INFORMAL COMMUNITIES AND THEIR INFLUENCE
ON WATER QUALITY : The Case of Umlazi

By

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DECLARATION

I, Arvana Gangoo, declare that this dissertation is entirely my own work, unless otherwise stated, carried out under the supervision of Mr J.S. Lutchmiah at the University of Durban-Westville in accordance with the requirements of the University for partial fulfilment of the Degree of Master of Arts (research masters).

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ABSTRACT

Water is the most important resource which is essential for sustaining all life forms, since without it, life cannot exist and industry cannot operate.
However, increasing concern is being expressed at the rate of degradation of this important resource, which, to a large extent, is due to the advent of industrialization and urbanization. The major causes for this concern is that the progress towards urbanization is often made without due regard to the consequences. Furthermore, the effect of man's social and industrial activities can be seen in the extent to which river water quality changes as a river flows from its source to the sea. Water which is returned to the river as effluent is rarely the same quality and is normally contaminated with some form of pollution.

South Africa is a country where water is a scarce and precious resource. Coupled with low rainfall and a high evaporation rate, is the lack of basic services which are concentrated in areas where demands of the most vital resource is ever increasing. In addition, urbanization is experienced at a phenomenal rate, much of which is in the form of informal settlements. These constitute overcrowded "shacks" with no running water and sanitation facilities. Furthermore, imbalances in the ecosystem are created when humans strive to undertake the economic demands of the world resulting in poor environmental management practices and unhealthy living conditions. These communities lack basic services and as a result, resort to environmental degradation where the removal of vegetative cover, waste disposal and water pollution are evident. Furthermore, many of the informal settlements are situated in close proximity to water source, especially rivers. In the absence of sanitation, these communities make use of shallow pit latrines, river banks, etc. The potential for pollution is therefore very high in these communities. This provided the researcher with the motivation for the study.

The purpose of the study was to determine the influence of the Umlazi informal community, L-SECTION on the water quality of the Umlaas River. The physical and chemical parameters viz., pH, E-coli, COD, turbidity, electrical conductivity, nitrate and phosphorous concentration were examined to provide the researcher with some indication of water quality. Water samples with an interval of 100 metres apart were collected upstream and downstream of the informal community. The samples were analysed at the Metro Waste Water management laboratory to determine the concentrations of the said variables. The purpose of upstream and downstream sampling was to enable the researcher to determine whether the difference in values between the two sets of data was significant or not. The statistical test was achieved through the application of the students t – test. The results of the investigation indicate that water downstream of the informal community is of a poorer quality than that of upstream. The results of the application of the test for each set of variables (upstream vs downstream) reveals that the difference is significant.

The findings of the study indicate that the informal community have a detrimental impact on water quality. Authorities responsible for management of water resources are required, as a matter of urgency, to implement necessary steps to ensure that water quality is not impacted upon negatively. Failure in this regard could lead to the following: a decline in water quality and quantity; a reduction in economic opportunities; deteriorating standards of human health and safety as well as a decline in the diversity of plants, animals, and fish in our rivers. However providing proper sanitation to people living in informal settlements; improving the quality of lives of the homeless people who resort to squatting as well as ensuring that policies ensure that minimum standards requirements are met are just some of the steps in overcoming the problem in water quality.

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CHAPTER ONE

INTRODUCTION AND CONTEXTUALISATION OF PROBLEM

1.1 Preamble

Pollution affects man in many different forms and a common theme which arises is that human beings often find it difficult to learn from their mistakes. Air pollution was a major problem in the 1950's with smog affecting virtually all industrialized cities world wide while from the 1970's onwards, the visible signs of smog were largely eliminated in many western countries. However, "invisible" atmospheric pollution in the form of carbon monoxide and ozone is present with us in ever increasing concentrations. London is now beginning to look like an earlier Tokyo with cyclists, traffic wardens and joggers wearing protective masks, as the major cause of this pollution is the motor cars and goods vehicles (Keller and Wilson, 1992). At the local level, much outrage has been expressed in the South Durban region regarding the construction of the gas pipeline increasing levels in an area already saturated with pollutants.

Society has always had to compare the risk and the benefits arising from a particular activity. The risk of fatalities or damage to the environment has to be compared to the benefits that would accrue to society. Some of these include the destruction of the rainforests to produce wood for furniture and newsprint; the use of chlorinated fluorocarbons within domestic refrigerators: the use of pesticides and fertilizers in agriculture to improve the aesthetic appearance of vegetables, grains and fruit; the exposure of a work force to hazardous materials used in the production of many consumer goods and the burning of fossil fuels in the generation of electricity. All of these improve the general standard of living but, many of these activities impose great risks to the entire environment and planet. However, these were all started when there was little or no appreciation of the possible undesirable effects such as climatic change, global warming, the destruction of the ozone layer and acid rain. Now that these global consequences are occurring, there is an urgent need for society, on a transnational basis to take actions to reduce risks to an acceptable level. (Keller and Wilson, 1992).

The social cost of the destruction of rain forests have now been modeled and predictions of major changes in the precipitation patterns across continents have now been made, as can be seen in the destruction of the Himalayan forest which has produced an increase in the intensity and frequency of floods within the river Deltas of Bangladesh. Chlorinated fluorocarbons (CFCs) and other chlorinated hydro carbons have also reduced the thickness of the ozone layer within the southern hemisphere and it is predicted that the number of epidermal cancers will increase. The destruction of the ozone layer has also been identified as a possible contributory factor in global warming. (Keller and Wilson, 1992)

The use of fertilizers and pesticides in agriculture within the developed world has led to the contamination of the drinking water supply and the production of toxic blue-green algae within static water bodies. However, the use and manufacture of some pesticides have been banned by certain countries with advanced economies. These include such countries as the United States of America; Europe and the UK. Companies still, however, are allowed to manufacture and sell these products in Third World countries who either do not have similar legislation as the UK or who do not have the necessary resources to purchase the more expensive but, less ecologically harmful, modern pesticides. In recent years though, due to rapid industrial growth, pollution of water supplies and the degradation of river systems and surface water quality have become a matter of intense public concern.

1.1.1 Water as a Resource

Water is a powerful symbol throughout the world, carrying with it ideas of baptism and new life, cleansing and healing and the promise of growth and prosperity. (Water Policy, S.A. 1997) It is the most important resource essential for sustaining all life forms. This resource is so vitally important that without it, all human activities would cease and hence all life forms would come to an end. In addition, wholesome water is a basic and an essential ingredient for life. Therefore, everyone should have convenient access to an adequate and reliable source of wholesome drinking water (Mogane, 1997). The United Nations Water Supply and Sanitation Decade (1981-1990) declared that "All the peoples, whatever their stage of development and their social and economic conditions, have the right to have access to drinking water in quantities and of a quality equal to their basic needs." Throughout the third world countries, including South Africa, water supplies for thousands of people are often unsatisfactory because of an inadequate quantity, poor quality and often difficult accessibility thus posing health risks to user communities. Furthermore, water is a precious and finite resource which many cities refuse to see and continue to squander and contaminate supplies (Sankar, 1996). In Manila, for example, 58% of water channeled into city pipes disappear unaccounted for while water related diseases also account for an estimated 10% of each persons working life and the urban poor are very often at the worse off (W.Q.1,1991).

However, increasing concern is being expressed on the rate of degradation of this important resource which, to a large extent, is due to the advent of industrialization and urbanization. The major causes for this concern is that the progress towards urbanization is often made without due regard to the consequences. Furthermore, the effect of man's social and industrial activities can be seen in the extent to which river water quality changes as a river flows from its source to the sea. Water which is returned to the river as affluent is rarely the same quality and is normally contaminated with some form of pollution. Such was the most serious incident of mercury poisoning that occurred in Northern Iraq in 1972 where a shipment of cereal grain seed pre-treated with a mercurial fungicide which was intended for the purpose of planting, ended up being produced for consumption by farmers, their families, friends and neighbours. As a result, many died with others suffering permanent brain damage. A consequence of this was that the farmers, rather than being caught with the seed, instead dumped their stocks into the nearby rivers and lakes which grossly polluted their drinking water (Keller and Wilson, 1992).

Another incident occurred during the late 1960's and early 1970's in Tokyo, Japan where over 500 000t of industrial waste was disposed off by a chemical company from material that was in great demand within the building trade because of its unusual hardening properties. However, underground sources were found to have a chromium salt content 200 times greater than those permitted by the European commission (Keller and Wilson, 1992).

Presently, the world's population is over 6 billion and as the population increases so does the water requirements, more food has to be produced as well as increasing the water requirement for agriculture. More water must also be available for industry, energy suppliers and domestic use. Vegetation is the greatest consumer of water on the land. According to Twort and Crowley (1985), the world's largest urban areas do not confirm to one and the same pattern. Water is very unequally distributed around the world and many countries are in water-deficient zones. This precarious situation prevails in both highly developed countries like the United States of America and less developed countries like countries within Africa. The reason for this is partly due to population increases and the misuse of water. Countries like Tunisia, Israel, Saudi Arabia, Libya and Kenya today, also face a critical challenge. However, it is important to highlight that water is a resource which cannot be produced or added as and when required by any technological means or devices. The total fresh and sea water content around the world is by all account fixed, though humans, in some places, have modified to a limited extent its pattern of availability with respect to space and time. The growing global concern is that very soon the demand for water will far exceed the supply capability and this will largely be as a result of the universal impact of industrialization and urbanization which will necessitate an urgent need for a reliable assessment of this valuable resource locally, nationally and internationally.

As much as it is true that India is endowed with four percent of the total average run-off in the rivers of the world, the per capita water availability of natural run-off is only 2500 cubic metres annually in comparison to more than 17 500 cubic metres for the former USSR, nearly 6500 cubic meters for Japan, 6200 cubic metres for the USA, etc. Mexico city has grown from one million in 1930 to 15 million in 1980 and is expected to have over 25 million inhabitants by the year 2000 (Twort and Crowley, 1985).

1.1.2 Water Situation in South Africa

South Africa is a country where water is a scarce and precious resource. Many parts of South Africa, such as the Kwa-Zulu Natal Midlands, do not have sufficient rainfall and many prolonged droughts have posed ever-present threats of water scarcity in all regions of the country (Sanker, 1996). South Africa is a country that could be described as a semi-desert region with a water shortage, where the average annual rainfall of 480mm is well below the world average of 870mm. Coupled with low rainfall and a high rate of evaporation of South Africa, is the lack of basic services which is concentrated on areas where demands of our most vital resource is ever increasing (Department of Water Affairs and Forestry, 1991).

In addition, South Africa is experiencing phenomenal urbanization, much of which, is in the form of informal settlements. These constitute overcrowded "shacks" with no running water and sanitation facilities resulting in the production of many third world type catchments such as Khayelitsha urban catchment in the Southern Western Cape (Sanker, 1996).

Previously, water and river awareness campaigns in South Africa had been organized on an informal basis but, now much effort is being put by government and communities towards protecting the vital resource, for example, the Department of Water Affairs and Forrestry published the "101" (1997) ideas for national water week where in different parts of the country awareness campaigns are held, like River Day – Cape Town, River Day – Durban, as means of indicating the sense of urgency to save water without delay. This also involved investing in water saving devices.

Access to water had in the past been the privilege of those wish access to land and economic power. In South Africa, 15 million people lack access to clean water and every day infants die from diseases bred of the unavailability of clean and potable water. Among the historically privileged population, infant mortality rates are about 20 per 1000 births while in water-deprived rural areas it is 370 per 1000 births (White paper on Water, 1997). Water access is a highly political and economic issue in South Africa. Degradation and historically skewed allocation of water presents huge challenges and are particularly acute in rural areas where water is used for irrigation, livestock and crop production, rural domestic purposes, wildlife and conservation.

As a result, the Department of Water Affairs and Forrestry and the new water policy of 1997, embodies the national values of reconciliation, reconstruction and development so that water is shared on an equitable basis while protecting the environment which sustains life.

In addition, water utilization, in general, is far from ideal socially, economically or environmentally. Demands range from domestic (cleaning; cooking; washing; gardening) uses to the trade and industrial demand, including farming, dry-land agriculture and forestry plantations which is an important part of the economy. The latter sector accounts for almost half of the nation's water use.

Within a geographical perspective then, current emphasis is focused on the social and environmental problems since the environment is the primary concern of people throughout the world. Furthermore, imbalances in the ecosystem are created when humans strive to undertake the economic demands of the world resulting in poor environmental management practices and unhealthy living conditions. As a result of urbanization and industrialization, informal communities have developed. However, these communities lack basic services and as a result resort to environmental degradation where the removal of vegetative cover, waste disposal and water pollution are evident.

1.2 CONTEXTUALISATION OF THE PROBLEM

Our perceptions of the developing world is generally that of the greater part of humanity struggling against poverty, squalor and disease.

We are aware of the gross differences in wealth, use of resources and the quality of life between countries of the first and third world. Environmental Management follows these differences and the solutions for the one are not those to be offered to the other. It has also been shown that the poor developing informal communities have very limited resources. Whilst residence in informal settlements have become a way of life for an increasingly high proportion of the population living in and around South African cities, very little is known about the housing and social circumstances of spontaneous settlers (Moeller and Stopforth, 1988).

Housing for the millions of poor informal communities, most of whom are in-migrants from the countryside, constitutes one of the most serious problems of urbanization. As a surge for space becomes keener, rents begin to rise further also leading to an increase in squatter settlements. An understanding of informal communities is therefore particularly important since the development of such communities is a direct manifestation of the high rate of urbanization. This unprecedented rise of informal communities and its immediate growth prospects have serious economic and social implications for employment, housing, education, health and the environment at large. Furthermore, the processes that contribute to water quality can best be understood if they are examined in the context of a catchment ecosystem. This consists of a river together with its non-living (abiotic) and living (biotic) including human components and their interactions (Gower, 1980). In addition, these growing informal settlements face the characteristic problems of a lack of facilities, resources together with infrastructure which is a daunting socio-economic challenge which provided the researcher with the motivation for the investigation (Gower, 1980).

South Africa, with its unique policy of apartheid, deprived the black communities of their right to a good and clean environment. There was no infrastructure in the locations in which they crowded and this directly degraded the environment, example open spaces and rivers were used as dump sites for their solid waste. South African cities, though, have in the last decade experienced as increasing strain on the infrastructural resources and the mushrooming of informal settlements in various parts of the country. The inhabitants of such settlements live in structures which offer partial shelter against weather elements, have inadequate access to basic facilities such as water, sanitation and refuse removal (Emmett, 1992). As a result, many of the informal settlements are situated close to any water source especially rivers. In the absence of sanitation, these communities make use of shallow pit latrines; river banks etc. The potential for pollution is therefore very high in these communities.

In South Africa, like in many other countries, man's activities are largely the cause of deteriorating water quality. Furthermore, activities of humans upset the aquatic system and cause change. Again, such aquatic systems are likely to receive a variety of effluents and reflect changes brought about by a mixture of wastes (Umgeni Water, 1999).

The fundamental need in environmental management lies in maintaining a balance between environmental protection and economic development. The environmental demands of a new democratic South Africa have also shifted from a green environment to a less attractive one. A political and corporate will with a greater commitment that has been experienced to date is therefore required to address issues of this "brown" environment. South Africa needs development in order to survive the current transition that is undergoing, however, this will not be free of pollution (Umgeni Water, 1999).

Pollution by people poses one of the most serious threats to water quality. The sheer volume and density of pollutants that find their way into the water course poses a threat to both the environment as well as human health. However, without proper management, water as a vulnerable resource may become overexploited and over utilised due to man's need for modernity at the expense of the environment. However, urbanization, domestic and industrial pollution are the activities that have the greatest impact on water quality, riverflow and therefore water use (Department of Water Affairs and Forestry, 1991).

The Umlazi area is one such area in the Durban Metropolitan Area that displays characteristics of apartheid urbanization. Being an area developed during the apartheid era, it does possess industries and a dumpsite together with informal communities that are situated along the Umlaas River. This community is characterized by conditions which are prevalent in areas that are no different to being less fortunate in terms of adequate housing, community facilities and basic services. All the above provided the researcher with the motivation for the study.

1.3 AIM, OBJECTIVES AND HYPOTHESIS

1.3.1 Aim of the Study

The aim of the investigation is to determine the influence of the Umlazi informal community on the water quality of the Umlaas River.

1.3.2 Objectives

The objectives of the study are:

a) To ascertain the E-coli concentration of water

b) To determine the COD concentration of water

c) To examine the turbidity of the water

d) To measure the ph of the water

e) To measure electrical conductivity

f) To determine the nitrate concentration

g) To determine the soluble reactive phosphorous concentration

h) To compare the above indicators upstream and downstream of the informal settlements.

1.3.3 Hypothesis

The informal communities of Umlazi impact negatively on the water quality of the Umlaas River.

1.4. CHAPTER SEQUENCE

The study comprises of five chapters. Following the Introduction (Chapter 1), Chapter two provides a conceptual framework by discussing the approaches to the study and a detailed review of literature concerning water quality. The methodology used to evaluate the investigation is explained in Chapter three together with a description of the study area. Chapter four addresses the issue of data analysis and evaluation while the final chapter focuses on discussion of the results, recommendations and overall conclusion.

1.5 CONCLUSIONS

Water quality and water resource protection are of fundamental importance in South Africa as rapid population growth and economic growth are both placing enormous demands on the countries diminishing water resources. In South Africa, political, social, environmental, economic and technical factors create challenges so diverse that the problems cannot be solved by merely scaling existing levels of services. New approaches are therefore needed to handle rapid urbanization to cope with the rate of change that is met in such a dynamic system. Issues concerning water quality have been a problem as long as urbanization proceeds at a fairly rapid rate. An integrated water management system is therefore required to handle such demands while communities and authorities should become more involved with their environment by ensuring that their environment is clean and not a health hazard risk to any individual.

CHAPTER 2

WATER QUALITY: A THEORETICAL REVIEW

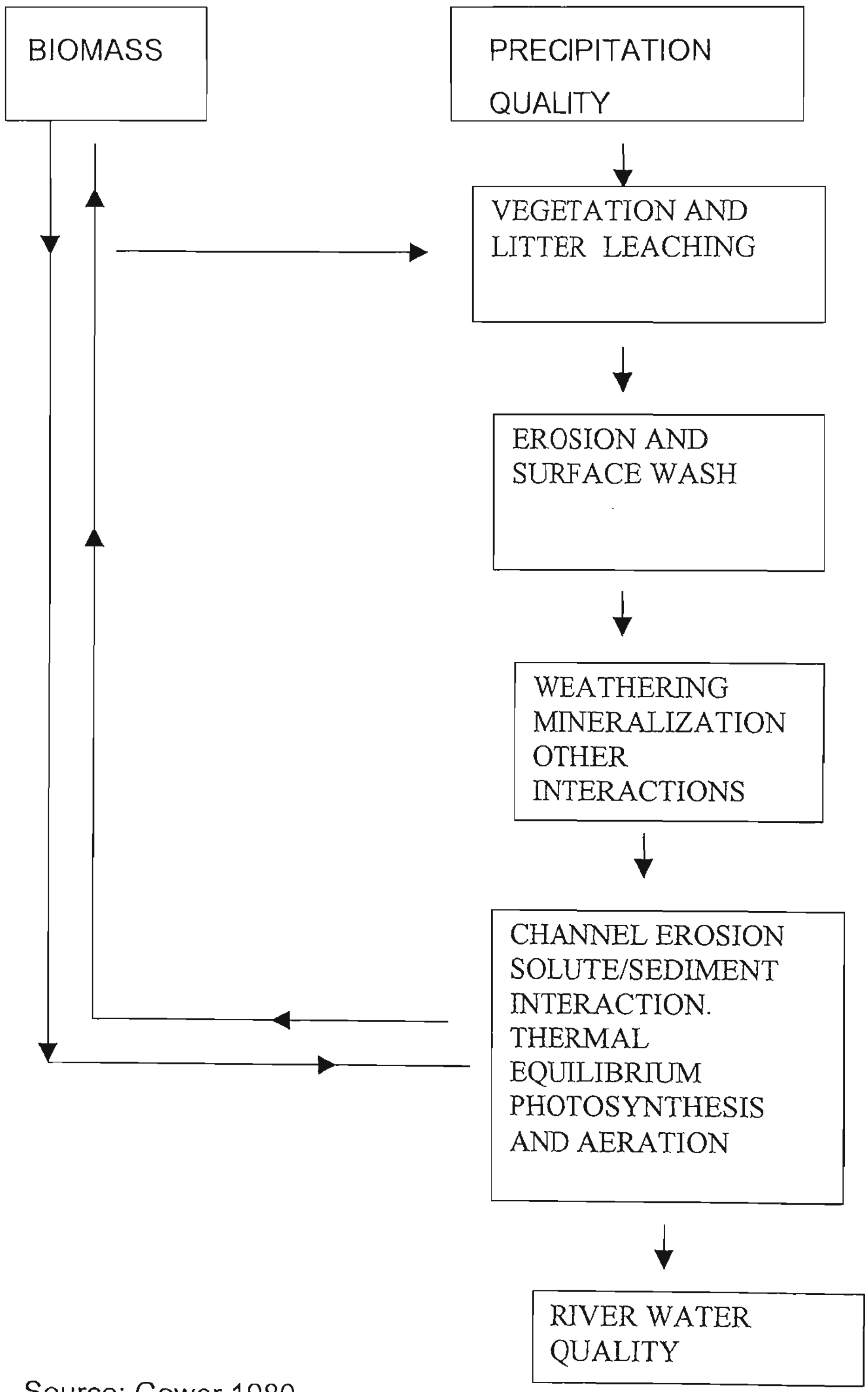
2.1 INTRODUCTION

There is an increasing public interest in water as a resource and an increasing awareness of the need to protect water quality. No doubt this is due, in part, to the demand for higher standards of living and also to an increase in time devoted to leisure activities, (Keller and Wilson, 1992).

The process that contributes to water quality can best be understood if examined in the context of a catchment ecosystem. Recognition of a catchment as an interrelated system is particularly instructive as it contains many of the factors that are relevant to the control and management of water quality. Humans modify water quality not only directly through discharges but also indirectly through such activities as adjusting flow regimes and impounding and abstracting. Clearly, man is a major biotic influence but, it is also important to realize that his activities in a catchment modify a system which is already dynamic and varying. Nevertheless, the impact of man emphasizes the need for careful management. (Gower, 1980).

The quality of water flowing in a river or stream will have evolved through a complex series of interactions with the soil, rock and biota of the catchment ecosystem and interactions need to be considered if the spatial and temporal variations in water quality are to be fully understood. (fig 2.1) Furthermore, the various processes controlling stream/river water quality, may be in a delicate balance and that a slight modification to the catchment could generate significant changes in water quality. (Gray, 1994).

Fig. 2.1 A simplified representation of the major mechanisms, influencing the quality of water involved



Source: Gower,1980

2.2 IMPLICATIONS OF HUMAN ACTIVITIES

If the complex and delicate nature of the system regulating stream-flow quality is recognized, then it is clear that human activities can readily upset the system and cause change. It is, in fact, difficult to conceive of the existence of areas where man has no influence on water quality processes. A knowledge of the various processes involved in the movement of water through the catchment ecosystem and in the control of water quality is essential in evaluating the impact of pollutants on river water quality and recognizing potential hazards,. With subsurface disposal of wastes in landfill sites and septic tanks, the movement of polluting substances to water courses will be governed by both physical and chemical factors. Biological activity must also be taken into account. However, the total catchment ecosystem rather than the immediate zone of disposal must be considered if the impact on water quality is to be fully understood. (Gower, 1980).

According to Gower (1980), constructional activities and agricultural techniques have been inducing environmental change for a long period of time. Many of man's activities will result in the addition of pollutants to the drainage system from both point and diffuse sources. The disturbance of the system may in itself condition significant changes in the water quality without the addition of foreign material. Where human activity involves widespread disturbance of soil and vegetation removal, mineral and nutrient cycles will be further disrupted by the acceleration of the natural weathering, mineralisation and leaching process. The effect of human activity on river water temperature may also be introduced as another example of man's disruption on the natural system. Furthermore, the removal of trees bordering a river will completely change the energy budget and may radically alter the thermal regime of the river. The significance of construction processes in contributing to environmental deterioration in recent times is now being increasingly recognized. Although small-scale urban developments which form part of a catchment may also occupy several adjacent catchments. The man-made environment we know as "urban" affects both the quality of water and its movement in the fresh water part of the hydrological cycle.

The effect of man's social and industrial activities can also be seen in the extent to which a river changes as it flows from its source to the sea. During this process, water is abstracted for potable and industrial use and is returned to the river as effluent which are normally contaminated with some form of pollution. In a large river system, water may be abstracted and returned several times before it reaches the sea. This is especially so in the United Kingdom where water demands are high relative to river flows. Furthermore, rivers in England and Wales have been classified into four categories to estimate the quality of the country's rivers namely:-

CLASS I : rivers polluted or recovered from pollution

CLASS 2 : rivers of doubtful quality and needing improvement

CLASS 3 : rivers of poor quality requiring improvement as a matter of some urgency; and

CLASS 4 : grossly polluted rivers

Many discharges of an "accidental" nature occur each year which can vary from a burst or leaking oil storage tank to the discharges of pesticides from storage areas following a fire. However, without adequate precautions, fish and bird life can be damaged as accidental discharges are more likely to cause fish mortalities. During 1977/78, 1895 incidents were reported within the Severn-Trent Water Authority, 36% of them being spillages of oil; 10% chemical spillages; 15% from sewers and sewerage works and 8% from agricultural activities, (Severn-Trent Water Authority, 1978).

2.3 ECOSYSTEM INTERACTIONS

A catchment ecosystem consists of a non-living abiotic component and a biotic component made up of living organisms, including man. These components interact through the flow of energy and cycling of nutrients and one result of the interactions is seen in the quality of the water. One of the striking features of lotic waters (e.g. rivers and streams) and lentic waters (e.g. lakes) is the way in which they interact with and are affected by the surrounding land. Drainage and discharge from the surrounding land affects the quality and quantity of water downstream and is therefore essential that water quality is assessed in the context of the catchment ecosystem (Gower, 1980).

One of the technical difficulties in the elimination of modern water pollutants, is complicated by economic, social and political issues. This means that people are exposed to a hazard which is not of their own making. A city taking its drinking water from a stream polluted by industrial wastes could, at great expense, purify the water and remove the offensive chemicals. However, to pay for this, the people of that city would have to be willing to tax themselves for an environmental hazard created by someone else. This arrangement would be regarded as unjust and would rather force the industrial plants to clean up their own wastes. However, waste controls cost money and increased production costs reduce profits. From the industrialist's point of view, the people downstream are an economic threat if they insist on the clean up. Moreover, if under pressure to control waste, businesses decide to close the plants then, there would be enormous job losses. The reason mainly is that the water quality like nearly every other environmental issue, is deeply embedded in the fabric of economic, social and political relations. There is an environmental crisis because the less than appropriate solutions seem to be incapable of providing a solution of preventing pollution problems on the water resource. Such an example will involve a careful look at the ills besetting Lake Michigan. Lake Michigan in Chicago had experienced a torrential downpour which resulted in the stormwaters flushing out the sewers and carrying sewage into the city's domestic water intake two miles from the shore. Sucked into the intake, the sewage made the return trip to the city through the water supply pipes. The result was an epidemic of typhoid fever that lasted several years. The Lake Michigan pollution became serious enough to prompt governors to request inter state conferences during the late 1960's, throughout the 1970s and early 1980. (Keller and Wilson, 1992).

Chicago, about a century ago, began to break the link between sewage and drinking water by a measure called diversion. This meant routing sewage or other polluted material from one area and into another. When the city was younger, the Chicago

River had received Chicago's sanitary and industrial wastes but, unfortunately the river carried the wastes to Lake Michigan and dumped them where the city abstracted its drinking water. All seemed fine to the Chicago residents but people living in other states bordering the Great Lakes feared their own water supplies might disappear down the Chicago River. However, questions arose as to what happened to the wastes, toxic materials in the wastes such as chlorinated hydrocarbon pesticides and chemical insulators known as polychlorinated binnenyls (PCBs) which are longer-lived and will be carried great distances in the water. Among the impacts were the rising level of phosphate nutrients from municipal sewage and agricultural runoff which produced an over fertilization of the in shore waters thereby reducing the dissolved oxygen content in the water and causing widespread eutrophic problems. Conditions favourable to eutrophication were further intensified by the phosphate nutrients from the decaying carcasses of the five billion fish (Alewives) introduced into the lake by man. Furthermore, Coho Salmon, introduced to Lake Michigan to prey on the alewives had acquired very high levels of DDT and its breakdown products were also higher in other species of fish (Tchobanoglous and Schroeder, 1985).

The Great Lakes diversion scheme was justified primarily in economic terms with considerable thought being given to savings in both municipal waste treatment cost and power and plant equipment. Waste treatment savings would occur because the increased stream flow from diversion would promote low-flow **augmentation** and dilation. When stream flow is artificially increased or augmented it can move efficiently diluted polluted water; this increases the stream's capacity for dissolved oxygen and biological activity, with a consequent improved decomposition of organic wastes and a lessened need for investment in treatment facilities. However, many long-lived pollutants requiring expensive advanced treatment for removal would simply be washed down finer. (Tchobanoglous and Schroeder, 1985).

Associated with the concept of dilution is mixing zone. This term refers to lateral, vertical and longitudinal forces, particularly those caused by turbulence that disperses pollutants to a certain concentration within a given time and area in a stream or other body of water. Decreasing industrial wastes does not mean that the wastes will disappear. Some waste material is now dumped into landfills which, if poorly designed, allows heavily contaminated liquids to reach out into surface waters. Reliance on deep wells for waste disposal involves the risk of contaminating subsurface waters that are critical to future domestic needs and in which pollutants persist even longer than in surface waters. The oversight is that wastes are discharges not just into water but rather into a gigantic worldwide hydrological cycle in which water circulates in different forms from land to lakes and oceans to the atmosphere and back to land again. A pollutant injected at one point in the cycle may be transferred to other points thus poisoning large segments of the cycle.

Such complicated microbial action dramatizes another dimension of our shortsightedness: the vast hydrological cycle is essential to all life and as such is so tightly linked to the existence of plants and animals at every level of biological complexity as to be inseparable from it. Our imperfect understanding of this relationship is illustrated by the use of biodegradation in secondary waste treatment facilities to decompose organic material without consideration because the products of the decomposition become a feast to organisms elsewhere. Such degradation makes domestic use of water increasingly difficult. Of even more immediate danger to human health is the biological magnification of persistent pollutants along the food chain until they even reach man's table in meat or vegetables. This magnification demonstrates the fallacy of man's reliance and "harmless" dilution of his wastes. (Tchobanoglous and Schroeder, 1985).

The most important use of water has been to support basic life processes and will continue to do so despite our need to put water to other uses. To learn how we can use water for other purposes without destroying its primary life support function, it is necessary to look at the characteristics which would tell us what to expect from the pollution now contaminating the world's biosphere.

2.4. THE HISTORY OF WATER SUPPLY SYSTEMS

Water, by its very nature, constitutes a special case when legislation or the law of economics have to be considered. As water moves in a dynamic manner under the influence of global and local forces, there can be no private ownership and it has to remain a common asset. The role of the government is principally that of custodian or guardian; this is maintained by both the courts and constitution in their legislative activity and administrative role. All humans have basic requirements for water be it for personal consumption, hygiene, transportation of goods or for recreation, requirements which have given rise to the concept of common ownership. (Keller and Wilson, 1992)

Humans have always tried to adopt the environment to suit their needs and this is as true for flowing water as it is for land. However, a type of balance between the needs of a community and that of an environment is difficult to achieve in a modern industrialized society where the damage inflicted on the environment, is at times, beyond the capability of the environment itself to repair. Government usually intervenes only when a crisis has occurred or is imminent; despite the government's role of custodian. The criteria defining a crisis may be of a physical nature such as river pollution, social such as the spread of water – borne diseases or political when major economic interests are threatened. (Keller and Wilson, 1992)

Any nation, conglomeration of people, tribe or village has the same basic requirements with regard to their need for adequate drinking water. The water supply must satisfy four basic conditions:

a) The supply of water must be in the required quantity;

b) The water must be in the right place;

c) It must be available at the right time; and

d) It must be of a suitable quality for the function for which it is required.

Any deviation from these basic conditions places a stress on those reliant on that water source. This stress can arise from any causes e.g. drought, flood, diseases or from permanent damage to the environment. (Keller and Wilson, 1992)

In the mid west of the United States of America, there had been a growing need over the past 40 or 50 years to irrigate arid land in order to maximize crop fields. Initially, the river water was of a suitable quality but insufficient quantity. With the advent of spray irrigation of crops the inorganic salt content of the soil increased and after winter precipitation, the inorganic salts were recycled into the river and then re-sprayed onto the fields giving rise to progressive cycles of increased salination. As a consequence, the fields are becoming increasingly less productive due to the stress being placed on the crops form the increased salinity of the soil. (Smethurst, 1988).

With the third world countries, a staggering range of complex, interrelated problems occur. Deforestation in the central Asian mountain ranges reduces the rate of evapotranspiration and subsequently, the precipitation on run-off from the land to the river systems is much increased. One of the consequences of this increased run-off is a rise in the rate of soil erosion and an increase in the particular content of the river water. With the destruction of drinking water supplies and degradation of effluent treatment systems, there is generally an increased rate of occurrence of water borne disease (Keller and Wilson, 1992).

2.4 HISTORY OF WATER QUALITY

In European and other industrialised nation, the major deviation from the four requirements for drinking water given earlier, is only that of water quality. The industrialised nations have mainly solved the problems of quantity and availability through storage, flood alleviation and reclamation systems.

It was during the Victorian era that industrialized nations made particularly dramatic advances in solving the problems of pollution of drinking water supplies. However, in more recent years, due to rapid industrial growth, pollution of water supplies and degradation of river systems, surface water quality is again increasingly becoming a matter of intense public concern (Keller and Wilson, 1992).

Many industries initially used private springs or wells as a water source with the local river usually being the major vehicle for liquid waste disposal. Although some industries may be located with reference to the availability of labour raw materials, many are sited to be close to reliable water supplies in sufficient quality and quantity. This applies as much in the twenty first century as it did in earlier times. For example, the siting of electrical power generation stations is always either on or close to major river courses, estuaries or coast lines. (Keller and Wilson, 1992)

In many ways, Victorian and earlier industries were more efficient in the recycling of another's waste material than they are today. For example, water from wool washings were fine-filtered to retain as much of the waste materials as possible. The trade effluent from modern industry, is, however, becoming increasingly insidious in character and consists often of diluted toxic materials released in a supposedly controlled and authorized manner. The major difference between the present and the Victorian era is that of increased technology and scale. The introduction of new technologies, e.g. pesticide manufacture and the scaling – up of the older technologies, such as the chemical manufacturing industries, have proved to be major components in pollution scenarios now developing (Gower, 1980).

Whilst pollution of river water is not a modern-day phenomenon, it is evident that the nature and quantity of the pollutants has changed dramatically for the worst. On passing through the uppermost layers of the earth's surface precipitation dissolves many other inorganic compounds but, usually there is nothing harmful to man arising from these processes. Therefore, there is a potential for river water to contain a large range of inorganic substances usually derived from naturally-occurring material. In the dissolved states, these substances may undergo complex chemical reactions and interactions involving precipitated water, the soil and its biota and the underlying strata through which they may percolate. The water will pick up colour from peaty substrates and from the humus in the soil. The activity of microbiological systems will add organic material to the water, but these are usually harmless. (Keller and Wilson, 1992).

Water, after treatment, usually contains up to 500mg/1 of dissolved solids consisting mainly of bicarbonates, sulphates and nitrates of calcium and magnesium with lesser quantities of sodium and potassium salts. There are usually a few trace elements present in drinking water including soluble salts of iron, manganese and aluminium and a wide range of trace metals and metalloids. Due to their toxicity, strict limits are usually set on permissible concentrations by legislative authorities. (Smethurst,. 1988).

The total organic content of drinking water is in the form of dissolved organic carbon and is usually present at about a level of 5mg.l. Although individual substances present appear to be of an anthropogenic origin, a clear distinction between those occurring naturally and those of a man-made origin is not always possible.

Anthropogenic activities produce a range of inorganic and organic substances, many of which are at levels which can now be currently detected in river water. This is partly due to increased sensitivity of analytical techniques and partly to increased releases into the environment. Such examples include soluble components from the exhaust fumes of internal combustion engines which accumulate in the air and on road surfaces and are washed into rivers via precipitation. Detergents from home laundering and industrial activities have resulted in an increasing phosphate content of surface waters with subsequent eutrophication of water bodies. (Keller and Wilson, 1992)

2.5 WATER POLLUTION

One of the most important properties of water is its ability to dissolve chemical substances and transport them between different points in the environment. These dissolved chemical substances in the aquatic environment can, at times be beneficial but in most instances are very detrimental. (Ellis, 1988).

A pollutant can have a wide range of definitions depending upon the terms of reference used. Ellis (1988) quotes various definitions including Dr Arthur Key who says : “A river is polluted when the water in its is altered in composition or condition, directly or indirectly as a result of the activities of man, so that it becomes less suitable for any or all of the uses which it would be suitable in its natural state.

Ellis (1988) claims more succinctly that:
There is no such thing as pollution. It is merely a problem of having valuable chemicals in the wrong place at the wrong time. Wisdom (1956) quotes the legal definition of pollution as: The addition of something to water which changes its natural qualities so that the riparian owner does not get the natural water to the stream transmitted to him.

Pollution in general is derived from humans and their activities and can be classified under three main categories with a fourth for other miscellaneous forms. These are:
INDUSTRIAL - These include products either used or produced in industries namely:
Engineering: hydrocarbons and trichlorinated solvents used in degreasing;
Insulation installer: Formaldehyde;
Printing: inks, dyes, bleaching agents
Electroplaters: heavy metal and arsenic salts;
Woolen mills: dyes, bleaching agents and pesticides;
Glass manufacturers: heavy metal and arsenic salts.

AGRICULTURAL – Pesticides and fertilizers stored in barns or outbuildings which if spilled into a water course where drinking water is abstracted, could cause serious damage. The leakage of silage with its high liquor content creates an extremely high biological oxygen demand on the water course and may reduce the available dissolved oxygen level below that necessary for the survival of the fish population.

SEWAGE RELATED - a diverse mixture of waste produced mainly by human activity. The mixture will contain human effluent; industrial effluent; runoff form roads; domestic waste water and a myriad of other minor sources. The mixture contains not only biodegradable materials but also insoluble substances, toxic and non-toxic materials as well as ineffective and non-infective agents.

OTHER THAN THE ABOVE – these include the fire-fighting activities and services which are normally called in to deal with chemical spillages during a road accident. Methods of disposal of spilled materials include covering up with an absorbent material and sweeping up or flushing down the nearest drain with large amounts of water.

In addition, natural pollution that is arising without the assistance of man and which creates an added demand for oxygen; can arise from the presence in water bodies of dead animals, decaying vegetation either from river plants or from vegetation falling into the water and animal wastes.

Natural pollution may increase the particulate content of the water, increase the acidity, add coloured material or give the water an unacceptable flavour. It may also reduce the oxygen content of the water to such an extent that the loss of aquatic life may occur. (Iwugo, 1995).

During the 1950's and 1960's, the major sources of pollution, within UK rivers were those of organic pollution arising from sewage, detergents and other foam producing agents and heavy metal salts. Point-source pollution, from sewage and effluent outfalls were major problems between 1960 and 1970. Regrettably, in the 1990's and presently, the problem with these sources still exist despite attempts by legislators and an unprecedented amount of public and media pressure. (Tchobanglous and Schroeder, 1985).

Pollution incidents arising in a water course usually derive from one of two types of sources namely Diffuse sources and Point sources.

Diffuse sources are those which continuously add extraneous material into a water course from a widely spread area. The following are examples:

a) Nitrates and pesticides used in agriculture which are washed into the rivers by precipitation run-off

b) Hydrocarbons and lead contained in the run-off from roads and highways

These diffuse sources can be further sub-divided as follows into the Uncontrollable diffuse sources and Controllable diffuse sources (Keller and Wilson, 1992).

Certain diffuse sources are either very difficult to control or are beyond practicable control when considering pollution prevention. The amount of nitrate or phosphate contained in the run-off from an agricultural field is such an example. The main reasons for this are the limiting factors which govern modern farming practice and over which the farmer has little or no control. For maximum benefit from a fertilizer or pesticide treatment it has to be done when the condition of the crops and the weather are appropriate – factors which are beyond the control of the farmer (Keller and Wilson, 1992).

Unfortunately, not all of the controllable sources are subject to legislation or are able to be controlled by legislation. When the source is detected, it is seldom economical or practical to contain it. Disturbance of a site and clean-up operations can take several years to accomplish, in which time a large proportion of the pollutant may have been released into the aquatic environment (Keller and Wilson, 1992).

Point – source pollution, as opposed to diffuse pollution, can be defined as a pollutant entering the environment from a fixed source and generally over a very limited period of time. Examples include the accidental releases of chemicals from industrial sites; leakage of silage liquor and yard washings from agricultural premises; discharge effluent outside the consent limits from sewage treatment works; industrial effluents; storm overflow from sewage works; illegal tipping off industrial and other wastes; run-off from fire-fighting activities; transportation accidents; agricultural and industrial treatment systems failures; release of sheep dip material after use and the discharge of excess pesticides from farms. (Tripathi and Pandey, 1995).

Industries are of great concern and industrialization contributing to water pollution has reached an alarming situation. Less than five per cent of the industries have provided adequate measures for the treatment of effluents. Factory wastes include:

a) *Oil:* in forming a thin, widely dispersed film on the surface , it reduces the intake of oxygen by the water;

b) *Detergents:* they reduce the oxygen absorption capacity of fresh water;

c) *Suspended* particles and Poisonous chemicals: (such as sulphides sulphides and sulphites) acting as reducing substances, these lower the oxygen concentration in the water. (Tripathi and Pandey, 1995)

Polluted and unpotable water due to poor environmental sanitation has been the major cause of diseases such as diarrhoea, dysentery, typhoid fever, intestinal heleminths, jaundice, cholera, etc. Sources of water pollution are countless and the most important and of great concern is due to human activities. Even today, open defaecation in the fields and along the drains and water resources are common in India, (Tripathi and Pandey, 1995). Whilst pollution of river water is not a modern-day phenomenon, it is evident the nature and quantity of pollutants has changed dramatically for the worst. The introduction of new technologies e.g. pesticide manufacture and the scaling up of older technologies such as the chemical manufacturing industries, have proved to be major components in pollution scenarios. Some of the examples include:

MINIMATA - JAPAN

At Minimata, in the Southern Western part of Kyushu in Japan between 1953 and 1959, several hundred of the population of the area became ill with the symptoms of mercury poisoning. Many died while others suffered impaired mental capacity. The source of the poisoning was found to be contaminated shellfish which formed a major part of the diet of the indigenous population. The source of the mercury was eventually traced to the discharge of the waste materials of companies manufacturing PVC in the affected area. This incident appears to be the first properly documented case of mercury pollution of an aquatic environment (Keller and Wilson, 1992).

LEIPZIG - GERMANY

During 1930, an outbreak of lead poisoning occurred in the town of Leipzig in Germany. The water of the river from which the towns drinking supply was obtained, had a very low calcium content and was regarded as very soft. One effect of this softness was to dissolve significant amounts of lead from the water supply pipes in the homes of the town. Samples taken from water standing in the pipes overnight showed that the concentration was far greater than it should be (Keller and Wilson, 1992).

NIAGRA - USA

During the period 1975 to 1984, more than 200 families had to be evacuated in Niagra, because their homes bordered a chemical dump site in the neighbourhood. The New York State Health Department found that babies born to families in this area were subjected to abnormal incidences of congenital defects, still births and miscarriages. Some children were born with either enlarged or deformed hearts, double rows of teeth and other serious congenital effects. It was discovered that a chemical company had been depositing toxic wastes on the dumps for over 20 years. These wastes, which had originated in the manufacture of pesticides, solvents and defoliants had, over time been continuously seeping into the ground in the surrounding area (Arnell, 1996).

CANADA – USA

Natural waterways can accommodate a certain percentage of pollution but, beyond that point the scales are tipped causing destruction to the river ecosystem. Pollution in the form of sewage is the host of a great number of serious and potentially killer disease such as typhoid, dysentery, polio and cholera. World-wide, the most common bacterial disease transmitted through water are caused by Shigella, Salmonella, E-coli, Campy Lobactor jejuni and Vibrio cholera. During the period, 1976-1980 , 13 out of a total 38 serioulogically confirmed outbreaks were caused by Norwalk virus. Giardiasis, is currently the most common cause of water borne disease that results from the consumption of untreated, inadequately surface waters in the United States. (Singh and Mcfeters, 1992).

2.6 THE IMPORTANCE OF WATER

A plentiful supply of water is clearly one of the most important factors in the development of modern societies. The availability of water for cleaning is directly related to the control or the elimination of disease while the convenience of water available in the home improves the quality of life. Water allows individuals and communities to beautify their surroundings and to use water as a carrier for household wastes. However, residents of most communities, could reduce water consumption from 10 to 25 per cent without significantly changing their life-styles. Forced reductions in water use due to drought have been experienced throughout the world. The use of the bathwater by more than one person, saving bath and washer water for lawn and shrub watering and flushing toilets only once or twice a day results in people being forced to use water sparingly. Although people in such areas such s the sub-Sahara region in Africa would still consider such conditions luxurious, drought conditions greatly affect the quality of life and agricultural, commercial and industrial activities. (Tchobanoglous and Schroeder, 1985).

2.6.1 WATER NEEDS VERSUS WATER AVAILABILTY

The need for water varies with culture, geography, type of community and season. The availability of water varies with geography and the provisions made to supply a constant source of water while the geographic location affects both the quantity and distribution of rainfall. Larger pipes, pumps, wells, treatment facilities and reservoirs are required in arid areas thus, greatly increasingly the cost of supplying water. Most of the world's water is found in the oceans and a relatively large amount is also contained in solid state as ice, snowpacks, glaciers and the polar ice caps. Surface water is found in lakes, streams and reservoirs. Groundwater is located in aquifers underground. Another fraction is present as water vapour in the atmosphere. (Manaham, 1997).

Excluding chemically bound water, the total amount of water on earth is about 1.4 billion cubic kilometres. Of this amount, about 97.6% is present as salt water in the earth's oceans. Even of this amount, 87% is present in solid form, predominantly as polar snowcap and another 12% as groundwater. There is just over 1% of all earth's fresh water that is distributed among surface water, atmospheric water and biospheric water. A report entitled "Comprehensive Assessment of the Freshwater Resources of the World" issued by the United Nations in 1997, warned of a global shortage of water that has become a limiting factor in the economic and social development of up to 80 countries containing 40% of the world's population. The report noted that whereas a 20% rate of utilization of water for household, agricultural and industrial purposes is considered acceptable, more than one billion people live in regions where usage exceed this rate and a significant fraction of the population live in countries with more than 40 percent water utilization. The report suggested that the percentage of water used in these countries for irrigation be lowered from its present level of 70 percent and that a high priority be given to conserving water, developing new supplies and purifying more wastewater for re-use. (Gray, 1994).

2.6.2 SOURCES AND USES OF WATER

Water is an essential element in the maintenance of all forms of life and most organizations can survive only for short periods of time without water. This fact has resulted in the development of direct relationships between the water availability, population density and quality of life. As well as being in an abundant supply, the available water must have specific characteristics and water quality is defined in terms of those characteristics. However, more recently, the introduction of anthropogenic chemicals that have an impact on health when present in trace amounts has become a problem. (Tchobanoglous and Schroeder, 1985). Most of the water used or affected by humans can be classified as fresh water because the concentration of dissolved constituents is low. The definition of fresh water is not precise but, a value of 1500g/m^3 total dissolved solids. (T.D.S.) is an approximate upper limit. Brackish water may have (T.D.S.) values of up to 5000 g/m^3, waters containing higher T.D.S concentration being termed "saline". Fresh waters are derived from surface sources and groundwater aquifers. Surface waters include lakes, rivers and those waters stored as ice or snow. These waters also tend to be turbid, a property caused by the presence of clays and other light – scattering colloidal particles. Groundwaters usually have higher T.D.S. concentrations than surface waters because of the mineral pickup form solids and rocks and groundwaters are noted for high concentrations of particular ions or elements such as calcium, magnesium, boron and fluoride. Since groundwaters are of a high quality with respect to potability and minimum treatment requirements, they are the preferred sources of water for individual homes and small communities. (Gray, 1994)

The quantity of water used varies widely from location to location. Factors that are of importance include the geographic location; type of community; economic status of the community; water pressure; cost; need for conservation and water system management (Gray, 1994). Municipal water use is generally divided into four categories, that is domestic; commercial and industrial (non-domestic); public service and also unaccounted system losses and leakage.

Domestic water use encompasses the water supplied to housing areas, commercial districts, institutional facilities and recreational facilities. The uses to which this water is put include drinking, washing, bathing, culinary, waste removal and yard watering. The per capital water supplied to individual residences and apartments varies from 150 litres per capita per day to 480 litres per capita per day, averaging about 220 litres per capita per day. This quantity includes the water used for the purposes mentioned above. In general, though, new developments have more water using appliances than older ones. Garbage disposals, dishwashers, the number of bathrooms and landscaping can be expected to increase with time in any given community.(Tchoganoglous and Schroeder, 1985).

The per-capital usage for commercial facilities will vary with the type of activity (e.g. stationery store versus restaurant). It has been proposed, however, that a value based on floor area is appropriate. Typical values range from 10 to 15 $1/m^2$ d, with a typical value being $12L/m^2.d$ (Tchobanoglous and Schroeder, 1985).
The per-capital water usage for institutional facilities is based on some measure of the size of the facility. Per student, per bed and per cells are representative units used to define water usage for schools, hospitals and prisons while water for recreational facilities of water is quite seasonal.

The amount of water provided by public water supply agencies to commercial and industrial users is usually limited although in some communities, industries such as canneries utilize public supplies. The largest industrial water use is for cooling which accounts for approximately 50 per cent of all non-agricultural water use in the United States. The non-agricultural industrial use varies widely accordingly to industry, geographic location, age of plant and cost of geographic water. The steam electric power industry is the largest industrial water user and the cooling requirements of other industries such as steel, oil refining and chemical production make a cooling-water requirements the dominant concern in the industry. The amount of water required is different in each situation. Food processing is also a major water-using industry. Water is used for washing, carrying products through the plant and is incorporated in some products. Since water is in contact with food, good sanitation must be maintained and the water, bacterially safe. Wastewater from food processing operations is usually high in soluble organic wastes such as sugars and acids. Meat processing wastewater contains blood, manure, grease and other difficult-to-handle materials. (Tripathi and Pandey, 1995).

Public water use includes the water used for public buildings for flushing and cleaning streets, for watering parks and green belts and for fire protection. Although the amount of water used for fighting fires is only a small fraction of the total supplied on an annual basis, the short-term demand rates can be very high and often dictate the sizing of pipes in small water supply streams. (Sinha, 1995).

It is predicted in South Africa that the total bulk demand of a water will increase from about 270 million $m^{3\ t}$ to about360 million m^3 in the next ten years and to about 620 million m^3 by 2025 – representing over 90% of use from the Mgeni River catchment by 2025. (Department of Water Affairs (1999). However, the new Durban Water Recyclying Works in Wentworth uses 40 million litres of water per day, saving more than the daily requirements of more than 40 000 households. (Metrobeat, 2001).

Agriculturally, water supply becomes the primary criterion in agricultural land development and in the choice of crops. In most cases, groundwater is a major source of irrigation water for historical reasons. People moved onto land hoping that wells would be productive. Where this was the case, development continued for example, the Sacremento Valleys of California are underlain by huge groundwater basins. These basins, relatively close to the surface made development of large tracts of rich farmland possible in the nineteenth century. (Howard, 1995).

However, more recently, intensive live stock farming has been found to cause an increase in phosphates. Pig and chicken farming on a large scale is an intensive form of live stock farming and is restricted to certain buildings. However, this has lead to the cleaning of these structures and the slurries from these pens are normally spread onto meadows causing faecal pollution. If these slurries can effectively be used for fertilizing pastures and crops, the impact would not be as high as it would be if the slurries are directly disposed into the river systems. Moreover, pesticides that are dumped "accidently" into water systems cause considerable damage to those water bodies while fertilizers can cause an increase of nitrogen, nitrates, phosphates and potassium. Water containing more than 150mg/1 of nitrogen causes an illness in babies called "blue disease" and excessive nitrites in decaying organic matter kills aquatic fauna. (Boyd, 2000).

Approximately 15 percent of the water withdrawn for municipal use cannot be accounted for in a water-balance analysis. (Umgeni water, 1999).
In most water-supplies, leakages within the distribution system accounts for most of the losses. Leakage is a function of the pipe size, joint construction, temperature and system age. Average, per-capital demand, as measured by water input, increases with the system age because of increased leakage at connections and taps as well as increased personal use. In some older systems that have not been maintained, the amount of water lost to leakage will often exceed the domestic use. (Gray, 1994).

Once the water supply of a community is used for the purposes intended, it is discharged as wastewater. With the exception of some public uses and leakages, wastewater is collected from all the locations where water is supplied, including, residential areas, commercial and industrial facilities and institutional and recreational facilities.

In general, wastewater flow rates are quite similar to water demand rates with two exceptions (i) water used for irrigation (of lawns, shrubs and gardens) generally does not enter the sanitary sewer and (ii) when sewer pipes are located below the water table, substantial infiltration may occur. In many older communities, the storm drainage system is combined with the wastewater system. Domestic dry-weather flow is composed of the wastes from sinks, baths, showers, toilets and other sources found in houses and businesses. In the United States of America, approximately 80 per cent of the house or per-capital domestic water demand is accounted for as wastewater but, other source (infiltration, roof drainage, industrial discharges) often result in wastewater flows that are greater than the water demand rates. (Tchobanglous and Scroeder, 1985).

Just as the demand for water fluctuates on an hourly, daily, weekly, monthly and yearly basis, so do wastewater flow rates. In the U.K. short-term fluctuations in waste water flow rates tend to follow a diurnal pattern. Minimum flow occurs in the early morning hours when water use is minimal then drops off in the early afternoon with a second peak occurring in the early evening hours between 6 and 9 pm. Seasonal fluctuations are also common in communities with seasonal commercial and industrial activities such as food processing, in resort communities and in small communities, with college or university campuses. (Twort, et al 1985).

According to Howard, 1995, maintaining ecological quality often requires significant amounts of water. An example is provided by the case of the Sacremento – San Joaquin River Delta in California. The delta contains over 1600 km of channels that provide a habitat for gamefish, water for irrigation of some of California's richest land and excellent recreational facilities for tens of thousands of people each year. When the river flow is low, saline water moves up the rivers and affects the delta ecology. Water quantity has ecological impacts in a number of ways. Flood flows flush out spawning areas, leaving clean new gravels washed out of the hills. High flow rates sweep debris from river channels and wash down new gravels needed for spawning of many fish. In past years, dilution was considered to be an acceptable "solution to pollution" and the self-purifying capacity of a stream was included in the design.

Although the hydrological cycle is a phenomenon easily grasped, two factors namely time and quality are often overlooked. The time scale is important because the natural storage of surface water and groundwater can impose significant time delays in the cycle. Furthermore, the quality of water at any point in the cycle is a dynamic variable.

Water is "pure" only in the vapour state and impurities begin to accumulate as soon as condensation occurs. Gasses dissolve in the droplets forming clouds and these gasses strongly affect water quality. Until recently, the most important dissolved gases were oxygen (O_2) and carbon dioxide ($C0_2$). Since gases can travel great distances before precipitation occurs, the cause and the effect of acid rain often occurs in different countries. (Tchoganoglous and Schroeder, 1985).

According to Tebutt (1990), upon reaching the surface, water either percolates into the soil becoming ground water or runs off along the surface in rivulets, streams and rivers. Minerals dissolve in both groundwater and surface water, but the greater contact with soil and minerals generally result in a higher dissolved salt concentration in groundwater. Chemical impurities commonly found in water in significant quantities include calcium, magnesium, sodium, potassium, bicarbonate, chloride, sulfate and nitrate while trace amounts of other ions such as lead, copper, arsenic, manganese and a wide spectrum of organic compounds are also common. The organic compounds originate from four principal sources namely decaying plant and animal matter, agricultural run-off, waste water and the improper management of hazardous waste discharges. The compounds themselves range from humic materials to the synthetic organics such as detergents, pesticides, herbicides and solvents.

In many groundwater basins, the amount of groundwater withdrawn for agricultural irrigation exceeds the rate of recharge. Since water is lost by consumptive use, evapotranspiration and surface runoff drops the level of groundwater. (Tchanoglous and Schroeder, 1985), At the same time, the concentration of impurities in the groundwater increases because of evapotranspiration and the leaching of salts from the soil and the application of fertilizers, for example, high nitrate concentrations in the groundwaters of the western United States are almost universally associated with fertilizer application. Surface water characteristics also change with time and space. Concentrations of impurities increase because of mineral pick up from surface run-off; silt and debris are carried by surface waters often resulting in muddy or turbid streams. Alien plants and algae tend to proliferate in water that are slow moving or stagnant. These plants impact negatively on the aesthetic nature of the river. Surface waters are used for the disposal of most of the world's liquid wastes. Wastes have a major impact on water quality and add greatly to the spectrum of impurities present. (Tebutt, 1990).

2.7 PHYSICAL, CHEMICAL AND BIOLOGICAL CHARACTERISTICS OF WATER

2.7.1 Physical Characteristics of Water

Water quality can be defined in two general ways: by describing the physical;

chemical and biological characteristics of water and by defining the suitability of water for a specific use. Most of our impressions of water quality are based on physical rather than chemical or biological characteristics. One expects water to be clear, odourless and colourless. Cloud waters are often coloured by organic materials picked up from decaying plants and backwaters sloughs and swamps are noted for their characteristic odours. Quantitative measurement of these characteristics is necessary for the determination of water quality. (Tchobanoglous and Schroeder, 1985).

Water quality measures can be classified in a number of ways but at most are grouped as physical, chemical and biological. However, there are other general categories namely gross and specific measures. With gross measures, distinction is made between the individual physical, chemical or biological species. Examples of such measures are suspended solids, odour, alkalinity, hardness and biological oxygen demand. In general, the gross parameters are the most easily measured and interpreted and they are the most commonly used descriptions of water quality. Specific measures are necessary when a single characteristic (e.g. toxic organic compound, heavy metals or species of fish) is of concern and are used to describe water quality as it applies to particular uses. (Boyd, 2000).

TUBIDITY: Perhaps the first thing noticed about water is clarity. Very clear water allows images to be seen distinctly at considerable depths such as Lake Tahoe, located on the California – Nevada border. The measurement of turbiality (turbindmetry) has however, little meaning except in relatively clear waters but, is very useful in defining drinking water quality in water treatment. Turbidity is the condition of reduced clarity in water caused by the scattering or absorption of light by suspended particles in coarse or colloidal suspension or the absorption of light by coloured constituents. Fine sediment often found in water from taps is often the extreme problem of particulate matter being present in water as usually only a slight cloudiness of the water (turbidity) will be noticed. (Boyd, 2000) Occasionally, it is possible for unfiltered water to pass into the distribution system. The presence of fine clay or silt particles and algae will increase the turbidity. Although inorganic particles such as clay do not usually affect health, taste maybe affected. High turbidity may also warn the user of a treatment plant malfunction which, may mean that the water has not been fully treated or disinfected. Turbid waters should also be treated with suspicion. In some instances, such as with groundwaters, soluble and manganese may be allowed into the mains which will then form insoluble particulate iron and manganese as the water is aerated and the ph increases (Gray, 1995).

SOLIDS – All contaminants of water, other than dissolved gases, contribute to the solids load. Solids can be classified by the size and state, their chemical characteristics and size distribution. Total dissolved solids are made up primarily by inorganic salts with small concentrations of organic matter. Contributory ions are mainly carbonate, bicarbonate, chloride, sulfate, nitrate, sodium, potassium, calcium and magnesium. The major contribution to total dissolved solids in water is the natural contact with rocks and soil and minor contributions from pollution in general, including urban runoff. In spite of the chemical composition, solids are classified among the physical or general parameters of water quality. Total solids content of 500mg/1 is a desirable upper limit. Values of up to 1,000 mg/1 of total solids have been encountered in drinking water. Several tests maybe performed in relation to solids: dissolved solids, settleable solids, suspended solids, total solids and conductivity. The following definitions apply namely:

Total Dissolved Solids (T.D.S): TDS in water sampled are limited to the solids in solution.

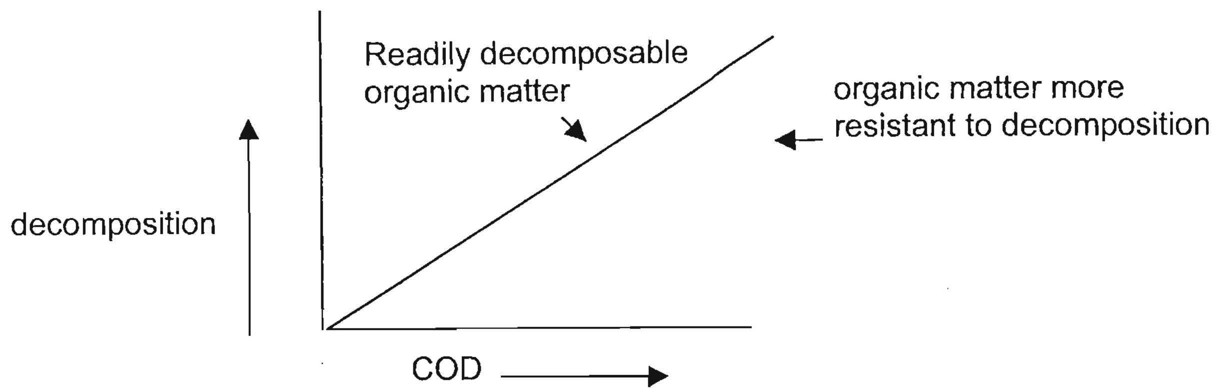
Settleable Solids: Solids in suspension that can be expected to settle by gravity only in oversized settling tanks. The period of time must be defined. Commonly used in the analysis of sewage, this test may indicate data useful to evaluate the sedimentation process but, only when very high turbidity is handled. Suspended solids (SS or TSS): Solids not dissolved; also called suspended matter. Little or no significance in water for domestic consumption where turbidity provides a proportional if not equivalent value but with easier determination.

Total Solids: All solids contained in the water sampled determined by evaporation and drying.

Volatile Solids: Solids made up of organic chemicals. This test has little and unreliable significance in waters intended for domestic consumption. If high organic content is expected, a COD (Chemical oxygen demand) or BOD (Biochemical oxygen demand) determination can be used for raw water evaluation (Boyd, 2000).

The chemical oxygen demand (COD) is a measure of the oxygen demand of the organic matter in a sample as determined by the oxidation of the organic matter with potassium dichromate and sulphuric acid. A known and excess quantity of potassium dichromate (K2Cr2O7) is added to a water sample that has been acidified with sulphuric acid. Chloride interferes with the COD procedure because it is oxidized to chlorine by dichromate and causes high results. The main reason for the COD test is to have a rigid way to assess BOD. The COD approximates the ultimate carbonaceous BOD because it represents the total amount of oxygen required to oxidize organic matter to carbon dioxide and water. Organic matter decomposes at different rates depending upon its composition and bacterial activity. COD only reveals the oxygen demand of the organic matter. Therefore, for a highly decomposable organic material in a nitrification - inhibited BOD test, the BOD might be nearly equal to COD. BOD may be considerably less than COD in a sample containing organic matter resistant to decay. If COD is used to routinely estimate the BOD of an effluent, it is necessary to know that the composition of the organic matter in the effluent will be almost the same at all concentrations and a factor developed to relate COD to BOD. The COD may also be used as an index of the concentration of organic matter in water samples because the amount of dichromate consumed in the digestion can be related to the organic carbon (Boyd, 2000).

Fig. 2.2. Examples of the Relationship between Chemical Oxygen Demand (COD) and Biochemical Oxygen Demand (BOD)



High content of solids in water have been inversely correlated with increased morbidity and mortality rates (possibility of potential danger of soft waters mainly on cardiovascular diseases). These mineral constituents have been related to hardness of water rather than total solids or dissolved solids. The solids found in water typically include silt and clay from riverbanks or lake bottoms and organic matter and microorganisms from natural or anthropogenic sources. The removal of solids is of great concern in the production of clear safe drinking water, in the process industries and wherever water of high quality is required. (Gray, 1994).

ODOURS : Odours associated with water usually result from the presence of decaying organic matter or, in the case of mineral springs, the reduction of sulfates by bacteria to H_2S gas. Decaying organic matter may accumulate in bottom deposits large enough to provide suitable conditions for the anaerobic bacteria that produce noxious gases. Sources of the organics include debris washed into the streams, dead animals, microorganisms and wastewater discharges. In addition to the H_2S gas which has a very distinct odour of a rotten egg, a number of other odours are commonly encountered. These are the Amines (fishy odour); Ammonia (ammoniacal odour); Diamines (decayed egg odour); Mercaptans (skunk secretion odour); Organic Sulphides (rotten cabbage odour); skatole (faecal odour). These odours often occur together making individual smells very difficult to separate and identify. Individuals very sensitive to odours and continued exposure to an odour tends to decrease sensitivity such as persons working next to an odour may be less sensitive to it than their occasional guests. (Tchobanoglous and Schroeder, 1985).

According to Zuane (1990), objectionable taste and odour can more likely be found at the source (raw water) than at a user's tap. Earth-musty odours are normally derived by natural biological processes. In analyzing odour thresholds of various substances in water, it can be stated that human abilities indicate the presence of concentrations as low as 1mg/1 for substances or as high as 20mg/1. Qualitative terms used to describe taste and odour are often cataloged as swampy, grassy, medicinal, septic, phenolic, musty, fishy and sweet. Problems with taste and odours are normally associated with surface water vs ground water (at least in the ratio of 2:1). Large surface supplies are detrimentally, affected by the biological degradation of algae and their waste products; algae are usually bloomed by nutrients produced by human habitation (failing septic tanks, sewage treatment plant affluents, landfill leachate, etc). One of the most common complaints of drinking water is the "chlorine taste" where the odour threshold is sometimes as low as 0.2-0.4 mg/l. "Taste and odour" and "colour" determinations, in spite of their aesthetic limitations, are nevertheless important in potability considerations. This is due to the fact they may be the first alarm signal for a potential health hazard and they play an important role in the user's evaluation of drinking water. Furthermore, odours occurring in natural waters are organic in nature with the exception of hydrogen sulfide. Natural sources of odours include microganisms of various types; decomposition of natural substances and the reduction of sulfate to hydrogen sulfide. One of the serious problems with surface water impoundments is the occasional development of odours and tastes due to the excessive growth of microorganisms and typically, algae that release taste and odour producing substances which are the responsible organisms. However, the biological decomposition of leaves and weeds can also lead to the development of odours (Gray, 1994).

TEMPERATURE: Temperature affects a number of important water quality parameters. Chemical and biochemical reaction rates increase markedly with temperature. Gas solubility decreases and mineral solubility increases with temperature. The growth and respiration rates of aquatic organisms increase and decrease with temperature and most organisms have distinct temperature ranges within which they reproduce and compete (Tebutt, 1990).

Many industrial processes generate waste heat that may be disposed of by the transfer to water. Thermally, enriched effluents may raise temperatures in streams or other water bodies to cause serious ecological perturbations. Not all pollution results from contaminants contained in runoff or effluents. Sometimes accidents may result in sudden spills of potentially toxic chemicals or other substances. For example, a highway or rail accident can result in a cargo being inadvertently spilled into a watercourse or a ship accident can spill crude oil or other substances into the ocean or into coastal and inland waters (Nostrand, 1990). Communities located in close proximity to the ocean often discharge wastewater directly to the sea through submerged outfalls. In most cases, a suitable stream is unavailable and the purpose of the ocean outfall installation is to provide enough dilution of the previously treated wastewater to prevent deterioration of the environment near the discharge point and the surfacing of the recognizable waste materials. Thermal effects are of particular interest in outfall design. One reason is that discharges generally are lower in density than the receiving waters and tend to be boyant. A second reason is that local warming of the environment changes the ecological makeup of the discharge area. Heated effluents such as the cooling water from power plants can result in greatly increased growth rates and changes in species makeup. Because the productivity of the region is increased, this effect is sometimes referred to as thermal enrichment as well as thermal pollution. (Tchobanoglous and Schroeder, 1985).

A wide range of organisms inhabit the waters of the world. Many organisms such as the stone fly and mayfly spend their larval stages attached to rocks in swift-running streams while Tubifex worms bury themselves in benthic (bottom) deposits and leave only an antenna like tail waving in the water to absorb oxygen. (Keller and Wilson, 1992).

Organisms found in water usually have relatively tight restrictions in their environment example, pacific salmon require temperatures below 16 degrees C and dissolved – oxygen concentrations above $5g/m^2$ to spawn. These fish will not enter a river on the spawning run until conditions are satisfactory (Keller and Wilson, 1992). Kelp, a species of ocean algae, require both a rocky bottom for attachment and clear water to allow light penetration for photosynthesis. Seemingly small changes in temperature or dissolved constituents will make one species more competitive. Environmental changes, therefore, can be expected to change the type of population present in any natural water. (Howard, 1995). According to Gray, 1994, the temperature of water is important for all its intended uses. Surface waters are subject to great temperature variations. In the United States, for example, river waters will vary from 0.5 degrees C to 3.0 degrees C in winter to 23 degrees C to 27 degrees C in the summer. The temperature of wastewater, though will generally be warmer than that of the water supply. Depending on the geographic location, the average temperature of wastewater will vary from 10 degrees C to 22 degrees C with a representative value being about 15.6 degrees C.

COLOUR: Many of the colours associated with water are not true colours but, the result of the colloidal suspension, tea is such an example of "colouration". True colours result from dissolved materials most often organics and since many industrial wastes are coloured, if not properly treated can impact colour to the receiving stream. (Tebutt, 1990). Colour when noticed in drinking water, is an objectionable characteristic that would make the water supply psychologically unacceptable. When turbidity is not removed, "apparent colour" is noted. It is possible that removing turbidity, may remove some "true colour". Colour is found mostly in surface waters although some deep ground waters contain colour in amounts that are noticeable. Water that has come in contact with decaying organic matter will have a light-yellowish to brownish colour. Where industrial wastes are discharged into streams, a wide variety of colours may be encountered depending on the industrial process, for example, if a soft drink that is normally clear is poured into a glass and is observed to have a yellow colour, its user acceptability will suffer although it may be safe to drink. A similar situation exists with drinking water. Colour can be used to asses the condition of wastewater with respect to how long it has been in a sewer as fresh domestic wastewater has a light-brown colour. As wastewater undergoes anaerobic decomposition, its colour will change from a light brown to a light grey. Ultimately, under anaerobic conditions, the colour will become black resulting from the formation of ferrous and other sulfides. (Tchobanoglous and Schroeder, 1985).

2.7.2 CHEMICAL CHARACTERISTICS OF WATER

Chemical measures of water quality include the analysis for the presence of specifications such as calcium, magnesium and lead. Gross chemical measures such as alkalinity and hardness are also used to define water quality. Most of the common water quality measures reflect combinations of or interactions between ions. (Tchobanoglous and Schroeder, 1985).

All natural waters contain dissolved ionic constituents. Typically, the ionic species that are present will be derived from the contact of the water with various mineral deposits. The most abundant species are the bicarbonates, sulfates, chlorides of calcium, magnesium and sodium. Potassium, usually present in small amounts, is derived from soil minerals from decaying organic matter and from the ashes of burned plants and trees. As with the major ionic species, most of the minor ionic species are derived from the contact with water. In addition, some of the minor constituents such as ammonium, carbonate and sulfide may be present because of bacterial and algal activity. (Tchobanoglous and Schroeder, 1985).

Since alkalinity is due to the presence of salts of weak acids, the major influencing components concerned are hydroxides, carbonates and bicarbonates. As far as potability is concerned, alkalinity is not a significant parameter. Variations of concentrations from 5 to 125mg/l are expected, and the extremes of these values are tolerated in water supplies. While raw waters normally contain alkalinity in the form of carbonate of soda or bicarbonate of calcium and magnesium, treated water alkalinity is mainly influenced by the chemical treatment for coagulation, water softening and corrosion control. The value of alkalinity examined actually gives an estimate of non-acid constituents of water. When the "basic" constituents in water are limited to salts of calcium and magnesium, alkalinity values are equal to hardness, values and when alkalinity is greater than hardness, (represents the total concentration of calcium and magnesium ions, reported as calcium carbonate), basic salts such as sodium and potassium may be present in addition to calcium and magnesium, the presence of salts of calcium and magnesium are more likely to be sulfates instead of carbonates. Alkalinity in water is related to ph, hardness, calcium, magnesium. Sodium, potassium and sulfates and total solids. Alkalinity represents a "status" of water, the "capacity to accept protons" or the "capacity to neutralize acid" (Zuane, 1990).

The principal nonionic mineral found in all natural surface waters and groundwater is silica usually expressed as S_iO_2. Reference to silicia is usually in the soluble form as compared to silica in the suspended solids. However, silicia present in water is troublesome especially in industrial applications where it may cause severe scaling problems in boilers and heat exchanges. (Tchobanoglous and Schroeder, 1985).

In addition to the major and minor ionic species found in natural waters, a variety of inorganic species of human influence, origin may also be found. These constituents are of concern mainly because of their toxicity to microorganisms, plants and animals. The presence of these constituents is mainly due to the discharge of improperly processed industrial wastes and high concentrations often found in wastewater sludges (Tchobanoglous and Schroeder, 1985).

Nitrogen and phosphorous are also essential for the growth of plants and animals. For this reason, these elements are referred to as nutrients when discharged in wastewater to surface waters. Nitrogen is a complex element that can exist in seven states of oxidation. From a water quality standpoint, the nitrogen – containing compounds that are of most interest are organic nitrogen; Ammonia (NH_3); nitrite (NO_2) nitrate (NO_3) urea {$CO(NH_2)_2$) and dinitrogen or nitrogen gas (N_3). In nature, nitrogen is cycled between its organic and inorganic forms. Bacterial and plants are responsible for the production of proteins from several inorganic forms of nitrogen. (Golterman,.. et.al. 1978).

Animals, including humans, cannot utilize nitrogen from the atmosphere or from inorganic compounds to produce proteins but, must obtain nitrogen in organic form. In turn, proteins are broken down by bacterial activity to urea. Ammonia from these two sources is then oxidized bacterially first to NO_2 – and then to NO_3 – Nitrite and nitrate can also be converted by bacteria to nitrogen gas. (Boyd, 2000).

Phosphorous, like nitrogen, is of great importance in water supply systems and in the aquatic environment. Phosphorous compounds are used for corrosion control in water supply and industrial cooling water systems and in the production of synthetic detergents. Phosphorous is essential for the growth of algae and other aquatic organisms. However, serious problems have resulted when excess phosphorous in treated effluents are discharged to the aquatic environment. Because of the many problems associated with uncontrolled algal bloom, the discharge of phosphorous to ecologically sensitive waters are now controlled. (Tchobanoglous and Schroeder, 1985). Phosphorous concentration in natural waters are low but, this nutrient is required in relatively large amounts in plants. Phosphorous is generally the most important nutrient in aquatic ecosystems. However, phosphorous pollution of natural waters is considered a primary cause of eutrophication. Increased phosphorous concentrations in natural waters, resulting from human activities, normally stimulate aquatic plant growth and especially phytoplankton growth. If phosphorous additions to natural waters are too great, eutrophication occurs with excess phytoplankton blooms or nuisance growths of aquatic macrophytes. Phosphorous additions to natural waters are therefore considered a form of water pollution. (Boyd, 2000).

Radioactivity in Water - Raw and drinking water and its possible consequences to the user's health has always been an essential issue since the 1950's and 1960's due to the fear brought about by nuclear testing. Compared with the background exposure of human beings to natural causes, it can safely be stated that radiation effects associated with water consumption are normally negligible. There is nevertheless the possibilities of encountering ground waters with relatively high concentrations of nuclear parameters. Sensitivity, nevertheless remains connected with the constant fear of potentially disastrous effects of radiation in humans due to the continuous increase in the number of nuclear plants, nuclear weapon arsenals, nations possessing nuclear power and nuclear explosives potentially in hijackers hands. (Nostrand, 1990). However, if water bodies are contaminated with radio-active materials, it has an adverse effect on life either killing it or giving rise to mutations. (Keller and Wilson, 1992).

ph (HYDROGEN ION CONCENTRATION) – The hydrogen ion concentration is important because it affects chemical reactions. Equilibrium relationships are strongly affected by ph and many biological systems function only in relatively narrow ph ranges, typically 6.5 to 8.5 (Tchobanoglous and Schroeder, 1985). However, raw water examined for potential use in a drinking water, has an expected ph value between 4 and 9 but, more than likely, encountered values will be between 5.5 and 8.6. Values higher than 7 are normally expected in raw water due to the presence of carbonates and bicarbonates (contact with rocks and stones), but acid rain may lower the ph to values under 7. However, any agitations in water samples could result in a loss of carbon dioxide which may change the actual ph value (Boyd, 2000).

Conductivity – Another parameter used to characterize the gross chemical characteristics of water is conductivity. The conductivity of a solution is a measure of the ability of that solution to conduct an electric current. Since the electrical current is transported by the ions in solution, the conductivity increases as the concentration of ions increases. Electrical conductance is measured by placing two platinum electrodes in a water sample and recording the resistance offered by the solution.

Conductivity is a useful test in raw and finished water for quick determination of minerals. Raw and potable waters normally register conductivity from 50 – 500 microohms/cm with mineralized water registering, values over 500 and even over 1000 microohms/cm. However, conductivity does not measure the dissolved or the total solids but, indicates with a simple test the ability of the water examined to carry an electric current. (Keller and Wilson, 1992).

Hardness – Magnesium and calcium are often present at significant concentrations in natural waters. These ions are easily precipitated and in particular react with soap to form a difficult–to–remove scum. Since 1950, detergents have largely replaced soap in developed countries and the economic impact of hardness has decreased somewhat. (Tchobanoglous and Schroeder, 1985). For most practical purposes, however, hardness of water can be represented as the sum of the calcium and magnesium concentrations, given in equivalent per cubic meter. The two types of hardness are carbonate hardness and non-carbonate hardness. The balance between carbonate and non-carbonate hardness is important in water softening (hardness removal) and in scale formation

Organic and Inorganic Compounds

The amount of organic matter present in most natural waters is low. Typically the source of the inorganic matter in water is from decaying weeds, leaves and trees. Humic acid, a high-molecular mass compound derived from the decomposition of plant matter, is found in most surface waters. At present, most surface waters and ground waters contain organic matter of anthropogenic origin. "Organic matter" includes whose origins could be from both natural sources and from human activities. The presence of organic matter in water is troublesome for many reasons including colour formation, taste and odour problems; oxygen depletion in stream; interference with water treatment systems and the formation of halogenated compounds when chlorine is added to disinfect water.

Most organic compounds are composed of various combinations of carbon, hydrogen, oxygen, nitrogen, phosphorous and sulphur. The principle organic compounds found in wastewater and to a much lesser degree in natural waters include proteins, carbohydrates and lipids.

Proteins are the principle constituent of animal tissue. In addition to carbon hydrogen and oxygen, proteins contain nitrogen which is their distinguishing characteristic and sulphur. However, although there are thousands of proteins they are made up of 26 basic building blocks known as amino acids which share a common structure. (Tchobanoglous and Schroeder, 1985).

Carbohydrates are widely distributed in nature. Carbohydrates include sugars, starches, cellulose and wool fiber. It is the principle constituent of plant and some animal tissue and are classified as monosaccharides, disaccharides, trisaccharides, polysaccharides. Low-molecular-mass carbohydrates such as mono-and disaccharides are generally soluble in water while polysaccharides are generally insoluble. With the exception of cellulose and wood fiber, most carbohydrates are readily biodegradable and because of this, it can lead to the rapid depletion of the oxygen resources of water. (Tchobanoglous and Schroeder, 1985).

Those constituents of animal and plant tissue that are insoluble in water but soluble in ether or other organic solvents are classified as lipids. Important lipids found in wastewater include fats, oils, greases and waxes which originate from butter, lard, margarine and vegetable fats and oils. Fats are also found in meat, seeds, nuts and certain fruits. However, because of their structure and low solubility, fats are not readily biodegradable. (Gray, 1994).

Many of the 100 0000 organic compounds are not widely used but, have become ubiquitous in use throughout the world. Of greatest concern are those organic compounds that may be carcinogenic or that may cause mutations in humans and other living forms at extremely low concentrations. (Gray, 1994).

Glycerides and other greases are among the agents responsible for binding dirt to surfaces. When soap or synthetic detergents are added to water, the nonpolar tails of the soap or detergent molecules tend to become embedded (dissolved) in the greaselike material. The polar end, resists this action and when assisted by mechanical agitation or boiling, the attached film breaks up into small particles that can be easily removed by washing. Before 1965, the surfactant in synthetic detergents was primarily of alkyl-benzene – sulfonate (ABS) type. These detergent compounds were difficult to treat biologically therefore in 1965, legislation was passed in the United States and ABS – type detergents were replaced with linear – alkyl-sulfonate (LAS) which is biodegradable. However, in some parts of the world, ABS type detergents are still in use. The presence of surfactants is measured by noting the colour change occurring in a standard solution of methyl- blue dye. The term MBAS (Methylene – blue active substances) is commonly used in reporting the presence or absence or detergents in water (Keller and Wilson, 1992). The chemicals on the other hand, used in agriculture for the control of diseases and of pest organisms are primarily of anthropogenic origin. The major source of these chemicals in surface waters is surface runoff from agricultural, residential and park lands. In addition, the presence of these substances in water is troublesome because they are toxic to most aquatic organisms. (Keller and Wilson, 1992).

Organic solvents are another group of compounds, that are of concern because many are known or suspected carcinogens. The detection of such compounds in groundwater near the industrial facilities are of great concern as solvents leak from the underground storage tanks into the underlying aquifers. Among the many solvents, the more common ones are acetone, benzine, carbon tetrachloride, ethyl alcohol, heptone, methyl alcohol, pine oil and trichloroethane. (Tchobanoglous and Schroeder, 1985)

In addition, it has been found that chlorine used for the disinfection of treated water and wastewater can react with some of the organic substances present to form chloroform (a trihalomethane) and other hydrocarbons. The organic substances involved in the reaction with chlorine are identified as precursors. The principle trihalomethanes of concern in water and wastewater treatment are chloroform; bromodichloromethane; chlorodibromomethane and bromoform. However, it should be noted that a variety of organic substances of both natural and anthropogenic origin can serve as precursors while humic acid, produced from decaying leaves, is a natural precursor. Moreover, the types of measures that maybe undertaken to control the contamination of an underground aquifer will depend on the nature and source of the contaminants. Different measures will be required if the source of the contaminant is continuous or a one-time input (Gray, 1994).

The gases found in water include nitrogen; oxygen, carbon dioxide; hydrogen sulphides; ammonia and methane. The first three are the common gases of the atmosphere and will be found in all water exposed to the atmosphere, while the latter three gases are associated with bacterial metabolism and respiration. Hydrogen sulphide is produced from the bacterial reduction of sulphate under anaerobic conditions while ammonia and methane are derived from the anaerobic biological decomposition of organic matter. (Tchobanglous and Schroeder, 1985). However, in considering the absence or presence of gases in water the solubility of the gas; the partial pressure of the gas in the atmosphere above the liquid; the temperature of the water and the purity of the water as measured by parameters such as ionic strength, salinity and suspended solids need to be considered.

2.7.3 BIOLOGICAL CHARACTERISTICS OF WATER

The biological characteristics of water, related primarily to the resident aquatic population of microorganism, impact directly on water quality. The most important impact is the transmission of disease by pathogenic organisms in water. Other important water quality impacts include the development of tastes and odours in surface waters, groundwaters, the corrosion of heat transfer surfaces in cooling systems and water supply and wastewater management facilities. (Gray, 1994)

2.7.3.1 THE USE OF ESHCERICHIA COLI (E. Coli) AS AN INDICATOR ORGANISM

Originally, the target of the contaminating bacteria was the Escheria Coli, highly present in the human intestine. There are many water suppliers and community workers who believe that water-borne diseases belong to the past or to Asia and Africa, unfortunately not so. In America, from 1971-1980, 50% of the outbreaks reported were in non-community water systems, 39% in community systems and 11% in private systems. 75% of the illness occurred from outbreaks in community systems. Almost all outbreaks were as a result of using ground water with inadequate treatment primarily interrupted in inadequate disinfection (Howard, 1995).

The coliform group of bacteria includes all aerobic and anaerobic, grown-negative, nonsport-forming, rod-shaped bacteria that ferment lactose with gas formation. Escheria coli is the most widely known member of the group of organisms used for bacteriological experiments. E.Col is a normal inhabitant of the intestine of warm blooded animals, including humans. Since the human intestinal tract has an abundance of E.coli, it was reasoned in the early 1900's that water could not become polluted with human faecal matter without this organism being present. However, this organisam was and is today, taken as an indication of the presence of faecal matter and of the possible presence of pathogenic organisms of human origin. In addition, since there is no way of knowing which pathogenic organism is present in the sample, E-coli has become to be used as an indicator for faecal pollution. Although E-col is part of the normal pathogens of the intestinal tract, certain strains can cause a moderate to severe gastroenteritis in humans and animals. At present three basic types of enteropathogenous are associated with the strains of E coli: enteropathogenic (EPEC), enterotoxigenic (ETEC) and enteroinvasive (EIEC) (American Public Health Association 1989), EPEC strains colonise the jejenum and upper ileum of the small intestine and cause acute gastroenteritis in newborns and in infants up to 2 years of age. EIEC strains invade epithelical cells of the large intestine and cause diarrhea in older children and adults. ETEC strains produce one or both of two different toxins, a heat-stable toxin (ST) and heat labil toxin (LT). Both toxins cause diarrhea in adults and infants. Most known agents of water – borne disease cause acute gastrointestinal disorders especially diarrhea and cramps. (Smethurst, 1988).

2.8 WATER IMPURITIES AND HEALTH

Water is of fundamental importance to the survival of human beings but, the quantity of water ingested by humans is very small compared with the quantity used for agriculture. However, if the water ingested by humans is not safe, then serious health problems can occur and may even result in death.

A large number of chemical elements and compounds that directly affect public health are found in natural waters. Health related impurities occur both naturally and through human activities. Magnesium nitrate and sodium are the only constituents commonly found in natural waters that have significant health-related effects. Magnesium has a mild laxative effect while nitrate in concentration exceeding $10gn/m^3$ interferes with oxygen utilization in newborn, babies. The resulting disease, methanoglobanemia is serious but easily prevented. In the past, sodium had been implicated in hypertension and high blood pressure. However, statistics indicate that high blood pressure most probably results from an imbalance of the cations in the system. Trace constituents not commonly found in water can be major health concerns, example, the dental caries preventative, fluoride (which in excessive amounts causes tooth discoloration and brittleness) and heavy metals such as lead and cadmium discharged in wastewaters are often present in small concentrations. (Tchobanoglous and Schroeder, 1985).

People remove water from streams, lakes and groundwater aquifers for domestic, commercial, industrial and agricultural uses and often they return the used water or wastewater to the same water source. Since micorganisms found in wastewater can survive for varying periods of time in natural waters, water use often becomes a health hazard as well as necessity. Waterborne and water-related diseases are among the most serious health problems in the world today. Up to 35 percent of the potential productivity of many developing nations is lost because of these diseases. In addition, many of the classic water borne infections (typhoid fever, dysentery and cholera) have been reduced to minor significance in developing nations (Keller and Wilson, 1992).

The following tables indicate the killer diseases associated with poor water quality practices.

Table 2.1 Bacterial Diseases generally transmitted by contaminated drinking water

Agent	Disease	Incubation Time	Symptoms
Shigella	Shigellosis	1-7 days	Diarrhea, fever, cramps, blood in stools
S. typhimurium	Salmonellosis	6-72 hours	Abdominal pains, diarrhea, nausea, vomiting, fever
S. typhi	Typhoid fever	1-3 days	Abdominal pain, fever, diarrhea or constipation, intestinal haemorrhage
Agent	Disease	Incubation Time	Symptoms
Enterotoxigenic E.coli	Diarrhea	12-72 hours	Diarrhoea, fever, vomiting
Compylobacter jejuni	Gastroenteritis	1-7 days	Abdominal pain, suggesting acute appendicitis, fever, headache, malaise, diarrhoea, vomiting.
Vibrio Cholerae	Gastroenteritis	1-3 days	Vomiting, diarrhoea, dehydration

Source: Ellis, 1988

Table 2.2. Viral and Parastic diseases generally transmitted by contaminated by drinking water

Agent	Disease	Incubation period	Symptons
Hepatitis A	Hepatitis	15-45 days	Fever, malaise, anorexia, jaundice
Norwalk-like Agent	Gastroenteritis	1-7 days	Diarrhoea, Abdominal cramps, headache, vomiting
Virus-like 27mm particles	Gastroenteritis	1-7 days	Vomiting, diarrhoea, fever
Rotavirus	Gastroenteritis	1-2 days	Vomiting followed by diarrhea for 3-8 days
G lamblia	Giardiasis	7-10 days or longer	Chronic diarrhoea, abdominal cramps, flatulence, malodorous stools, fatigue, weight loss.
Agent	Disease	Incubation Time	Symptoms
Cryptosporidum	Cryptospordiosis	5-10 days	Abdominal pain, anorexia, water diarrhoea, weight loss, immuncocomprised individuals may develop chronic diarrhoea.
Entamoeba Histolytica	Amebiasis	2-4 weeks	Vary from mild diarrhoea with blood and mucous to acute or fulminating dysentery with fever and chills

Source: Ellis, 1988

The contamination of waters with disease organisms of human origin seems to be a major concern in many developing nations. If human faecal material enters water, the risk of disease being spread through drinking water is greatly increased. Water quality management, though, has its roots in disease prevention. Only recently, a few nations had the luxury of discussing such water quality aspects as aethetics and the preservation of endangered species and of natural conditions. These however, are only 25 per cent of the world's population and are endangered species themselves. Many children die as a result of poor environmental sanitation. Water is in short supply for much of the world's population either because of its lack or a lack of distribution facilities. In such areas, ponds and streams are often used for washing clothes, carrying wastes and drinking and since access is uncontrolled, drinking water is often taken from a contaminated source. People carrying heavy water cans over long distances to their homes, also, are unlikely to wash their hands frequently or to keep the dishes sparkling clean at all times. The result is a high incidence of water-related disease like diarrhea. Since diarrhea weakens the body by dehydration, malnutrition is also advanced and as a result, many people have chronic health problems. Human faeces are also known to contain over 100 virus types and an infected person may excrete as many as 10 000 000 particles of bacteria in 1g of faeces. In addition, natural waterways can accommodate a certain percentage of pollution, but beyond that datum point the scales are tipping bringing destruction to the river. Pollution in the form of raw sewage is the host of a great number of serious and potentially killer diseases. (refer to tables 2.1. and 2.2) The health problems emanating from squatter communities with no sanitation and inadequate services are also serious and could result in outbreaks of epidemics. Furthermore, city health officials say run-off form home-built pit toilets and river banks are one of the main causes of pollution in Durban's rivers. (Daily News, May 20, 1997). The potential for disease transmission is therefore very great. (Keller and Wilson, 1992).

Other impurities in water are important because their presence affects the use potential of a particular source of water. Agriculturally related impurities in water are those that affect plant growth and soil characteristics such as permeability which have a negative effect on agricultural production. Examples include salinity which affects the availability of crop water; sodium which, because of its large radius of hydration, causes clay soils to disperse and boron which is toxic to many plants at concentrations below $1g/3^3$. Soil pore size is reduced and permeability of water is greatly decreased when clay soils are dispersed. Calcium and magnesium, however, are more tightly bonded to clay surfaces than sodium and so are preferentially absorbed. (Tchobanoglous and Schroeder, 1985). In addition, impurities that affect the ecosystem through toxicity or growth stimulation are ecologically related. These are related to the phenomena of eutrophication and acid rain. Microorganisms affecting aesthetic characteristics such as floating algae or producing toxic materials such as the blue-green algae are also included. Most impurities in water have some ecological impact and many of the impacts change markedly with concentrations. Many heavy metals are required in trace amounts for plants and animal growth but are toxic when concentrations approach the 0.1 to $1.0g/m^3$ range. Three dissolved gases are important namely ammonia; carbon dioxide and oxygen. Ammonia is however, very toxic to fish while carbon dioxide occurs in equilibrium with carbonic acid, bicarbonate ions and carbonate ions. These impurities are important factors in determining the ph value of water. Oxygen is required by most living organisms and the presence or absence of oxygen is probably the most single factor in the aesthetic quality of water. Moreover, organisms found in water can be classified as saprophytic (those that use dead and decaying organic materials as their food source), chemoautotrophic (those that obtain energy from the oxidation of inorganic chemicals and carbon from carbon dioxide); chemophototropic (those that use light as an energy source) and predatory (those that use other living organisms as a source of food. Some species fall into more than one group. The system is almost an endless chain or circle fuelled by solar energy trapped in photosynthesis. Environmental changes such as the passing seasons or discharges of wastes may directly stimulate or restrict one segment of the chain more than others but, since the entire chain is connected, all segments will be effected. Natural waters therefore must be considered as complex ecosystems rather than habitats for specific species such as game fish. (Tripathi and Pandey, 1995).

Natural waters may be classified according to their ability to support life as oligotrophic, mesotrophic and eutrophic. Oligotaphic waters containing low concentrations of essential nutrients from runoff result in a gradual increase in nutrient concentrations and the waters become increasingly productive. Mesotrophic waters are characterized by the abundance and diversity of life forms at all trophic levels while eultrophic waters have fewer species present but, the concentration of algae is particularly high. The process of moving from oligotrophic through mesotrophic to eutrophic conditions is called eutrophication and is a natural process and may occur over relatively short periods (decades) or geologic time periods (long periods) depending on conditions. (Keller and Wilson, 1992).

2.9 WATER AND WASTEWATER TREATMENT

Over the years, a variety of methods have been developed for the treatment of water and wastewater. In most situations, a combination of methods will be needed. The specific sequence/method required will depend on the quality of the untreated water or wastewater and the desired quality of the product (Smethurst, 1988).

2.9.1 CLASSIFICATION OF TREATMENT METHODS

The contaminants in water and wastewater are removed by physical; chemical and biological means. The specific methods are classified as physical unit operations; chemical unit processes and biological unit process.

2.9.1.1 PHYSICAL UNIT OPERATIONS

These are treatment operations in which change is brought about through the application of physical forces. Such operations include screening, mixing, gas transfer, sedimentation and filtration.

2.9.1.2 CHEMICAL UNIT PROCESSES

Treatment processes in which the removal or treatment of contaminants is brought about by the addition of chemicals or by chemical reactions and chemical precipitation and disinfection are two examples. (Gray, 1994).

2.9.1.3 BIOLOGICAL UNIT PROCESSES

These are treatment processes in which the removal of contaminants is brought about by biological means. An example of this is the activated sludge process used for the treatment of the organic matter in wastewater (Gray, 1994).

2.9.1.4 WATER TREATMENT METHODS

The most important objective of water treatment is to produce water that is biologically and chemically safe for human consumption. Quality requirements for domestic use will also apply for most industrial users. According to Gray, (1994) biological processes are not used because appreciable amounts of organic matter are not present in most natural waters and biological processes are not suitable in situations where contaminant concentrations are low. In general, effluents from biological treatment processes do not meet source standards for domestic water supplies. However, many community water supplies contain treated effluents from upstream wastewater discharges example, the New Orleans water supply contains discharges from Minneapolis – St Paul and all other communities in the Mississipi watershed.

2.10. LEGISLATION

Water, by its very nature, constitutes a special case when legislation or the law of economics have to be considered. As it moves under the influence of global and local forces all early and modern legislation has established that water has to remain a common asset and the role of government is only of custodian or guardian which usually intervenes only when a crisis has occurred or is imminent. The criteria defining a crisis may be of a physical nature such as river pollution; social, such as the spread of water-borne diseases of political when major economic interests are threatened (Keller and Wilson, 1992).

According to Iwugo (1995), all farms of land-based water pollution are on the increase in most developing countries mainly because there are no well-established technological, economic, legislative and other regulatory instruments to control it or they are not being implemented. Furthermore, with the general perception being that there were considerable resources available, the demand for economic development outweighed environmental or resource management concerns. As a result, water resource exploitation and the discharge of domestic, industrial and agricultural wastes in the aquatic environment were neither controlled nor regulated. (Sankar, 1996).

However, until fairly recently, water pollution control was not a high priority for many developing countries, particularly those outside North Africa and parts of Asia where due to the lace of water resources, waste pollution control and conservation of water are necessary measures to meet the demand for water (Howard, 1995). According to the agenda 21 of the 1992 "Earth Summit" the movements of people, raw materials and the manufacturing of goods, are among problems of pollution which now have global significance. The United Nations (UN) and its specialized agencies have progressively become involved in a wide range of activities concerning water pollution. International efforts are effective as they remove the constraints of political boundaries and the limitations of resources. The United Nations Environment Programme's mission is to provide leadership and encourage partnerships in caring for the environment by inspiring and enabling people and nations to improve their quality of life.

In the United States of America, the Environmental Protection Agency (USPEA) had been mandated by the United States Congress to protect the environment. This agency administers ten comprehensive federal environmental protection and pollution control laws including the Clean Water Act 9, the Toxic Substances Control Act (TSCA), the Resource Conservation and Recovery Act (RCRA) and the Comprehensive Environmental Compensation and Liability Act (CERCLA) also known as "Superfund". Australia's government has also responded to environmental problems by developing an Ecologically Sustainable Development Policy (ESD) which attempts to ensure that orderly economic, industrial and urban development is achieved without long-term degradation of Australia's resources and environment (Keller and Wilson, 1992).

In the past, legislation had been used to attempt to control river pollution but, it has proved to be unsuccessful. Despite the legislation in force, the number of recorded pollution incidents within the rivers in the United Kingdom rises every year. The Control of Pollution Act (1974)(COPA 11) was introduced to control the pollution occurring within the surface waters of the U.K. It endowed sweeping powers upon the authorities. The act was a radical change in direction with regard to river pollution and subsequent water related problems. However, there were certain clauses contained within the act which were never enacted through due legal procedures. The powers conferred on the Water Authorities allowed them to take stringent action against illegal industrial discharges. As a result, the number of prosecutions for illegal discharges rose (Keller and Wilson, 1992). The Water Act of 1983 further increased the power of the Water Authorities with regard to industrial pollution and the clauses in a COPA were further rewritten and strengthened. The clauses on farm pollution were reviewed but farmers remained almost immune from prosecution through providing evidence that they had adopted the "best possible means" of preventing pollution incidents arising from their premises. The full power of the law was never enacted but, the Water Act 1989 had the necessary powers to make a serious start on preventing releases of potentially hazardous materials at industrial and other sites (Keller and Wilson, 1992).

2.10.1 SOUTH AFRICAN LEGISLATION

In keeping with most countries of the world, industrialization sparked the beginning of South Africa's pollution problems. As a result, South Africa's economy has played a major role in the development of legislation controlling water pollution. The promulgatiòn of the Water Act (Act 54 of 1956) signified the move from an agricultural based economy to one in which industry played a major role. According to this Act, industries were not longer allowed to discharge raw effluent to the treatment works without prior arrangement with the Treatment Works. Industries must pre-treat effluents to specific standards thus removing toxic compounds, non biodegradable

organic, mineral salts, organic loadings before discharging the effluent to the Treatment Works for final treatment.
The purpose of legislation is therefore to assume that the water entering the water systems meet a minimum national standard for the protection of the waterbodies and for the protection of public health. As a result, of the decline in quality of South Africa's limited water resources, the government has imposed legislation to curb the pollution of the water resources. The role of the South African government, through the Department of Water Affairs and Forestry is one of leadership. As custodian of the water resources of South Africa, the Department of Water Affairs and Forestry plays a leading role in the development of guidelines and procedures for water resources management as well as ensuring that the country's water needs can be met. The new National Water Bill also provides legislation for water management responsibilities (Umgeni Water, 2001).

South Africa's new water legislation recognizes that there are limits to the development of new dams and water transfers as water is a limiting factor to economic growth. In order to provide for growth and development of the South African economy in the twenty first century, attention is being paid to current water usage which is often wasteful and inefficient. There has, thus, been a paradigm shift in approach away from an exclusive focus on conventional resource development to one which encompasses water conservation.

According to the White Paper on Environmental Management Policy of SA, the present water policy emphasizes the environment's role as the source of water rather than a user competing for the resource and the need to identify a reserve of water to meet environmental and domestic consumption needs. Water quality management now embodies the principles of pollution prevention, a precautionary approach and receiving water quality standards to meet user needs. Furthermore, it is estimated that South Africa is using about two-thirds of annual average rainfall and irrigation (52,2%) is the largest user, and at present, an estimated 21 million South Africans do not have adequate sanitation.

Proportional Water Demand by Sector:1980 AND 2010 (estimate)

	1980(%)	2010
Irrigation	52.2	45.9
Ecological use, estuaries and lakes	17.0	10.7
Municipal and domestic	9.3	17.3
Forestry runoff reduction	7.9	6.6
Industrial	6.3	11.4
Mining	2.9	2.5
Power generation	1.7	3.5
Stock watering	1.6	1.4
Nature conservation	1.1	0.9

Source: Department of Water Affairs, 1997

2.10.1.1 NATIONAL WATER ACT (NO 36 of 1998)

The main purpose of the National Water Act (no 36 of 1998)(NWA) is to ensure that the country's wastewater resources are developed, conserved, managed and controlled in ways which take into account a number of actors including promoting the efficient, sustainable and beneficial use of water in the public's interest. The Act sets out a number of general conditions pertaining to water conservation, inter alia:

a) Section 5-7 require that the Minister of Water Affairs and Forestry establishes a National Water Resources Strategy which sets out the strategies, objectives, plans, guidelines, procedures and institutional arrangements relating to the protection, use, development, conservation, management and control of water resources;

b) Sections 8-11 require that the Minister establishes a catchment strategy which sets out the strategies, objectives, plans, guidelines and procedures of the catchment management agency for the protection, use, development, conservation, management and control of water resources within its management area; and

c) Section (56(2) makes provision for the setting of water use charges to fund water resource management including water conservation (Umgeni Water Conservation Policy, 1999).

2.10.1.2 WATER SERVICES ACT (NO 108 OF 1997)

The Water Services Act (No 108 of 1977) (WSA) allows water boards to be established by the Minister of Water Affairs and Forestry with their primary function being to provide water services to other water services institutions within a defined area. A Water Board may perform other activities only if such activities do no limit its capacity to perform its primary activity. A policy statement and a Business Plan prepared by each Water Board annually for the following five financial years are used to regulate and monitor the performance of a Water Board (Umgeni Water, 1999).

The constitution of South Africa (1996) guarantees the people the right to life (and to a life of dignity); the right to access to sufficient water and the right to an environment that is not harmful to their health or well-being. The White Paper on a National Water Policy for South Africa (1997); the Water Service Act (1977) and the National Water Bill are now three documents which will enable the government to protect the rights of the people of South Africa in relation to water.

As a means of complying to the right to access to sufficient water, government has decided to provide 6000 litres of free water per household per month which contradicts the internationally accepted conventional wisdom that even the poorest should contribute to their cost of water consumption (White Paper on the National Water Policy, 1997).

It was argued that if people don't pay, then they will waste water and allow the infrastructure for the supply of free water to run down. However, Water Affairs and Forestry Minister Ronnie Kassrils outlined what prompted him to defy the orthodoxy of water experts. He concluded that even though piped water was provided to the rural areas, the people would rather avoid the taps and meters and payments on metered water instead draw free water from streams "no matter how polluted the water was" (Laurence, 2001).

There are new institutional changes currently under development and as such there is a corresponding shift in powers and legislative controls with local governments being given increased powers to manage individual provinces.

2.11. CONCLUSION

Water is an essential element in the maintenance of all forms of life and most living organisms can survive only for short periods without water. This fact has resulted in the development of direct relationships between the abundance of water, population density and quality of life. As well as being in abundant supply, the available water must have specific characteristics. Water quality is defined in terms of those characteristics. Throughout history, the most important of the characteristics has been the concentration of dissolved solids (salts) because of the relationship between salt and land productivity. As population densities increased, health – related characteristics, such as the presence of disease – causing (pathogenic) microorganisms also became more important. The usefulness of water declines as water quality deteriorates and high quality water is in greater demand and possesses more value than low quality water. As humans begin to exert control over the quantity of water, it was found that different waters varied in character such as temperature, colour, taste, odour, etc. and noted that these characteristics influenced the suitability of water for certain purposes. Salty water is unsuitable for human and livestock consumption or irrigation while clear water was superior over turbid water for domestic use while some waters could cause illness or even death when consumed by humans. It is now apparent that there is an ever-increasing risk to the river systems from irregular pollution incidents within the nations of the world and the same causes of pollution seem to occur time and time again with unfailing repetition with man often finding it difficult to learn from his mistakes. (Zuane, 1990). Furthermore, any physical, chemical or biological property that influences the use of water, is a water quality variable resulting in standards being developed to serve as guidelines for selecting water supplies for various activities. Water quality is therefore a complex topic extending into many scientific and practical endeavours.

CHAPTER 3

STUDY AREA AND METHODOLOGY

3.1 INTRODUCTION

A clear statement of the Research Methodology and study area should be an integral part of an investigation. A detailed description of the study area is important to the reader and future researchers. It informs the reader of the location where the study was carried out, what type of study has taken place and the choice of that particular area for the investigation. In addition, maps serve as important tools to geographically locate such an area. This allows the reader and future researchers to understand the geographic location of the study area.

According to Leedy (1993), Research Methodology is a continuing process. It is a continuum that is ever changing and ever developing. A detailed description of the research methodology informs the reader exactly how the researcher intended to proceed and how the researcher handled the data. The methodology part of this chapter also enables the researcher to understand why a particular research technique was chosen. It also helps to explain what the nature of the data was and what method was used to collect them. Finally, it is vital that the reader understands "how" the study was carried out, "why" the study was carried out and what reasoning formed the basis upon which the "how" was justified. Hence, the methodology should be clearly expressed and substantiated to validate the research.

A scientific, valid and recognized method of investigating, therefore has to be implemented while a detailed description of the method implemented to execute the investigation is essential mainly for the reader to understand how the data was collected, analysed and presented.

3.2. THE STUDY AREA

The Umlazi community situated approximately thirty kilometers to the south of Durban (Fig 3.1) consisting of 26 sections was the result of the provisions of the

Group Areas Act of 1950. This Act, which followed the National Party victory of 1948, embodied the policy of separate development in different areas for the various population groups, that is, the Whites, Indians, Blacks and Coloureds. The Umlazi townships, exclusively for Blacks, was developed on this basis. Many families in Umlazi expressed feelings of suffering arising form forced removals and dispossession of properties while other grievances included the clustering of houses, inadequate community facilities such as recreation grounds and especially the inaccessibility of essential services. Much of the criticism had been leveled against the town planners and unfortunately in Umlazi, many of the planning regulations had been developed with insufficient research and standards had been adopted without any regard for the changing life-styles as well as the rapid rate of urbanization.

3.2.1. THE INFORMAL COMMUNITY OF UMLAZI – L. SECTION

This community consists of approximately 5000 dwelling units situate along the Umlaas River. (Fig. 3.2). The inhabitants of informal areas, in general, live in structures which offer partial shelter against the weather elements, have no or inadequate access to basic facilities such as water, sanitation and refuse removal (Emmett, 1992).

Furthermore, due to a lack of these basic services, the inhabitants of this community are forced to settle close to a water source, namely the river which caters to their daily needs in terms of their domestic use. The presence of a landfill site also serves as a food source to this community who scavenge and thrive on it for their daily survival. However, the absence of piped water, sanitation and other basic services results in the community disposing of their wastes into the Umlaas river.

THE STUDY AREA

and the Durban Metropolitan Area

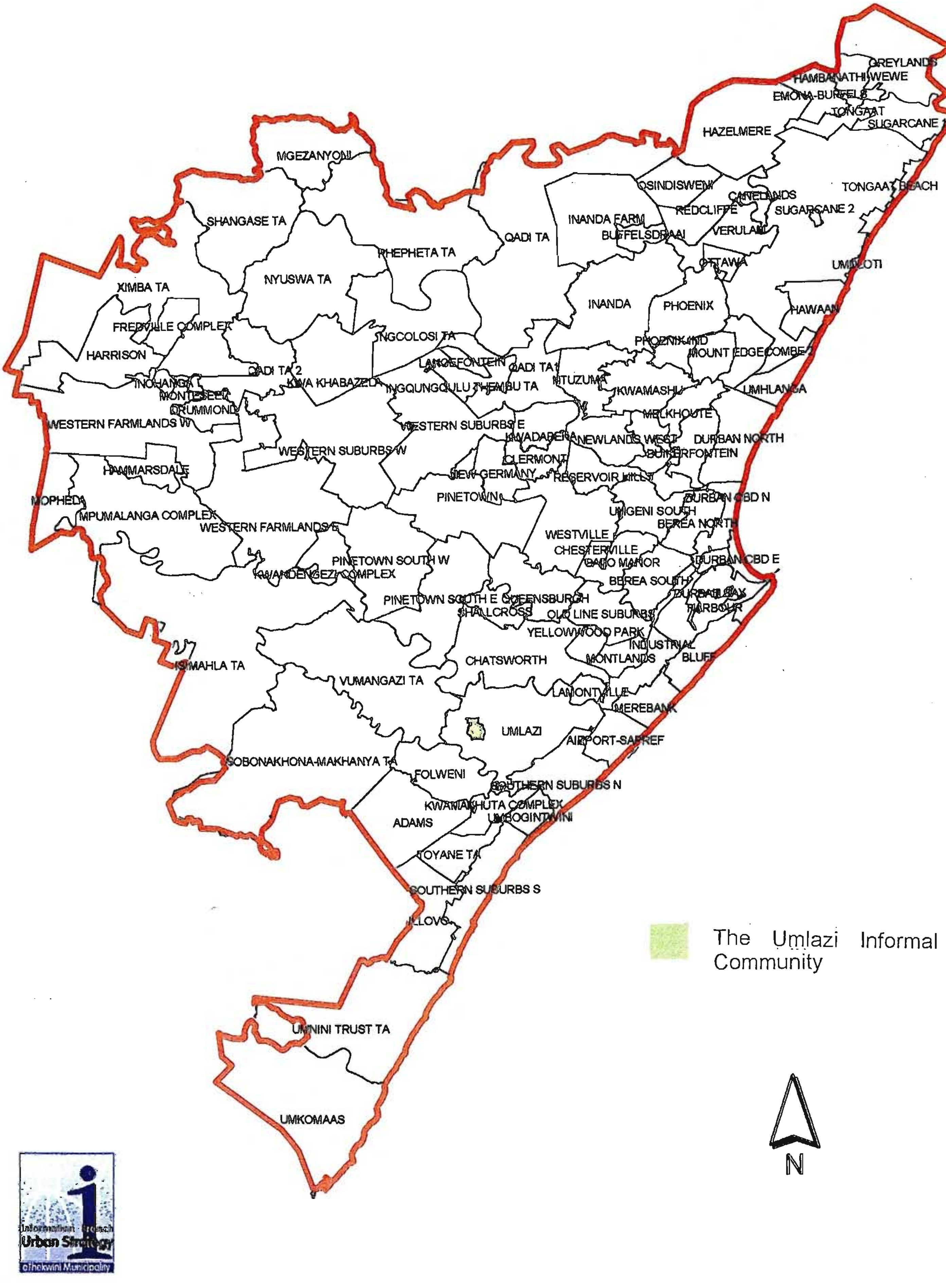


Fig 3.1

Plate 3.1 The Umlazi Informal Community situated along the Umlaas river.

3.2.1. THE UMLAAS RIVER

The Umlaas River catchment has an elongated shape lying in an east-westerly direction with the eastern end on the border of the Indian Ocean. The river discharges into the Indian Ocean through the Umlaas canal near the Durban International Airport (Sankar, 1996). According to Richards (1991), the Umlaas River is one of the many rivers in Kwa-Zulu Natal that transfers high pollutant loads from various point and non-point sources into the Indian Ocean and could become an open sewer in the foreseeable future. The predominant point source is effluent form sewage treatment works and industrial discharges while the main non-point source is the consequence of the presence of informal settlements. These informal settlements pose a threat to the water quality. Neytzell-Dewible (1991), indicates that soil erosion and faecal contamination of the water resources are two of Kwa-Zulu Natal's priority problem area. The Umlazi informal community, due to a lack of basic services and sanitation, tend to defaecate in shallow pit latrines, in shrubs and on river banks. This situation worsens during times of rainfall as these wastes tend to end up in the water source. It is therefore assumed that there is a high potential of sewage present and as a result of this, acute bacteriological contamination of the water resource could be very high. The effects on human health could be detrimental because of the potential for such diseases as chlorea and dysentry to be present.

Plate 3.2 The Umlaas River

3.3. METHODOLOGY

For any investigation, one has to implement a scientific, valid and recognized method of investigation. Each method of investigation provides a different glimpse of reality and all have limitations. In undertaking any investigation, the researcher would do well to ask if a particular method is the most appropriate and fruitful method for the problem at hand.

Since water is an almost universal advent, all natural waters contain small amounts of other materials, dissolved from the air in the case of precipitation and from the earth's surface and from the soil and rocks for surfacewaters and groundwaters respectively (Tebutt, 1990). This means that in reality, there is no such thing as "pure water". In addition, to constituents which are mainly inorganic in nature, there will also be a gradual accumulation of organic material from vegetation and animal wastes. The presence of organic matter in solution and in suspension will encourage the growth of microorganisms resulting in the natural watercourse becoming a complex ecological system. Human activities in a catchment result in the production of domestic and industrial wastewaters which, if not effectively treated, can destroy the ecological balance in the waters into which they are discharged. Therefore, assessing the quality of water and the nature of wastewaters, it is necessary to utilize standard parameters to express the complex composition of water in its various natural and polluted forms. (Tchobanoglous and Schroeder, 1985).

3.3.1. WATER QUALITY PARAMETERS

Since water is a good solvent there is on almost endless list of materials which could be present in a particular sample. When assessing water quality it is therefore often convenient to use what are termed "blanket parameters" which measure the presence of a group of contaminants or indicate a particular property. The relevance of various water quality parameters depends upon the nature of the water or wastewater and its actual or potential use. There are three basic types of characteristics which are of importance. These include:

3.3.1.1. PHYSICAL CHARACTERISTICS

These are properties which are often apparent to the observer and include such parameters as colour, taste, odour, temperature and suspended solids, et (Gray, 1994).

3.3.1.2 CHEMICAL CHARACTERISTICS

Alkalinity, hardness, organic content, nutrients, dissolved oxygen, inhibitory and toxic compounds comprise the category of chemical characteristics (Gray, 1994).

3.3.1.3. Biological Characteristics

Natural waters normally form a balanced ecosystem containing microorganisms such as bacteria, protozoa and algae. Microorganisms provide food for fish and other higher life forms. Wastewaters often contain large numbers of microorganisms, particularly bacteria and are potentially hazardous because of the connection with water-related diseases. Although on occasion individual species may be identified, it is common for blanket determinations of biological populations (Tchobanoglous and Schroeder, 1985).

3.3.2. SAMPLING TECHNIQUES

Sampling is a very important stage in the assessment of water quality since if the sample is un-representative, any analytical results will be useless. Representative samples are obtained because the data from the analysis of the samples will ultimately serve as a basis for pollution control and measures to be implemented. Suitable sampling locations must therefore be selected and the frequency and quantity of the sample to be collected must be determined. The collection of a representative sample from a source can be achieved by a simple grab sample. (Hounslow, 1995). The sample collected at a particular time and place can represent only the composition of the source at that time and place. However, when a source is known to be relatively constant in composition or over substantial distances in all directions, then the sample may be said to represent a larger volume. In such circumstances, the source may be represented adequately by grab samples. In addition, when a source is known to vary with time, grab samples collected at suitable intervals and analysed separately, can document the extent, frequency and duration of these variations. Grab samples are also appropriate if the purpose of sampling is to monitor whether or not quality is within a specified limit. However, where the waters flow and quality are variable then, a composite sampling technique should be available (Bitton, 1994).

In most cases, the term "composite sample" refers to a combination of grab samples collected at the same sampling point at different times. Sometimes, the term "time-composite" is used to distinguish this type of sample from others (Hounslow, 1995).

3.3.2.1. ANALYTICAL METHODS

In general, concentrations of impurities are expressed in terms of milligrams per litre (mg/l) and analytical procedures must be carefully carried out to obtain accurate information. There are four main types of physical and chemical analyses which are commonly employed in the examination of waters and wastewaters. These are gravimetric; volumetric; colorimetric and the use of electrodes. Specialized microbiological analyses are used to detect and emunerate bacteria and other microorganisms in samples. (Tchobanoglous and Schroeder, 1985).

3.3.2.1.1 GRAVIMETRIC ANALYSIS X

This form of analyses relies on weighing solids obtained from a known volume of sample after evaporation, filtration or precipitation The main uses of gravimetric analysis are found in the determination of total solids by evaporation and of suspended solids by filtration. A sensitive analytical balance, drying over and dessicator are essential for gravimetric determinations which are not feasible for field use. (Tchobanoglous and Schroeder, 1985)

3.3.2.1.2 VOLUMETRIC ANALYSIS X

Many determinations in water quality can be rapidly and conveniently carried out by volumetric analysis which depends on the measurement of volumes of a known strength liquid reagent which reacts with the constituent being determined. Volumetric analysis can usually be carried out in the field if necessary. (Tchobanoglous and Schroeder, 1985).

3.3.2.1.3 COLORIMETRIC ANALYSIS

It may be possible to utilize the formation of a soluble coloured compound following the addition of a special reagent as a means of analysis. The colour solution must be such that light absorption through it increases exponentially with the concentration and also that light absorption increases exponentially with the light of the light path through the solution. The colour intensity can be measured by visual comparison with standards or by instruments provided with colour filters. (Tchobanoglous and Schroeder, 1985).

3.3.2.1.4 ELECTRODES

For many years, ph, which expresses the intensity of acidity or alkalinity of a solution, has been measured using a glass electrode which is sensitive to hydrogen ions in solutions. More recently, many other electrodes have become available to measure specific ions such as ammonium, nitrate, chloride, calcium, sodium, etc. dissolved oxygen is also easily measured by means of a special electrode which is suited for field use. (Gray, 1994).

3.3.2.1.5. MICROBIOLOGICAL ANALYSES

Most determinations in microbiological analyses are concerned with enumerating bacteria. They are based on total cell counts on a general purpose medium or specific medium and incubation conditions for the normal indicator organism Escheria coli (E-coli) whose presence is taken as positive evidence of human faecal pollution. (Gray, 1994).

3.3.2. RESEARCH METHODS EMPLOYED IN THE CURRENT INVESTIGATION

The two most common types of sample collection techniques are grab samples and composite samples. The latter involves collecting individual samples at known time intervals. A grab sample involves taking a sample from the source by submerging sampling bottles into the water, taking the required amount thereafter immediately sealing the bottle. The following procedures were adopted in this study:

i) THE COLLECTING OF THE WATER SAMPLES

For the present study, the researcher had to ensure some degree of accuracy. This was maintained by the researcher visiting the area of study, the Umlaas River and obtaining a measurement of the distance of the informal community along the river. This procedure involved the use of a measuring tape which measured a length of 1000 metres. However, due to the area being characterized by violence the researcher had to request the assistance of a community worker to provide assistance during the fieldwork as well as to ensure safety. In avoiding any possible health-related effects on the researcher, protective clothing had to be worn to prevent a contamination from the possible high levels of pollutants in the Umlaas River. The researcher had to also take into consideration a climatic variable as rainfall could dilute the variables present in the water. This was ensured by waiting for a minimum period of at least one month after a rainfall event.

The grab sampling method as well as the systematic sampling procedure was then used. Water samples with an interval of a 100 metres apart were collected upstream and downstream of the informal community. Sterilised glass bottles were used for the collection of Escheria coli (E-coli) samples to prevent any possible contamination. Once the water samples were collected, they were then sealed, placed in a cooler box and then transported to the Ethekwini Wastewater Management Laboratory for analysis. The samples were kept as cool as possible without freezing as freezing would have caused the glass bottles to break. The immediate transportation of the water samples to the Laboratory was to ensure that the shorter the time elapsed between the collection of the samples and its analysis, the more reliable the analytical results would have been.

ii) LABORATORY ANALYSIS

The water samples were then analysed at the Ethekwini Wastewater

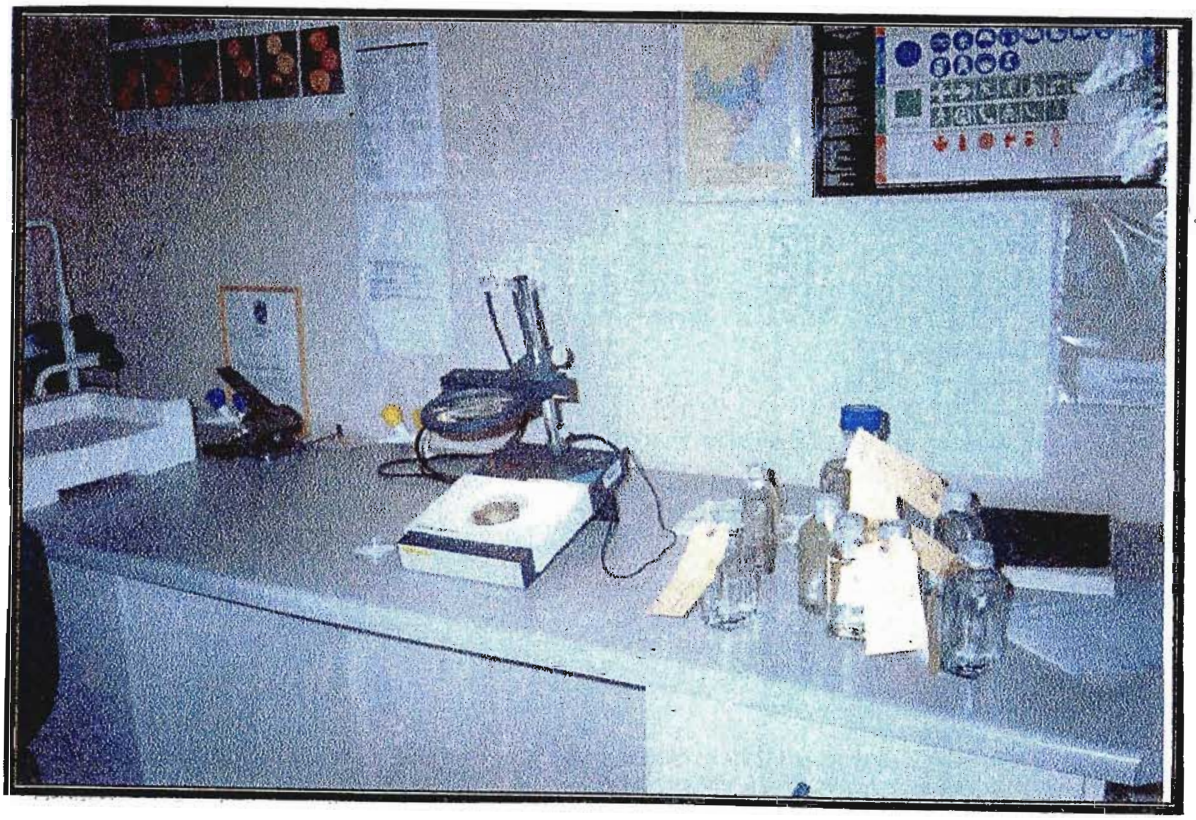
Management Laboratory to determine the concentrations of the indicators stated in the objectives of this study.

THE INDICATORS OF THE STUDY INCLUDE :

a) ESCHERIA COLI(E-COLI)

E-coli was chosen as an indicator organism as counts of these organisms give the estimate of recent pollution by wastes from warm blooded animals. The potential for disease could also be quantified.

Plate 3.3 Instrument: Coloniccounter used for E-coli Counts



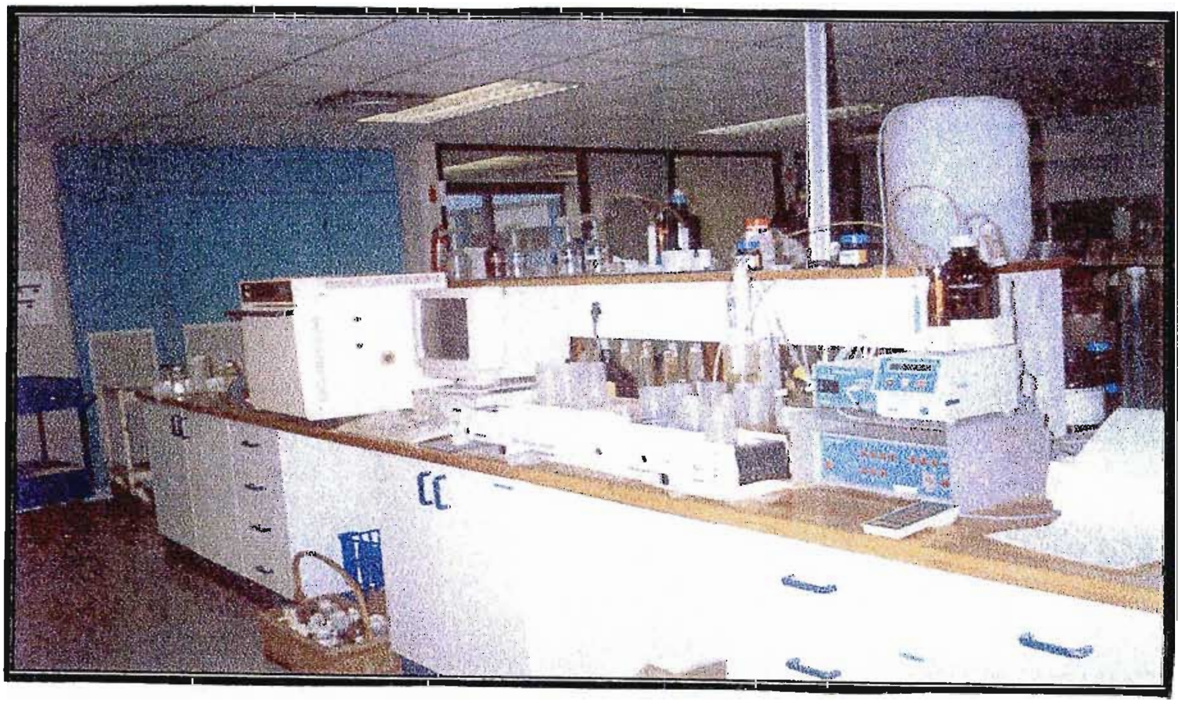
b) **CHEMICAL OXYGEN DEMAND (COD)**

When organic compounds are oxidized by microorganisms in the presence of oxygen, the rate at which oxygen is utilized can be used as a measure of the strength and biodegradability of the organic matter known as the chemical oxygen demand. Since the reaction is biochemical, it proceeds relatively slowly.

It determines the oxygen absorbed by a sample of water incubated at 20 degrees C for five days.

METHOD: The test portion is digested for 26 minutes in a strongly acidic dichromate solution using silver sulphate as a catalyst and mercuric sulphate as a masking agent. The dichromate is partially reduced the oxidizable material present in the sample. The excess dichromate is titrated with ammonia iron II sulphate and the COD value calculated from the amount of dichromate reduced.

Plate 3.4 Instruments : Microwave digestion unit MLS 1200 Mega; Control terminal, Mega 240; Exhaust module Em – 45/A; 10ml micropipettes; bruette and 5 ml automatic dispensing pipette. Used for analyzing COD.



c) TURBIDITY

Turbidity is an expression of the optical property that causes light to be scattered and absorbed rather than transmitted in straight lines through the sample. It can be determined for any water sample that is free of debris and rapidly settling coarse sediments. In river water, turbidity is produced by the presence of suspended solids.

d) CONDUCTIVITY

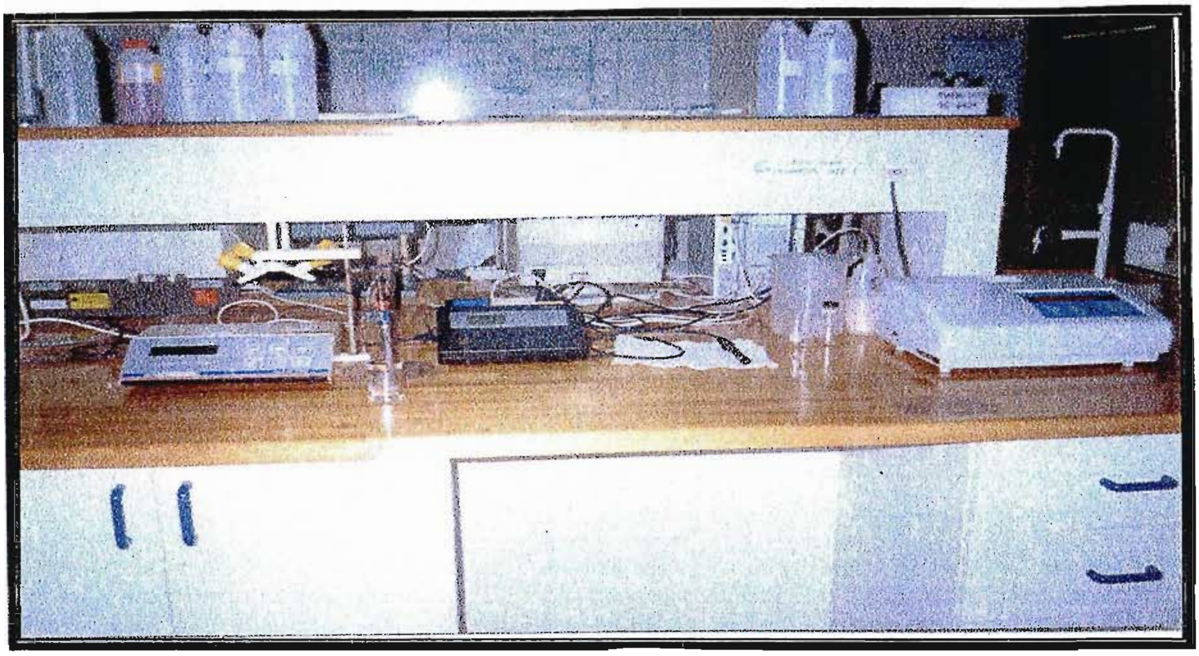
Conductivity concentration in the Umlaas river is used to estimate the salinity of the river as conductivity gives an indirect measurement of the dissolved solids concentrations.

METHOD

Conductivity – conductivity meter displays the conductivity reading in ms/m over selected ranges.

Turbidity – a comparison of light scattered by the sample under defined conditions with the intensity of light scattered by a standard reference suspension under the same conditions. The higher the intensity of scattered light, the higher the turbidity. Formazin polymer is used as the reference tubidity standard suspension.

Plate 3.5: Instruments : Centre : conductivity meter, used for measuring conductivity.
Right: Hach Model 18900, Turbidimeter, used for measuring turbidity.



e) **NITRATE CONCENTRATION**

This is used to estimate eutrophic conditions in the Umlaas River. Since human excrement is considered to be one of non-point polluting sources, the nitrate concentration is valuable in the estimation of such pollution.

METHOD

Nitrate is quantitatively reduced to nitrate by the passage of the sample through a copperized cadmium column. The nitrite (reduced nitrate plus original nitrite) is then determined by diazotizing with sulfanilamide followed by coupling with N-(1-naphthyl) ethylenediamine dihydrochlorided. The resulting water soluble dye has a magenta colour which is read at 520n. Nitrite alone can be determined by removing the cadmium column.

f) **SOLUBLE REACTIVE PHOSPHOROUS**

This gives an estimate of the amount of phosphorous immediately available for biological consumption thus indicating the potential growth of algae and aquatic macrophytes. The combined nitrate and phosphorous loadings therefore give an estimation of the nutrient loadings in the Umlaas River. The presence of sewage in the river will also result in phosphorous levels to increase causing a depletion of oxygen.

METHOD

Ammonium molybbdate and potassium antimonyl tartrate react in acid medium with orthophosphate to form phosphomolybdic acid which is reduced to an intensity coloured molybdenum blue by ascorbic acid.

Plate 3.7 Instrument; LCHAT – used for determining nitrate, phosphorous concentration.

iii) **STATISTICAL ANALYSIS**

The Student's t-test will be used to determine whether the water samples upstream and down stream of the informal settlement are different. The test is one of the most powerful parametric tests and will establish whether a difference does exist, and how significant it will be at a level of significance of 99%.

3.4 CONCLUSION

Common analyses in the field of water quality are usually based on relatively straightforward analytical principles. Quantitative analysis may be carried out by gravimetric, volumetric or colorimetric methods. And, to obtain a true indication of the nature of a water, it is first necessary to ensure that the sample is actually representative of the source.

This chapter has therefore provided an introduction to some of the tools of research. It outlined the study area, the need for the methodology as well as the characteristics for the need for such detail in an attempt to explain the analysis of the results which would follow in the next chapter.

CHAPTER 4

RESULTS AND DATA ANALYSIS

4.1 INTRODUCTION

One of the most challenging and rewarding tasks in research comes after the samples or data has been collected, statistically analysed and interpreted. Statistics provide the basic tools for summarizing data and for measuring the degree of association between variables and subgroups (Hounslow 1995). This chapter focuses on the practical steps in moving towards the final tabulations and graphical representation of the data.

4.2 DATA ANALYSIS

Water quality data may be interpreted on the basis of both individual analysis and sets of analyses from one sampling site or different sampling sites in an area being examined (Hounslow, 1995). Data obtained from analysis of water undertaken at the Ethekwini Wastewater Laboratory for the twenty samples collected 100 m apart downstream and upstream of Umlazi informal community, will be examined in this chapter. The variables for which lab analyses were undertaken included E-coli concentration; COD (chemical oxygen demand) concentration; turbidity; electrical conductivity; nitrate concentration and phosphorous concentration.

4.2.1 E-COLI CONCENTRATION

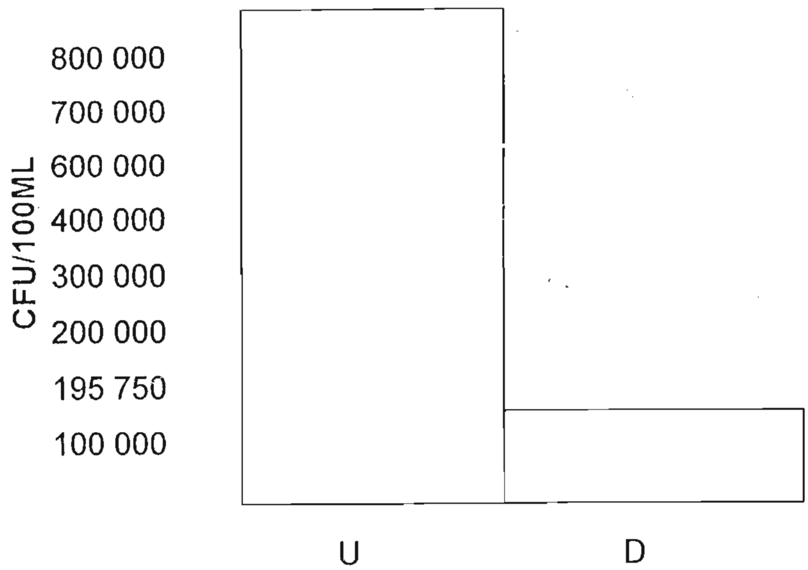
Escherichia coli (E-Coli) normally inhabits the intestinal tract of man and animals and is excreted with the faeces. It is considered nonpathogenic but, may cause infections of cholera the genito-urinary tract such as gastroenteristis, a useful indicator of pollution since it shows that the water has been polluted by raw sewage.

TABLE 4.1 E-COLI COUNT FOR DOWNSTREAM AND UPSTREAM UNIT: COLIFORMUNIT PER 100 MILITRES (cfu/100ml)

NUMBER	E-COLI UNIT: cfu/100ML	NUMBER	E-COLI UNIT: CFU/100ML
D1	120 000	U1	20 000
D2	130 000	U2	60 000
D3	140 000	U3	30 000
D4	150 000	U4	60 000
D5	160 000	U5	110 000
D6	140 000	U6	40 000
D7	160 000	U7	60 000
D8	200 000	U8	2 500
D9	230 000	U9	4 000
D10	170 000	U10	5 000

The above table, D1-D10 represents downstream; U1-U10 represents upstream. It appears that the E-Coli count for downstream is much higher than the upstream. This is an indication of faecal contamination, a characteristic of the faeces of man. The difference in average will be depicted graphically.

FIG 4.1 **DIFFERENCE IN AVERAGE OF E-COLI COUNT BETWEEN DOWNSTREAM AND UPSTREAM**



U = Upstream
D = Downstream
t(calc) value: 8

Significance level : 99%

t(crit) value : 2.879

The average of the E-coli count is 800 000 cfu/100ml downstream while that of upstream is 195 750 cfu/100ml. The difference in average between downstream and upstream and upstream was 60 4250 cfu/100ml. The application of the statistical analysis test, the students t-test, revealed that the critical value of 2.879 was below than the calculated value of 8%. This application was executed at the 99% confidence limit. The comparative statistical analysis indicates that the downstream concentration differs significantly from that of upstream. It can be stated that the raw sewage content is greater downstream of the community than upstreams of the community.

4.2.2 THE COD CENTRATION OF WATER

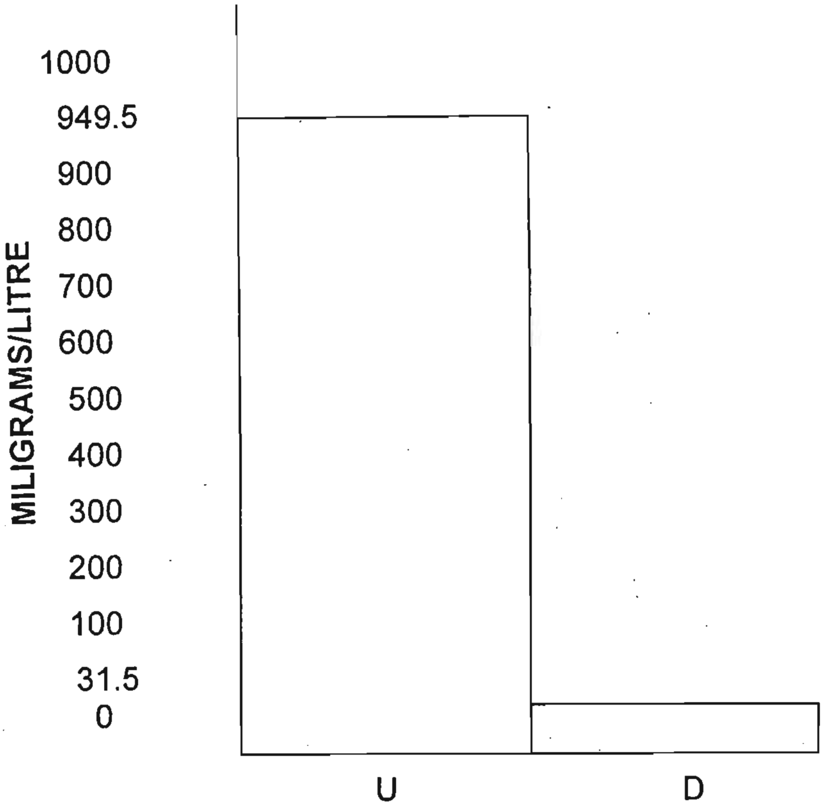
The chemical oxygen demand is the oxygen created when strong chemical oxidants are used to degrade organic material. COD is generally used for samples containing compounds that can't be degraded by microorganisms.

TABLE 4.2 COD CONCENTRATION FOR DOWNSTREAM AND UPSTREAM

NUMBER	COD:UNIT:MILIGRAMS/LITRE	NUMBER	COD:UNIT MILIGRAMS/R
D1	184	U1	5
D2	187	U2	6.8
D3	189	U3	7
D4	192	U4	4.5
D5	190	U5	6
D6	187	U7	6.2
D7	193	U8	5.2
D8	185	U8	7.1
D9	195	U9	7.9
D10	197	U10	8.2

The COD concentration of the downstream samples (D1-D10) appear to be higher than the upstream samples (U1-U10). This is an indication of the quantity and type of organic material that is present as well as at an increased level. Since sewage is made up of lots of small bits of organic material dissolved or suspended in water, it begins to break down very quickly, creating an immediate demand for large amounts of oxygen.

Fig 4.2 DIFFERENCE IN AVERAGE OF COD CONCENTRATION DOWNSTREAM AND UPSTREAM



U = Upstream
D = Downstream
t(calc) value: 129.54

Significance level :99%

t(crit) value:2.879

Downstream, the average of the COD concentration is 949.5 while upstream, the average concentration is 31.95. The difference in average between the downstream and upstream concentration is 917.55. A further observation of the average does appear to be very significant. The students t-test further confirms that the difference in average between the downstream and upstream concentrations is significantly different as the calculated value of 129.54 is much higher than the critical value of 2.879. Larger amounts of oxygen is therefore required downstream than upstream of the community due to the presence of the large quantities of raw sewage.

4.2.3 THE TURBIDITY OF WATER

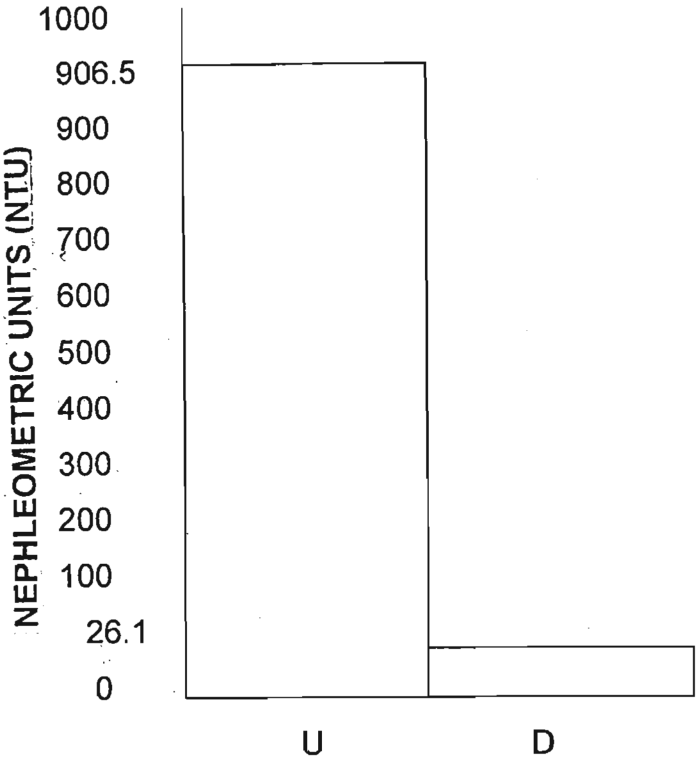
This indicates if the presence of colloidal solids which gives water a cloudy appearance, is aesthetically unattractive and may be harmful. Turbidity in water may be due to clay and silt particles, discharges of sewage or industrial wastes or to the presence of large numbers of microorganisms (Tebutt, 1993).

TABLE 4.3 TURBIDITY OF WATER DOWNSTREAM AND UPSTREAM
UNIT: NEPHLEOMETRIC UNITS (NTU)

NUMBER	TURBIDITY.UNIT:NTU	NUMBER	TURBIDITY:UNIT:NTU
D1	170	U1	5.6
D2	164	U2	6.1
D3	168	U3	4.9
D4	175	U4	4.7
D5	179	U5	3.9
D6	184	U6	6.8
D7	189	U7	5.5
D8	192	U8	5.1
D9	195	U9	4.2
D10	197	U10	5.4

Turbidity readings downstream appear to be higher in concentration indicating the presence of a pollutant, raw sewage or the presence of soil particles. Furthermore, concentrations downstream appear to be higher which could be attributed to faecal contamination from the nearby informal community.

FIG.4.3 DIFFERENCE IN AVERAGE OF TURBIDITY DOWNSTREAM AND UPSTREAM



U = Upstream
D = Downstream
t(calc) value: 46.86

Significance level : 99%
t(crit) value:2.879

The average of the turbidity concentration downstream (906.5 NTU) and 26.1 NTU represents the average concentration of the turbidity concentration upstream. The difference in average is 880.4 NTU. A significant difference in average between the turbidity concentration downstream and upstream does appear to be present. This is confirmed by the application of the students t-test at the significance level of 99%.

4.2.4. ELECTRICAL CONDUCTIVITY

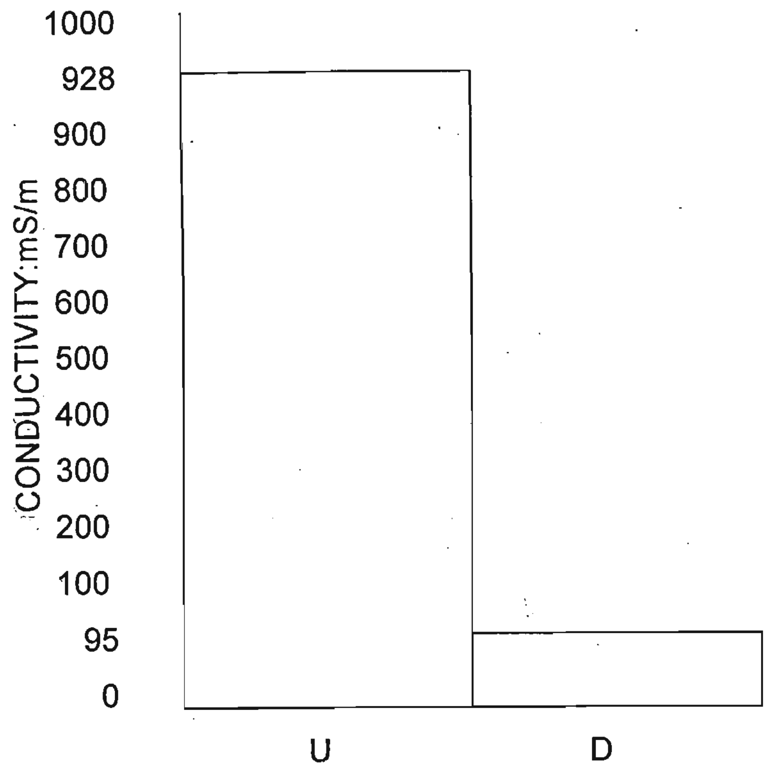
Also called conductivity, specific conductivity or conductance. The conductivity of a solution depends on the quantity of dissolved salts present and for dilute solutions, it is approximately proportional to the total salts content (Tebutt, 1993). It is also the ability of a solution to conduct an electric current.

TABLE 4.4 ELECTRICAL CONDUCTIVITY DOWNSTREAM AND UPSTREAM UNIT : MICROSIEMENS/MINUTES(mS.m)

NUMBER	CONDUCTIVITY:mS/m	NUMBER	CONDUCTIVITY: mS/m
D1	171	U1	11
D2	173	U2	9
D3	179	U3	15
D4	182	U4	25
D5	185	U5	27
D6	190	U6	29
D7	192	U7	28
D8	194	U8	12
D9	193	U9	15
D10	197	U10	19

The electrical conductivity of the downstream (D1-D10) samples appear to be higher than the electrical conductivity of the upstream (U1-U10) samples. This indicates a high electrical conductivity level which is due to the presence of raw sewage.

Fig. 4.4 DIFFERENCE IN AVERAGE OF ELECTRICAL CONDUCTIVITY DOWNSTREAM AND UPSTREAM



U = Upstream
D = Downstream
t(calc) value: 44.34

Significance level : 99%
t(crit)value: 2.879

Downstream, the average of electrical conductivity is 928 NTU and upstream, the electrical conductivity is 95 NTU, providing a graphical representation of the averages. The difference in average of electrical conductivity downstream and upstream is 833 NTU. The average does appear to be significant from an observation. The students t-test confirm that the difference in the electrical conductivity downstream and upstream is significantly different as indicated by the critical value of 2.879 being lower than the calculated value of 44.34.

4.2.5 THE NITRATE CONCENTRATION

Nitrates occur in almost all natural waters. Of the common nitrogen species, the nitrate ion is not readily absorbed by clay minerals. The primary source of all nitrates is atmospheric nitrogen gas (Hounslow, 1995). The nitrate concentration, a constituent of water is responsible for a disease known as methemoglobinemia or "bluebabies" in infants under two months of age if consumed and if concentrations are too high.

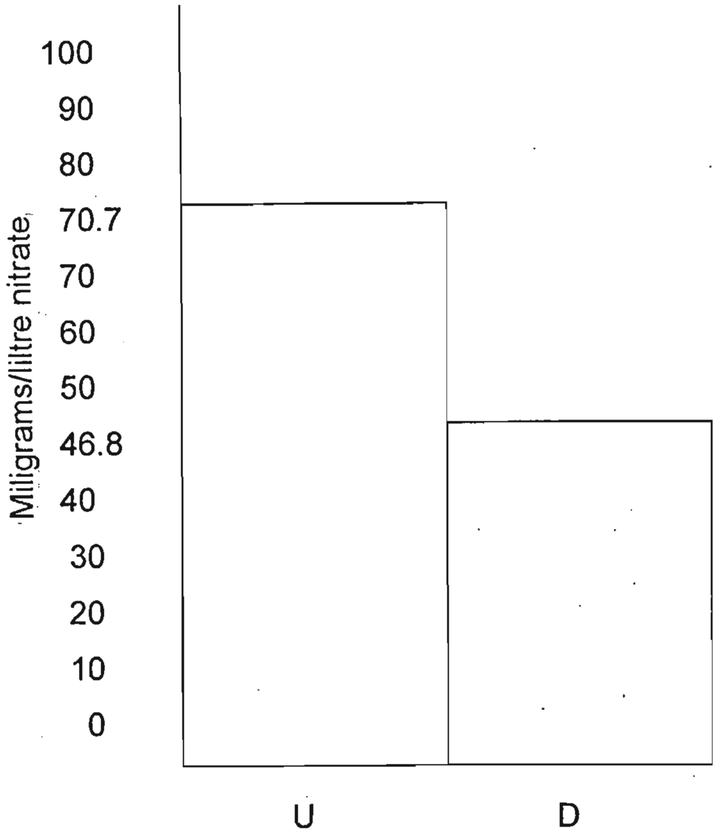
TABLE 4.5. THE NITRATE CONCENTRATION DOWNSTREAM AND UPSTREAM

UNIT : Miligrams/litre nitrate (mg/ln)

NUMBER	NITRATE:MG/IN	NUMBER	NITRATE:MG/IN
D1	9.5	U1	3.3
D2	13	U2	12
D3	15	U3	11
D4	15.5	U4	9.6
D5	14.9	U5	7.0
D6	13	U6	9.7
D7	14	U7	11
D8	14.7	U8	10
D9	15.8	U9	10
D10	16	U10	10

Points D1-D10, representing downstream appear to be higher in concentration for the indicator, nitrate. This is an indication of the nature and strength of the samples. The presence of the nitrate is mainly due to the presence of sewage contamination. Nitrates are important for biological reaction.

FIG. 4.5 DIFFERENCE IN AVERAGE OF NITRATE CONCENTRATION DOWNSTREAM AND UPSTREAM



U = Upstream
D = Downstream
t(calc) value: 3.44

significance level 99%
t(crit)value:2.879

The average of the nitrate concentration downstream is 70.7mg/lN while the average of the upstream nitrate concentration is 46.8 mg/lN. 23.9 mg/lN is the difference in the average of the nitrate concentration. An observation indicates the average to be significant. The students test does confirm a significant difference between the downstream and upstream nitrate concentrations when applied at the 99% confidence limit. Faecal contamination is higher downstream of the community than upstream of the community.

4.2.6 THE PHOSPHOROUS CONCENTRATION

Phosphorous is an essential nutrient required by aquatic plants to grow. However, in large quantities, it can cause a major water pollution problem. Sewage does contain phosphorous, about half occurs naturally in human waste while the other half comprises phosphates from the laundry detergent.

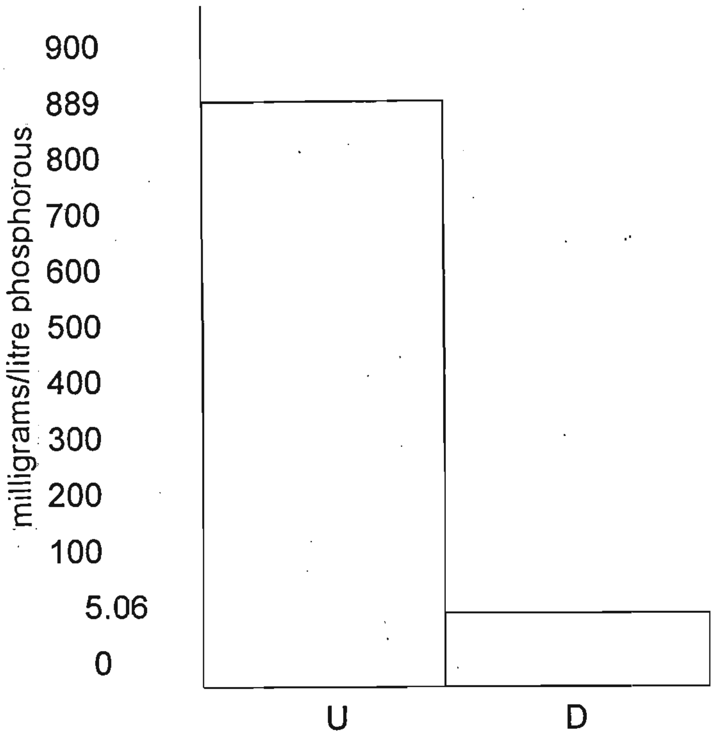
TABLE 4.6 <u>THE PHOSPHOROUS CONCENTRATION DOWNSTREAM AND UPSTREAM</u>

Unit: milligrams/litre phosphorous

NUMBER	PHOSPHOROUS:mg/IP	NUMBER	PHOSPHOROUS:MG/IP
D1	156	U1	0.35
D2	162	U2	1.8
D3	168	U3	1.3
D4	173	U4	1.2
D5	176	U5	0.13
D6	181	U6	1.0
D7	185	U7	1.1
D8	189	U8	0.94
D9	192	U9	1.1
D10	196	U10	1.2

It appears that the phosphorous concentration downstream is much higher than the upstream concentration. This is an indication of the contamination in the water source, namely sewage. High concentrations of phosphorous however, increase aquatic plant growth clogging the waterways

FIG 4.6 DIFFERENCE IN AVERAGE OF PHOSPHROUS CONCENTRATION DOWNSTREAM AND UPSTREAM



U = Upstream
D = Downstream
t(calc) value: 42.33

Significance level: 99%
t(crit) value: 2.879

The phosphorous concentration downstream indicates an average of 889 mg/lP and the average of the phosphorous concentration upstream is 5.06 mg/lP. The difference in average of the phosphorous concentration downstream and upstream indicates a value of 883.94 mg/lP. A significant difference in the average of the phosphorous concentration downstream and upstream does exist. This is confirmed by the students t-test executed at the 99% significance level. The nitrate concentration is therefore higher in concentration downstream of the community due to the presence of raw sewage.

4.3 CONCLUSION

The focus in this chapter was on the analysis of the results that were obtained from the samples collected at the Umlaas River and analyzed at the Ethekwini Wastewater Laboratory. From these, it may be said that a lack of sanitation facilities is a major problem that gives rise to an increased level of microbiological content of the water source. The major source of pollution originates from the discharge of raw sewage which does have an impact on the quality of the river water. Not only is faecal contamination a problem to the water quality, but, the potential for disease is also very high especially to the inhabitants of the informal community that rely on this water source for their survival. The various indicators that were analysed further indicate the presence of a contaminant, namely sewage with concentrations downstream appearing to be higher as compared to the upstream of the river. The following and last chapter will provide the final conclusions from the findings of the analysis together with recommendations as a possible means of action to the problems associated with water quality.

CHAPTER 5

DISCUSSIONS, RECOMMENDATIONS, CONCLUSIONS

5.1. INTRODUCTION

Where there is water, there is life. Where the quality is poor and scarce, life has to struggle. There is an ever increasing awareness of the need to conserve our environment and in recent times, considerable emphasis has been placed on the pollution of rivers and streams. Water resources are becoming more and more contaminated with pollutants derived from ever expanding urbanization and industrialization (Tebutt, 1983). The main cause of poor water quality is population increases or the concentration of people who by their mere existence, cause the immediate environment to be overloaded with effluents to such an extent that nature cannot restore the balance (Umgeni Water, 1996).

Unlike many other raw materials, there is no substitute for water in many of its uses. Water plays a vital role in the development and establishment of a permanent community. Unfortunately, due to the solid and liquid wastes from such a community and informal communities, the potential for environmental pollution is quite considerable (Tebutt, 1983).

In developed countries, the delivery of basic services are usually of a high standard and since populations are in low or zero-growth states, the demands on water resources are usually not excessive. In developing countries, however, the situation is very different where large proportions of the population are without safe water and adequate sanitation (Arnell, 1996). It is further estimated that one billion people do not have access to clean water and one billion do not have proper sanitation (World Summit on Sustainable Development, 2002). The provision of services in informal communities are also very poor.

According to Abrams (1996), water is a scarce resource and is inequitably distributed in South Africa where 43% of all waterfalls on 13% of the land and with high variability and unpredictability. In addition, surface water resources are dwindling due to South Africa being underlain by hard rock formation while the potential for contamination of this resource, could be expected to increase as water outbreaks of disease are likely to occur especially in the informal settlement water supply scene in South Africa. Great importance is therefore placed on the water resources in South Africa with a high priority being placed on the water quality control (Mvula Trust, 1999a).

5.2. DISCUSSION

There is an estimated eight million South Africans living in informal settlements that do not have access to potable drinking water and use untreated water from rivers and streams which could be hazardous to their health (Preston Whyte, 1999). Furthermore, according to the World Health Organization, about 50 000 people die everyday as a consequence of using poor quality water and living in unsanitary conditions.

Water supplies must be fit for human consumption, i.e. potable and it should also be palatable, i.e. aesthetically attractive as well as be suitable for other domestic uses such as clothes washing, bathing, etc. If contaminated however, water has a high potential for transmitting a variety of diseases and illnesses. The commonest form of water-related disease and certainly that which causes most harm on a global scale includes those diseases spread by the contamination of water by human faeces or urine. With this type of disease, infection occurs when the pathogenic organism gains access to water which is then consumed by a person who does not have immunity to disease (Arnell, 1996).

The situation in KwaZulu-Natal, especially which has many informally communities, is extremely serious as these communities are seen as the prime cause of water pollution. In addition, informal communities establish themselves on the banks of rivers to be close to the water source which does place increasing pressure on the water courses. When latrines (toilets) are placed on river-banks, run-off from these toilets causes further pollution. The potential for water-borne disease such as cholera, gastro-enteritis, hepatitis, dysentery, had been reported as being highly contagious during the cholera epidemic in 1997, in KwaZulu-Natal. Approximately 200 000 people, mainly young children, die every year from water related diseases (Alcock, 1985).

According to the Department of Water Affairs and Forestry (1997) everyday infants die from the diseases bred of the unavailability of clean and potable water and among the historically privileged population, infant mortality rates are about 20 per 1000 births while in some water-deprived areas, 370 infants per 1000 births are lost. Water related diseases are to a large extent related to inadequate sanitation facilities and practices.

The Umlazi informal community, L Section, consisting of approximately 5 000 dwelling units, is no different to any other informal community. It lacks proper sanitation and refuse removal with inhabitants living in structures which offer partial shelter against the weather elements, facilities that no doubt add to the problems of poor water quality and environmental pollution. Shallow pit latrines, shrubs and river banks provide a means of defaecation for the inhabitants of this community who live along the Umlaas River where the levels of pollution appear to be high. Furthermore, environmental problems originating from such a community with no sanitation and inadequate services are serious and could result in outbreaks of epidemics. An emergency plan is therefore needed to address Durban's sewage crisis and provide effective sanitation to the informal sector to control the epidemic of life-threatening diseases. Pollution in the form of raw sewage is the host of a great number of serious and potentially killer diseases such as polio, dysentery, typhoid and cholera. The implications of water pollution for the health of rural and informal communities are often assessed solely in terms of the large-scale epidemics of water transmitted disease. Results obtained from studies undertaken by the water quality branch of Umgeni Water indicate that there is a steady decline in the water quality as rivers progress downstream. The contamination of water by raw or partially treated sewage carries an associated threat of disease some of which are life threatening to humans. People who have no water source other than the local water are therefore exposed to the risks of water-borne diseases (Preston Whyte, 1990). The resultant implications for the health of informal dwellers is that water will be insufficient; the local sources of water are likely to be contaminated and the rivers downstream will probably be heavily polluted necessitating elaborate and expensive treatments to render the water suitable for human consumption. Hence, Escherichia Coli (E-coli); Chemical Oxygen Demand (COD); Turbidity; Conductivity; the Nitrate concentration and phosphorous concentration have been selected to investigate the water quality of the Umlaas River, the water source to the nearby informal community.

5.2.1. E-coli concentration in the Umlaas River

The faecal coliform bacteria, E-coli originates primarily in the mammalian intestine. It is excreted in enormous numbers and fresh faeces may contain from five million to five hundred million per gram, the average amount being about eighty two grams daily per person (Steel, 1979). These bacteria pass from the human intestines along with the faeces and therefore occur in sewage-contaminated waters. A low coliform count indicates a low number of pathogenic bacteria in the water while a high coliform count indicates the presence of a high number of disease causing bacteria. Coliform bacteria are used for monitoring the bacteriological safety of water supplies on the basis that the presence of coliform bacteria in water is an indicator of potential human faecal contamination and therefore the possible presence of enteric pathogens (Garcia-Lara, 1993). In the Umlaas River, the E-coli count downstream appears to be much higher than the E-coli count upstream. This is an indication of faecal contamination as indicated by the high average downstream E-coli count of 800 000 cfu/100ml when compared to the low upstream E-coli count of 195 750 cfu/100ml resulting in a large difference of 604 250 cfu/100ml. A factor contributing to the high E-coli count is mainly due to the informal community lacking sanitary facilities. The size of the population within the settlement could also contribute to the high numbers of coliform bacteria. The statistical analysis test further confirms a significant difference between the downstream and upstream E-coli counts. Coliforms per 100ml are greater than the maximum allowable limit of 5 per 100ml as stipulated by the South African Bureau of Standards (SABS). For drinking water, the accepted counts for E-coli are zero and a maximum of 120 for recreational water according to SABS. Studies undertaken indicate that the Cato Manor rivers running through Cato Crest had a count of 37 000, the Umgeni River count was 1 500 while 13 000 was the count of the rivers in Chatsworth. It is however, important to note that residents of all informal communities rely on untreated river water supplies for their domestic use like washing and sanitation. High bacterial numbers especially faecal coliform are significant because they contribute to environmental pollution and present a potential health hazard. Previous studies also indicate that the river running through Cato Crest informal settlement, where no sanitation exists, was 300 times more than the accepted health levels. Furthermore, the micro-biological content of river water in the province is particularly of an unsatisfactory quality, the major problem being the lack of sanitation facilities in the informal communities. Durban had been experiencing an epidemic of life-threatening disease called the Shigella dysentery as discussed in chapter two due to poor environmental practices while more recently, the cholera epidemic had inflicted itself upon KwaZulu-Natal (August 2000-2001), water-borne diseases spread by the contamination of water by urine and faeces. The water of the Umlaas River exceeds the bacteriological limits allowed by the SABS and therefore cannot be used for drinking. It can be stated that the raw sewage content is greater downstream of the community than upstream of the community and a lack of sanitation can therefore be considered to be the primary contributor to the faecal loadings in the Umlaas River.

5.2.2. The COD concentration of the Umlaas River

The chemical oxygen demand is the amount of oxygen necessary to oxidise carbon completely to carbon dioxide, water and ammonia. In general, one gram of carbohydrate or one gram of protein is approximately equivalent to one gram of chemical oxygen demand. However, if the COD value is very high, then it is an indication that the water contains large amounts of organic compounds that are not easily biodegraded (Bitton, 1994). The COD concentration downstream of the Umlaas River appears to be very much higher than upstream of the community. This is evident in the difference in the average between upstream of 31.95 and downstream of 949.5 values. An immediate demand for oxygen therefore exists downstream due to the presence of sewage. Sewage is made up of small bits of organic material dissolved or suspended in water and begins to break down very quickly thereby creating large demands on oxygen as indicated by the significant difference value of 129.54, much higher than the critical value of 2.879. However, when organic material is reduced, it liberates ammonia and neither oxygen depletion nor ammonia liberation is good for fish or other aquatic organisms for example, salmon and trout require a minimum oxygen level of six milligrams per litre to live in a river. Trout cannot grow if the ammonia concentration exceeds 0.025 milligrams per litre and will die if it exceeds 0.25 milligrams per liter. High levels of sewage therefore resulted in high COD levels indicating a high level of contamination in the Umlaas River.

5.2.3. The turbidity of the Umlaas River

Turbidity refers to the presence of colloidal solids which gives water a cloudy appearance, is aesthetically unattractive and may be harmful. It may be caused by clay or silt particles and in the Umlaas River, it is due to both clay and silt particles as well as the presence of sewage. If these are not removed, they will cloud the river water, preventing sunlight from penetrating through thus depleting the amount of food for the aquatic life for example, some fish species like the northern pike and trout rely on sight to feed, and they cannot survive in highly turbid water. In addition, water is critical for a healthy community and health is measured in terms of mortality rates. Turbidity readings downstream of the Umlaas River are therefore high due to the presence of the informal community lacking these vital services. The difference in average value of 880.4 NTU is indicative of the extent of sewage contamination prevalent more on the downstream than upstream of the Umlaas River. The potential for transmitting diseases by animals living within the informal community is also high as water contaminated with animal wastes could also be harmful as was seen in the United Kingdom : serious outbreaks of cryptosporidium caused by contaminated drinking water had been traced to the spores of the faeces of the infected cattle grazing (Stauffer, 1998). Sewage is responsible for the high turbidity readings downstream as well as the brownish water colour of the Umlaas River.

5.2.4. The Electrical Conductivity of the Umlaas River

It is evident from the very low upstream electrical conductivity readings that the influence of the informal community is not prevalent. Downstream readings, however, indicate very high electrical conductivity levels. This is due to the presence of raw sewage from the nearby informal community. It is further evidenced from the presence of the organic material that significant differences exist between the downstream (928 NTU) and upstream (833 NTU) averages. The value of 2.879 further confirms the vast differences between the downstream and upstream values which is far lower than the calculated value of 44.34. The large quantities of raw sewage therefore lead to high values of electrical conductivity while at the same time being a contaminant in the water supply of the nearby informal community. The potential for disease, as mentioned earlier, being ever present.

5.2.5. The Nitrate Concentration of the Umlaas River

The nitrate concentration in the Umlaas River was used to estimate the eutrophic conditions in the river as well as its tributaries. The downstream concentration of nitrates appears to be at an increased level when compared to the upstream concentration as evidenced by the significant difference in averages. The application of the statistical analysis test further supports this finding at the 99% confidence limit. It serves to confirm that the nitrate concentration downstream is much higher than the upstream concentration mainly because of the faecal contamination emanating from the nearby informal community. Since human excrement is considered to be one of the non-point polluting sources, the nitrate concentration was valuable in the estimation of such pollution. Nitrates are present in all sewage effluents and are undesirable due to the potential health hazard to young babies (Tebutt, 1993). It can be a source of the potentially fatal condition in infants known as methaemoglobinaemia or infant cyanosis (Ellis, 1989). This disease causes "blue babies" and has caused some 262 reported cases and 29 deaths in the U.K. (Steel, 1979). It is caused by nitrates in water consumed by infants under two months of age. In children of that age or under, the nitrates are reduced to nitrates which react with the oxygen receptor sites on the haemoglobin fraction of the blood and impair its oxygen-carrying capacity. This reaction, however, does not occur in older children or adults (Steel, 1979). Nitrates however, are also suspected of combining with other materials in the water to produce potentially carcinogenic compounds such as nitrosamines. In addition, the source of nitrates found in surface waters is not only sewage but also from run-off from agricultural land containing fertiliser (Ellis, 1989). In the case of the Umlazi informal community, however, such a practice had been minimal and sometimes non-existent. The nitrate concentration within the Umlaas River especially downstream had been high mainly as a result of the sewage content from the informal community.

5.2.6. The Phosphorous Concentration in the Umlaas River

Phosphorous is an important element in surface water quality. It is essential to life and in many situations, it may be the growth-limiting element. Relatively high concentrations may be present in some surface waters as a result of having been derived from domestic detergent powders. It may also be present as a result of agricultural run-off, in animal wastes or in decay cell material (Ellis, 1989). In the Umlaas River, the phosphorous concentration downstream appears to be extremely high yet again, when compared to the upstream phosphorous concentration of a low average of 5.06 mg/lP. As mentioned earlier, the source of pollution is mainly due to the nearby informal community. High levels of sewage has led to high phosphorous levels since sewage does contain phosphorous, about half occurring naturally in human waste and the other half as phosphates from laundry detergent (Stauffer, 1998). It is also likely that the increased concentration of phosphorous were probably due to the washing of clothes in the Umlaas River by the informal dwellers. The amount of phosphorous in the water also determines plant growth, the more phosphorous gets into the water, the more will plants grow causing eutrophication. Due to the high phosphorous level, excessive growth of water hyacinth severely limited the recreational use of the Umlaas River, giving a clear indication of the trophic status of the river. It did promote a greenish tint in the river water and was aesthetically displeasing and almost clogging the waterway. Objectionable odours also resulted while the potential danger to human health did exist from the presence of toxic cyanobacteria in algal blooms (Ellis, 1989). Excessive nutrients are one of the biggest contributors to surface water pollution in the United States while even larger amounts stimulate the rapid growth of plants and algae which, when eventually die, use up large amounts of oxygen reducing the amount available for fish and other aquatic species. In extreme cases, this can lead to a completely oxygenless environment that can support nothing except a few species of anaerobic bacteria (Stauffer, 1998). Such unattractive conditions prevailing in the Umlaas River poses a problem not only to the environment but, to human health since utilising such water could be harmful to health. Poliomyelitis, among other harmful diseases, is found in the faeces of infected persons and in sewage. Hence, it is assumed that the virus might occur in drinking water and it has, in fact been detected here (Steel, 1979). The high phospherous concentration downstream of the Umlaas River therefore provides evidence of the nutrient loading in the river. Raw sewage therefore appears to be at higher levels downstream than upstream of the informal community.

5.3. RECOMMENDATIONS

Attaining health for all is dependent on knowledge of environmental aspects of disease and how environmental management can improve human health. Good health and well being cannot be attained or maintained in deteriorating or hazardous surroundings (Sankar, 1996). In addition, with the increase in informal communities, associated problems have been recognised but, actions are minimal. It has also become obvious that the rapid urbanisation that has occurred in the informal communities, has played a major role in the deterioration of the water quality of the Umlaas River. As a result, the following recommendations can be made:

- The improvement in the living conditions by the elimination of uncontrolled informal settlements would reduce the faecal pollution in the Umlaas River;

- The extensive use of pit latrines requires the quantification of groundwater contamination. This quantification of nitrate pollution from groundwater contamination needs to be assessed so as to counteract any future deterioration of the water quality;

- Developing alternate sanitation systems since sanitation affects the quality of life and the quality of the water sources. Consideration must therefore be given to on-site sanitation, especially water borne sanitation since it has been shown that in developing countries where water borne sanitation had been used, there has been substantial improvements in health and environmental quality;

- The Umlaas River still requires extensive cleaning up even though Umgeni Water is committed to the principles of integrated catchment management. The polluted stormwater run-off needs to be quantified and the movement requires good control to restrict excessive pollution loads entering the river after heavy rainfall;

- Furthermore, the water hyacinth in the river needs to be removed which would promote healthy conditions within the river; it would make the river aesthetically pleasing and promote greater recreational activities in the river ultimately promoting social upliftment in the Umlazi area while the residents of the informal community can involve themselves with the cleaning up of the river. Educating these residents would also help improve the quality of the water in terms of river health and;

- The water must be classified since when this happens, one can determine whether the water can be used for domestic use or not, in relation to drinking, cooking, bathing etc. (Water Research Commission, Department of Water Affairs and Forestry, 1999). This system would involve a colour and code criteria namely: blue = class 0 = ideal water quality; green = class 1 = good water quality; yellow = class 2 = marginal water quality; red = class 3 = poor water quality and purple = class 4 = unacceptable water quality.

All the above are possible steps to be undertaken as a means of improving the water quality of the Umlaas River.

5.4. CONCLUSION

Modern society too often views water as a convenient vehicle for disposing of waste and the results are becoming increasingly apparent. Analysis of fresh water supplies frequently reveals disturbing levels of pollution including human waste, heavy metals and synthetic chemicals to the detriment of human health and the health of the entire ecosystems. Even today, humans continue to ignore the vital importance of water while consuming more and more. Not only is the level of water in the global well getting low, the water is also polluted, sometimes to the point where it is no longer drinkable (Stauffer, 1998).

Water quality control combined with water resource protection is of fundamental importance in South Africa as rapid population growth are placing enormous demands on the countries diminishing water resources. South Africa's droughts have exacerbated the adverse effects of increased water pollution from the industrial and domestic sources and the reuse of polluted water may be the only means of balancing supply with demand (Furness and Richards, 1989). The judicious use of water will be a key factor which will lead to a sustained and healthy socio-economic development and the prevention of water pollution (Sankar, 1996).

Like many other countries, in South Africa, man's activities are largely the cause of deteriorating water quality. Furthermore, the effect of man's social and industrial activities can be seen in the extent to which river water quality changes as a river flows from its source to the sea. Water which is returned to the river as effluent, is rarely the same quality and is normally contaminated with some form of pollution.

Among the many problems facing the environment. informal communities have become a growing concern as a result of rapid urbanization, widespread poverty, unemployment and a severe housing shortage. Being situated close to any water source due to a lack of basic services, leads to these communities impacting negatively on the rivers polluting them to the extent of the rivers losing their ability to assimilate pollution and providing adequate water fit for use.

It can therefore be said that from the study undertaken on the Umlaas River, the high E-coli counts, COD concentration, turbidity, electrical conductivity, nitrate concentration and phosphorous concentrations, observed, likened it to an open sewer. The combined effects are the primary cause of faecal pollution. As long as sanitation services continue to be poorly serviced, the Umlaas River will be unfit for any use whatsoever. In addition, unsanitary living conditions have become the living standards of the informal community and it is a deterioration in environmental health and public health which gives attention to a problem resulting from urbanisation and industrialisation.

Pollution by people therefore poses one of the most serious threats to water quality. The sheer volume and density of pollutants that find their way into the water course poses a threat to both the environment as well as human health. In addition, there is an increasing public interest in water as a resource and an increasing awareness of the need to protect water quality. However, without proper management, water as a vulnerable resource may become over exploited and over utilised brought about by man's need for modernity at the expense of the environment. However, urbanisation, domestic and industrial pollution are the activities that have the greatest impact on water quality, river flow and therefore water use. The study of water quality is therefore of enormous value for the quality of water is dictated by a pattern of interactions rather than by any factors in isolation. It is further hoped that this investigation of water quality will prove to be of benefit to the communities, especially informal communities as well as assist policy makers in devising policies regarding issues of sanitation and environmental quality especially when urbanisation is on the increase. It is therefore critical that any future developments are evaluated from a holistic environmental perspective within a framework of an integrated catchment management plan since it may be concluded that informal communities do have a negative influence on water quality.

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