
b) **Bilharzia**
c) **Dysentery**
d) **Malaria**

Disease	Person suffered	Name of Hospital or Clinic Where treated	Frequency Per year	Costs (consultation plus drugs fees)
Typhoid	1. 2. 3. 4. 5.			
Bilharzia	1. 2. 3. 4. 5.			
Malaria	1. 2. 3. 4. 5.			
Dysentry	1. 2. 3. 4. 5.			
Gastroentritis	1. 2. 3. 4. 5.			

This Question targets those who were born before 1992 and at least 10 years by the time the reservoir was created.

What about before 1992 can you vividly remember the kind of diseases that you suffered? Please list them:

Disease	**Person who suffered**	**Name of Hospital or clinic where the person attended**	**Frequency**	**Costs**
	1. **2.** **3.** **4.** **5.**			
	1. **2.** **3.** **4.** **5.**			
	1. **2.** **3.** **4.** **5.**			
	1. **2.** **3.** **4.** **5.**			

Would you say that these illnesses have increased with the creation of the dam?

Why do you say so?

Overall Community Perception Analysis

1) How would you rank the impact of the reservoir in terms of its positive or negative attributes?

SCORE (%)	POSITIVE IMPACT	NEGATIVE IMPACT
0-20	DON'T KNOW	DON'T KNOW
21-40	NO IMPACT	NO IMPACT

41-60	USEFUL	DISTURBING
61-80	VERY USEFUL	VERY DISTURBING
81-100	EXTREMELY USEFUL	EXTREMELY DISTURBING

PART C

Hospital records of patients with illness related to Water borne diseases and then relate them to Part B.

- **This will be a table of records of the various illnesses associated with water and include figures of at list 2-2 years before the dam (reservoir) was constructed and the record of all the duration after the dam is constructed.**

- **Results of interviews with medical personnel where applicable especially on disease occurrence will be included.**