EFFECT OF SEPTIC TANKS ON WATER FROM SHALLOW WELLS IN AKURE METROPOLIS.

BY

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DECLARATION.

I Tanimola, Moses Oladejo declare that this thesis was prepared entirely by me under the supervision of Dr. A. M Oguntuase of Department of Civil Engineering, Federal University of Technology, Akure. The thesis has not been presented either wholly, or partly for any degree elsewhere before.

All sources of information consulted have been duly acknowledged.

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CERTIFICATION

I certify that this project was carried out by TANIMOLA, MOSES OLADEJO of the Department of Civil Engineering, Federal University of Technology, Akure.

.... 13 NOV 2006

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DEDICATION

As a man cannot receive anything, except it is given to him from above, this project is solely dedicated to the Almighty God who has created avenues and good health to make it a fulfilled dream. May His name be praised.

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ABSTRACT

This research project dealt primarily with the effect of Septic tanks on water from shallow wells in Akure metropolis. Shallow wells, being the main water source available to almost every home in the study area which forms part of underground water is facing problems of pollution which can constitute threats to the quality of underground water and public health now or in future.

The criteria used in determining the effect of Septic tanks on shallow wells was to take water samples from located wells in the metropolis and analyze them to determine the physical, chemical and biological characteristics.

The results of the physical, chemical and bacteriological qualities of the sampled wells have ranges of 7.0 – 8.0 for pH, 20.0^{0}c- 27.9^{0}c for Temperature, 113 μmho – 1116μmho for conductivity, 26.4mg/l – 180.5mg/l for hardness , 18.1mg/l – 140.0mg/l for Calcium, 0.03mg/l – 0.88mg/l for manganese, 1.0NTU – 10.0NTU for Turbidity, 1.0mg/l – 311.0mg/l for Sulphate, 0.0mg/l – 140.0mg/l for Nitrate, 0.0mg/l – 3.0mg/l for Phosphate, 0.0TCU – 40.0TCU for colour and 0.0MPN – 18.5MPN for Coliform.

The results obtained were compared with WHO International Standard on potable water and wells 6,11,13,14,17,19,21,22,25,27,31,41,53 and 55 are contaminated, but the level of contamination is within limit with exception of wells 1, 36 and 44 which have contaminant concentrations exceeding the maximum permissible limit.

Shallow wells sited very close to the septic tanks with distance less than 14.0m suffered contamination and had concentrations of chloride, calcium, hardness, sulphate, nitrate, phosphate and coliform exceeding the maximum concentration limits. The concentrations of the parameters mentioned above were used to formulate mathematical relationship between concentrations and distance and model equations were obtained.

CHAPTER ONE

INTRODUCTION

1.1 General:

Akure metropolis was formerly a town in the Ondo province in the then Western State of Nigeria and became the capital of old Ondo State in February, 1976 when the State was created. It was then not largely populated. Over the years it has increased geometrically in terms of size and population as a result of urbanization.

Industrialization and the establishment of Federal and State Ministries, Parastatals, Agencies, Institutions and Banks have led to the large influx of people to the metropolis. This in turn has resulted in the generation of enormous human wastes from home and offices. Also a lot of buildings have been built in the metropolis and hundreds of shallow wells have been sunk for domestic consumption, as the government could not provide sufficient pipe-borne water supply for all.

There is a great danger of groundwater pollution due to the positioning and locations septic tanks in every building with respect to the source of their water supply, i.e., shallow well. The problem is aggravated in areas of high building density.

Groundwater has been the major source of drinking water for the people of the metropolis. Water drawn from wells is used directly without treatment. A significant proportion of the water from the wells has suffered contamination from the septic tanks (pit-latrines and septic system) which in the short and long term may result in deleterious health effects.

According to Hamill and Bell (1986), it was estimated that in Africa in 1984, more than 9000 million people were without public water service of any kind while by 1992, the situation had deteriorated and many were affected by water related diseases.

In Nigeria, especially in this part of the country, where normal layouts are not followed, and where it is followed, individuals build their houses to their own tastes and desires and there is no regard or consideration for the allowable space and arrangement of sanitary systems as they affects their source of water supply – wells. It is technically and scientifically clear that the arrangement of these septic tanks will affect the quality of water obtained from the shallow wells that are dug in the premises of such building. Due regard must therefore be given to this problem, since the only source of water supply that is guaranteed and void of acute shortage and failure in this area is shallow wells. The care of shallow wells and preventive measures against any form of contamination assures the normal standard of good, potable and quality water supply to every community at a relatively low cost.

Every normal human being passes out waste products from the body, in the form of excreta and urine. The process itself is a healthy one, but if the waste products are not properly disposed of they may constitute problems and damages to existing sources of water supply –

shallow wells and therefore pose dangers to the health of the nearby dwellers.

It is bad enough that the local draughts men and bricklayers who are mainly engaged in drawing plans and building houses respectively do not pay close attention to the arrangement of septic systems as they affect the sinking of shallow wells that will supply water to the occupants. This is out of ignorance. The local planning authority that is responsible for plan approval do not attach great importance to this aspect. Worst of all are the houses that are constructed without plan even within the state capital. A visit to a particular location in Ijoka axis of Akure metropolis revealed a situation where a bathroom and a shallow well were located at a distance of 2.0 m from each other.

Hence when groundwater is contaminated, it is very difficult and expensive to clean up; thus it is better to adopt pollution prevention and control methods in order to protect contamination of groundwater supplies. [Thus in this study, the groundwater (shallow well water) contamination of Akure metropolis is evaluated and control measures and solutions for elimination of the source of the contamination, which pose threat to public health, are suggested.]

.2 Objectives of the Research:

The specific objectives of this study are to:

(i) Determine the level or extent of groundwater (shallow wells) contamination of Akure metropolis due to the use of septic tanks with respect to its orientation and relative distance to the well;

(ii) investigate and identify the contaminants and the contaminants concentration level in the well water whether approaching maximum concentration limits or exceed WHO International Standard for drinking water; and

(iii) recommend environmental control and any treatment required to make it safe and prevent long-term effects on the consumers.

1.3 Scope of the Project:

A detailed field reconnaissance of the project area was carried out to determine the level of urbanization, location of wells and proximity of the wells to the septic tanks. Available information such as street guide map of Akure metropolis was obtained.

The geological condition and the profile of a typical borehole in the study area were collected from WATSAN to determine the profile of layers of sand band, thickness of underlain sand band and aquifer horizon. Water samples were collected and analyzed in the laboratory to determine their physical, chemical and biological characteristics.

This research work was carried out to evaluate the vulnerability of groundwater to contamination by human waste only. The contaminants of major concerns are chloride, hardness, calcium, manganese, sulphate, nitrate, phosphate and coliform. This study does not include soil investigation which is left for further study. The area of study was limited to Akure metropolis in Ondo State, Nigeria.

1.4 Justification of the Study:

Groundwater is vulnerable to contamination; however, the ease with which it can be contaminated depends on the characteristics of the aquifer materials, the topography of the area concerned, the groundwater level, recharge rate, relative distance between the well and the on-site sanitation systems, etc. At least 90% of houses in Akure depend on shallow wells as their source of water supply, hence any useful information to the public on the level of contamination of the groundwater is important as this leads to appropriate control measures.

CHAPTER TWO

LITERATURE REVIEW

2.1 Water Supply and Human Health:

Water is essential to man, animals and plants. Without water life on earth would not exist. From the very beginning of human civilization, people have settled close to water sources, along rivers, besides lakes or near natural springs. Indeed where people live, some water is normally available for drinking, domestic use, and possibly for watering animals. This does not imply, however, that the available source of water is convenient and of sufficient capacity, or that the water is safe and wholesome. On the contrary, in many countries people live in areas where water is scarce. Often it has to be carried over long distances, particularly during dry periods. Scarcity of water may also lead people to use sources that are contaminated by human or animal faeces, and are thus dangerous to human health (Hofkes, 1983)

A few liters of water each day are sufficient for a person's basic drinking and food preparation requirements, depending on the climate and lifestyle. Much larger quantities are necessary when water is used for other purposes such as personal hygiene, cleansing of cooking utensils, laundry and house cleaning. Safe, adequate and accessible supplies of water combined with proper sanitation, are surely basic needs and essential components of primary health care. They can help reduce many of the diseases affecting underprivileged populations, especially those who live in rural and urban fringe areas (Hofkes, 1983).

Because of the essential role played by water in supporting human life, it also has, if contaminated, great potential for transmitting a wide variety of diseases and illnesses. In the developed world, water-related diseases are rare, essentially due to the presence of efficient water supply and wastewater disposal systems. However, in the developing world, more than 2000 million people are without safe water supply and adequate sanitation. As a result, the toll of water-related diseases in these areas is frightening in its extent. A recent WHO survey has highlighted the following facts:

a. Each day some 30,000 people die from water-related diseases.

b. In developing countries 80 percent of all illness is water-related.

c. A quarter of children born in developing countries will have died before the age of 5, the great majority from water-related disease.

d. At any one time, there are likely to be 400 million people suffering from gastroenteritis, 200 million with schistosomiasis, 160 million with malaria and 30 million with onchoceriasis.

All of these diseases are water-related although other environmental factors may also be important (Tebutt, 1983). Safe drinking water is important in the control of many diseases. This is particularly well established for diseases such as diarrhea, cholera, typhoid and paratyphoid fever, infectious hepatitis, amoebic and bacillary dysentery. It has been estimated that as many as 80 percent of all diseases in the world are associated with unsafe water.

This association can take a number of different forms, and diseases may be grouped accordingly (Table 2.1).

Water-borne diseases are those carried by water that is contaminated with infecting agents from human or animal origin. When the water is drunk the infecting agents will be ingested and may cause disease. Control of such diseases calls for improving the quality of the water (Tebutt, 1983).

Diseases due to lack of water tend to be a serious health hazard. When people use very little water, either because there is little available or because it is too far away to be carried home in sufficient quantity, it may be impossible to maintain a reasonable personal hygiene. There may be simply too little water for washing oneself properly, or for cleaning food utensils and clothes. Skin or eye infections are thus allowed to develop, and intestinal infections can more easily spread from one person to another. Clearly, the prevention of these water-washed diseases depends on the availability of, and access to adequate supplies of water rather than its quality (Tebutt, 1983).

Water-based diseases do not spread directly from person to person. They are caused by infecting agents that form an essential part of their life cycle develop in specific water animals, chiefly snails and

Table 2.1: Diseases related to Deficiencies in water supply and/or sanitation

Group	Diseases
Diseases transmitted by water (water-borne diseases) water acts only as a passive vehicle for the infecting agent. All of these disease depend also on poor sanitation	Cholera, typhoid, Bacillary dysentery, infectious hepatitis leptospirosis, Giadiasis, gastro enteritis.
Diseases due to lack of water (water-washed diseases). Lack of adequate quantity of water and poor personal hygiene create conditions for their spread. The intestinal infections in this group also depend on lack of proper human waste disposal.	Scabies, Skin Sepsis and Ulcers, Yaws, Leprosy, Favourable Lice and Typhus Trachoma, Conjunctivitis, Bacillary Dysentery, Ameobic Dysentery, Salmonellosis, Enterovirus Diarrheas, Paratyphoid Fever, Ascariasis Trihcuriasis, Whipworm (Enterobius), Hookworm (Ankylostoma)
Diseases caused by infecting agents spread by contact with or ingestion of water. (Water-based diseases). An essential part	Schistosomiasis (urinary & rectal), Dracunculosis (guinea worm) Bilharziosis, philariosis,

place in an aquatic animal. Some are also affected by waste disposal	
Diseases transmitted by insects which live close to water (water-related vectors). Infections are spread by mosquitoes, flies, insects that breed water or bite near it. These are especially active and aggressive near stagnant open water. Unaffected by disposal.	Yellow fever Dengue + dengue, hemorrhagic fever, west-Nile and Riff valley fever, Arbovirus, Encephalitides, Bancroftian, Filariasis, Malaria (diarrhea) – Mosquito Onchoceroiasis Similium fly, Sleeping sickness – Tsetse fly
Diseases caused by infecting agents, mostly contracted by eating uncooked fish and other food. (faecal – disposal diseases)	Clonorchiasis, Disphyllobothriasis, - fish fasciolopsiasis – Edible plant Paragonimiasis – Crayfish

(Source: Hofkes, 1983).

crustaceans. Over a period of days or weeks, the parasite larvae or eggs mature in these intermediate hosts, and then are shed into the water. The matured larvae or worms are infective to people drinking the water or having contact with it.

In tropical countries biting insects are common. Most of these, notably the mosquitoes, breed in pools or other open water, and sometimes even in household water. Such water-related vectors carrying pathogens can transmit disease.

Health hazards also emanate from infection sources other than water. Diseases may spread through direct contact (e.g., soiled hands) or through food, particularly fish, vegetables and fruit eaten raw. Besides safe water supply, the necessary measures to control disease therefore should include personal hygiene and inspection of food storage and market places(Tebutt, 1983).

Very important is the provision of adequate sanitation, including sanitary facilities for human waste disposal. All the water borne and many of the water-based diseases depend for their dispersion on infecting agents from human faeces getting into drinking water or into food. The diseases chain of transmission may be broken as effectively by sanitary disposal of faeces as by the provision of safe and adequate water supplies. There are certain agents, such as hookworm, for which sanitation is much more important than water supply in the prevention of disease because transmission is from the faeces to the soil, and then by direct contact and penetration through the human skin.

2.2 Water Quality:

The relationship between water quality and health effects has been studied for many water quality characteristics. An examination of water quality is basically a determination of the organisms, and the mineral and organic compounds contained in the water.

The basic requirements for drinking water are that it should be:

1. Free from pathogenic (disease causing) organisms
2. Containing no compounds that have an adverse effect acute or in the long term, on human health.
3. Fairly clear (i.e., low turbidity; little colour).
4. Not saline (salty).
5. Containing no compounds that cause an offensive taste or smell.
6. Not causing corrosion or staining clothes washed in it.

For their ready application in engineering practice, the results of the studies and research on drinking water quality must be laid down in practical guidelines. Usually these take the form of tables, which provide the highest desirable level and the maximum permissible level for a number of selected water quality parameters. Such values should be regarded as indicative only, and should not be taken as absolute standards. Table 2.2 is a typical guideline, which could be useful in the examination of water quality for drinking purpose.

The most important parameter of drinking water quality is the bacteriological quality, i.e., the content of bacteria and viruses in the waters. It is not practicable to test the water for all organisms that it might possibly contain. Instead, the water is examined for a specific type of bacteria which originates in large numbers from human and animal excreta and whose presence in the water is indicative of faecal contamination. Such indicative bacteria must be specifically faecal and not free-living. Faecal bacteria are members of a much wider group of bacteria, the coliforms. Many types of coliform bacteria are present in soil. Suitable indicator bacteria of faecal contamination are those coliforms known as Escherichia - coli (E-coli), and faeca streptococci. They are capable of easy multiplication. When these bacteria are found in the water, fairly fresh faecal contamination is indicated, and on that basis there is the possibility of the presence of pathogenic bacteria and viruses. Either one or both of these coliform and streptococci bacteria may be used as indicator organisms (Hofkes, 1983).

Table 2.2: Guidelines for Drinking Water Quality

Water Quality Parameter	Measured as	Highest Desirable level	Maximum Permissible level
Total dissolved solids	Mg/1	500	2000
Turbidity	FTU	5	25
Colour	Mg pt/1	5	5
Iron	Mg/Fe+1	0.1	1.0
Manganese	Mg Mn++1	0.05	0.5
Nitrate	Mg NO_{3-}/1	50	100
Nitrite	Mg N/1	1	2
Sulphate	Mg SO_4/1	200	400
Fluoride	Mg F-/1	1.0	2.0
Sodium	Mg Na^+/1	120	400
Arsenic	Mg As+/1	0.05	0.1
Chromium hexavalent)	Mg Cr^{6+}/1	0.05	0.1
Cyanide (free)	Mg CN-/1	0.1	0.2
Lead	Mg pb/1	0.05	0.10
Mercury	Mg Hg/1	0.001	0.005
Cadmium	Mg cd/1	0.005	0.010

(Source: Hofkes, 1983).

2.3 Groundwater:

The flow of rainwater into the ground is known as infiltration. The movement of water after entrance is known as percolation. A portion of rainfall percolates in the ground and is stored as ground water at hard stratum. Sometimes this ground water appears again at surface in the form of spring or dry weather flow of streams. The amount of infiltration mostly depends on the following:

(i) Rainfall characteristics;

(ii) Soil characteristics

(iii) Soil cover

An aquifer holding water is known as water-bearing stratum. Aquifer is simply defined as a rock or soil which not only contains water, but from which water could be drawn or readily abstracted in significant quantities. These are natural storage reservoirs of water under the ground from which water can be withdrawn. The top of water level in these reservoirs is known as water table, which is subjected to variations throughout the year. In rainy season, water table rises whereas in summer season it is depressed. When the water enters into the ground, it starts filling its pores. When all the voids of the pores are filled with water, the soil is known as saturated soil or saturated formation (Hamill and Bell, 1986).

The capability of a formation of soil to pass water through it is called permeability. It is measured by the coefficient of permeability, which is defined as the amount of water flowing through unit area of the formation per unit time. It has a dimension of velocity (m/s).

2.4 Types of Aquifer:

An aquifer is described as unconfined when the water table is open to the atmosphere, that is, the aquifer is not overlain by material of lower permeability. Conversely a confined aquifer is one which is overlain by and/or underlain by an aquitard(s), and is described as a leaky aquifer (Hamill and Bell, 1986).

2.5 Groundwater Contamination:

According to Palanichami (2002), groundwater contamination is the addition *of* elements, compounds and or pathogens to groundwater, which alters its composition, and renders it unfit for drinking. Groundwater contamination occurs through the following sources; septic tanks, unlined sanitary landfill, leaky storage tank, hazardous waste sites and use of chemicals;

Other sources resulting from human activities include accidental spills, mining, atmospheric contaminant and acid rain, surface water, improperly planned groundwater development leading to salt intrusion and improper well construction and maintenance. Since groundwater is a part *of* the hydrologic cycle, what can contaminate other parts of the cycle such as the air or surface. Such water can eventually get into the groundwater (Funk and Mcclenaghan 1980).

Once a well or well field has been successfully put into supply, it must be recognized that there exists the strong possibility that groundwater pollution may occur at some time in the future. Certainly groundwater pollution is not an abstract concept, it is of common occurrence. A survey of recent literature shows for instance, that the problems facing Dade County in Florida, USA are high nitrate level and volatile organic pollution (Esca, et al., 1995). In Nigeria, in the coastal areas, there is also a problem of saltwater intrusion that affects the groundwater quality (Nigeria water Sanitation Association, 2003).

Steiner et.al (1979) defined pollution as an impairment of water quality by chemicals, heat or bacteria to a degree that create an actual public health hazard. Thus, the purity of groundwater should not be taken for granted and untreated water should not be put directly into supply. Some form of chlorination or other type of disinfection is at least necessary for the water to be used for domestic purpose.

According to Hamill and Bell (1986), as many as 500 million people per year were affected by water-borne or water related disease in the developing countries. By 1990 the situation had deteriorated. The World Health Organization (WHO) then estimated that 1320 million people (57 percent) of the developing world (excluding China) were without potable water supply, while 1730 million (75 percent) were without adequate sanitation. At least 30,000 people per day die in the Third World because they have inadequate water and sanitation facilities. Therefore, the control of water pollution in developing countries is a necessity.

The greatest danger of groundwater pollution is from surface sources such as farm animals, man wastes, sewers, polluted streams and sanitary landfill. So, the obvious precaution against pollution is to locate the wells as far from any potential source of contamination as possible and to fence off the tops of well so that animal cannot defecate adjacent to the well. Good well design and construction is also important (Oteze, 1983).

According to Walton (1985), contaminated groundwater is very difficult and expensive to clean, thus it is better to adopt pollution prevention and conservation practices in order to protect important groundwater supplies. Contaminant source control and elimination technologies are groundwater interception, hydraulic barrier, dewatering trench (water treatment plant), adsorption (activated carbon and resin), chemical addition (coagulation and precipitations), filtration, chemical oxidation, ion exchange, excavation and disposal of contaminated soil. The efficacy of the process for the ultimate prevention or reduction of groundwater contamination relies on the formulation of policies that are scientifically and technologically sound, economically and financially - feasible, socially equitable, environmentally safe and legally compliant.

Although groundwater is normally effectively purified, as far as suspended matter is concerned by the straining action of rock as water percolates through it, soluble impurities are not so readily removed, although there is the possibility of ion – exchange reactions. Nitrogen compounds in agricultural drainage and in effluents discharged to soakaways for the disposal of domestic and industrial effluents may impair groundwater quality unless there is an impermeable stratum between the disposal areas and the aquifer (Tebutt, 1993).

2.6 Components of the Contaminants:

The types of chemicals that emanate from anthropogenic sources of contamination are listed in table 2.3. They range from simple inorganic ions such as nitrates (from septic tanks, feedlots, and fertilizer use), chloride (from highway de-icing salt, saltwater intrusion, certain industrial processes), radioactive materials and heavy - metal ions (e.g., chromium from plating works) to complex organic compounds resulting from manufacturing and industrial activities and household wastewater (Fuhriman and Barton, 1999). When the constituents of such wastes interact, new compounds may be formed, but that would not appear on the original waste content inventory. Many industrial waste disposal practices involve stabilization of waste, thereby rendering it less chemically active, but leachate product may still alter some of these chemicals (Lindorff and Cartwright, 1977). The degradation of contaminants by microbial organisms in the soils also changes the chemical composition, thus making it almost impossible to predict precisely what contaminants reach the aquifer (Hammer, 1977).

Table 2.3: **Components of the Contaminants**

Elements & Compounds of Contamination	Comment
Arsenic As	Usually causes severe poisoning
Antimony Sb	Similar to Arsenic but less severe
Barium Ba	Muscle stimulant
Beryllium Be	Causes illness
Boron B	Ingestion of large amounts can affect central nervous system
Cadmium Cd	Causes illness (13 – 15 ppm)
Chromium	Carcinogenic
Copper	In large amount causes health hazard
Fluoride	Dose above 2250mg can cause death
Iron, lead, manganese and mercury	Serious cumulative body poison
(Sodium, Calcium, Magnesium Bicarbonate)	Serious cumulative body poison
Iron, Strontium, Potassium Carbonate)	Causes health hazard
(Nitrate, Boron)	Causes illness

Source: (Hamill and Bell, 1986)

2.7 Attenuation of Pollution:

The attenuation of a pollutant as it enters and moves through the ground occurs as result of four major processes:

(i) Biological Process: Soil has an enormous purifying power as a result of the communities of bacteria and fungi which live in the soil. These organisms are capable of attacking pathogenic bacteria and can also react with certain other harmful substances (Gibb and Hearn, 1980).

(ii) Physical Process: As water passes through a relatively fine grained porous media such as soil and rock, suspended impurities are removed by filtration (Gibb and Hearn, 1980).

(iii) Chemical Process: Some substances react with minerals in the soil/rock, and are oxidized and precipitated from solution. Adsorption may also occur in argillaceous or organic material.

(iv) Dilution and Dispersion: The traditional method of disposing of effluent has generally been to dilute it with a large quantity of relatively pure water so that the concentration of the pollutant eventually becomes negligible at some distance from the source (Cooper, 1989).

2.8 Source of Groundwater Contamination:

Some of the major sources of these contaminations are:

(a) Storage tanks;

(b) Septic tanks systems;

(d) Landfills;

(e) Chemicals, and

(f) Faulty well design and construction.

(a) **Storage Tanks:-**

Storage tanks may contain gasoline, oil, chemicals, or other types of liquids and they can either be above or below ground. It is estimated that over 10 million storage tanks are buried in Nigeria. After some time the tanks can corrode and crack and leakage can develop. If the contaminants leak out and get into the groundwater, serious contamination can occur, (Fuhriman and Barton, 1999).

(b) **Septic Systems:**

Septic systems can be another serious contamination source. Septic systems are for homes, offices or other buildings that are not connected to a city sewer. Septic systems are designed to slowly drain away human waste underground at a slow, harmless rate. An improperly designed, wrongly located, poorly constructed or maintained septic systems can leak bacteria, viruses, household chemicals and other contaminants into the groundwater causing serious problems (Ethler and Steel, 1978).

(c) **Hazardous Waste Sites:**

Abandoned and uncontrolled hazardous waste sites grow in numbers every year. Hazardous waste sites can lead to groundwater contamination if there are barrels or other containers lying around, that are full of hazardous materials. If there is a leakage, these contaminants can eventually make their way down through the soil and into the groundwater (Moriber, 1988).

(d) **Landfills:**

Landfills are another major source of contamination. Landfills are the sites where garbage is taken to be buried. Landfills are supposed to have a protective bottom layer to prevent contaminants from getting into the water. However, if there is no protective bottom layer or it is cracked, contaminants from the Landfill (car battery acid, paint, household cleaners, detergent, plastic etc.) can make their way down into the underground (Tchobanoglous and Thiesen, 1977).

(e) **Chemicals:**

Chemicals include products used on lawns and farm fields to kill weeds and insects and to fertilize the plants, i.e., insecticides, herbicides, pesticides and fertilizer (Warren, 1981).

(g) Other sources of groundwater 'contamination are human activities which include accidental spills, mining and atmospheric contaminants, acid rain, improperly planned groundwater development leading to salt water intrusion, and improper well construction and maintenance (Hamill and Bell. 1986).

2.9 Groundwater Water Quality

The quality of water is assessed in terms of its physical, chemical and biological characteristics. For example, distilled water is physically, chemically and bacteriological pure. A complete chemical analysis of a sample of groundwater includes the determination of the concentration of all the inorganic constituents present, the pH value, oxidation - reduction potential (ORP), hardness, chemical oxygen demand, alkalinity and acidity. Physical properties of a groundwater are colour, temperature, turbidity, odour and taste, (Krusenan, 1995). Bacteriological analysis consists of test to detect the presence of coliform organisms, which indicate the sanitary quality of water for human consumption. Coliform organisms are normally found in intestines or man and animals, the presence of these in groundwater is tantamount to its contact with sewage sources.

2.9.1 Bacterial Analysis:

Most pathogenic bacteria that are found in water are indigenous to the intestinal tract of animals and man. Bacteria of the coliform group are relatively easy to isolate and identify, standard tests to determine their presence or absence in a water sample are taken as a direct indication of the safety of the water for drinking purposes. Coliform test results are reported as the Most Probable Number (MPN) of coliform group organisms in a given volume of water (Fair, et al., 1988).

2.9.2 Physical Analysis:

In physical analysis of groundwater, temperature is reported in ^{0}C and measured immediately after collecting the sample; colour in groundwater may be due to minerals or organic matter in solution.

Turbidity is a measure of the suspended and colloidal matter in water, such as clay, silt, organic matter and microscopic organism (Freeze and Cherry, 1980). However, taste and odour may be derived from bacteria, dissolved gases, mineral matter or phenols.

2.9.3 Chemical Analysis:

Concentrations of the common ions found in groundwater are reported by weight in parts per million (ppm). This is the same as concentration in milligram per litre (mg/l). Chemical analysis involves the measurement of cation (metallic. ions), anions (non metallic ions), toxic and non-toxic compounds (Fair et al., 1988).

2.9.4 Water Quality Criteria:

Determination of the suitability of groundwater for a particular purpose depends on the criteria or standards of acceptable quality. Drinking water supplies in Nigeria conform to the standards established by WHO (World Health Organization, 1992). Concentration exceeding WHO standard of acceptable quality for drinking water can lead to health hazard.

2.10 Water Quality Parameters:

2.10.1 Colour:

Colour is important from the aesthetic point of view and it is measured in TCU. Water that is coloured is unpleasant when used for domestic and particularly for drinking as it always gives rise to doubt regarding its potability (Funk and McClenaghan, 1982).

2.10.2 pH:

pH value indicates whether the water is acidic or alkaline. pH values less than 7 indicate acidity and values greater than 7 indicate alkalinity. The regular measurement of pH is an essential factor in water treatment practice. In particular, it plays an important part in the efficiency of the coagulation process (Esca et al., 1995).

2.10.3 Turbidity:

It is a measure of the amount of suspended material within the sample and it is measured in NTU. Turbidity is related to transparencies and the acknowledgement of turbidity is an indispensable factor in water treatment (WHO, 1992).

2.10.4 Calcium:

The presence of calcium among the elements in order of abundance in water supplies result from passage through or over deposits of limestone, dolomite, gypsum and gysifeorous shale. Calcium content may range from zero to several hundred mg/l, depending on the source of the water (Hammer, 1977).

2.10.5 Total Hardness:

Total hardness is a measure of the capacity of the water for precipitating soap. Soap is precipitated chiefly by the calcium and magnesium ion commonly present in water. Hardness is defined as the characteristic of water that represents the total concentration of just the calcium and magnesium ions expressed as calcium carbonate. The hardness may range from zero to hundred of mg/l in terms of calcium carbonate depending on the source and treatment to which the water has been subjected (Fair et al., 1988).

2.10.6 **Iron:**

Iron ranks next to aluminum in abundance of metals in the earth crust. Natural waters contain variable, but minor amounts of iron. Iron's presence in water is observed from the stains imparted to laundry and porcelain and also the bittersweet, astringent taste, which may be detectable at level above 2mg/l (WHO, 1992).

2.10.7 **Manganese:**

Manganese in groundwater is generally present in the soluble divalent ionic form because of the complete absence of oxygen. The total manganese determination does not differentiate the various manganese valence states. If its presence is in excess of 1mg/l, it impacts objectionable and tenacious stains to laundry and plumbing fixtures (WHO, 1992).

2.10.8 **Copper:**

The presence of more than trace amount of copper in water may be attributed to corrosive action of water on copper pipes. Copper impacts a disagreeable colour and metallic taste to water. Copper causes severe gastro-enteritis (cumulative poisoning of brain, liver and kidney) at concentration higher than the lethal level (Esca, et. al., 1995).

2.10.9 **Magnesium:**

Magnesium is a common constituent of natural water supplies. It is an important contributor to the hardness of some waters. Magnesium salts back down on heating to form deleterious scale boilers if the concentration is in excess of 125mg/l, and can also exert a cathartic and diuretic action. Chemical softening treatment or ion exchange is employed to reduce the magnesium and associated hardness to a tolerable level. The magnesium concentration may vary from zero to several hundreds mg/l depending on the source of the water (Esca et al., 1995).

10.10.10 **Chlorides:**

Chlorides are present in all natural waters. Sources of these anions are numerous and these include many sedimentary rocks, oil field drainage, domestic and industrial wastes. High concentrations of chlorides in both surface and groundwater are often due to contamination from ocean and many brackish supplies.

The sudden increase of chloride in water above their natural level indicates pollution. A high concentration of chlorides imparts a salty taste to water. Chlorides have corrosive effects on various domestic and industrial equipment.

10.10.11 **Sulphate:**

Sulphate is mostly derived from evaporated sediments such as gypsum and anhydrite. Other sources are; oxide anion of sulphur containing organic compounds, sulphides and sulphite, sodium sulphate deposits and industrial waste. Certain cations, namely barium, strontium and lead, form fairly insoluble sulphate salts and significant concentrations are in the presence of these cations. Sulphate causes odour problem as it is converted to hydrogen sulphide under anaerobic conditions. Sulphate in excess of 250mg/l as magnesium salt may cause diarrhea or other disorder of the alimentary tract in person not accustomed to the water. The level of sulphate is important in determining the suitability of water for drinking (Ababio, 2002).

2.10.12 **Nitrate and Nitrite:**

These anions are usually found in water contaminated with nitrogenous materials, such as farmyard wastes, nitrite oxidized by bacteria and industrial wastes containing nitrite. The use of fertilizer may also add nitrate to both surface and groundwater. Groundwater may contain very high-level concentration of nitrate due to feacal pollution and several hundreds part per million in some cases. The presence of nitrate and nitrite causes disease called infantile cynopsis and it occur mainly in infants. The nitrite reacts with hemoglobin and formed methleglobin. Also, excessive amounts of nitrite may lead to prolific and objectionable growth of aquatic plants. Irrigation water containing nitrate generally stimulate plants growth because of the fertilizer value impacted by this constituents (Esca et al., 1995).

2.10.13 Chlorine:

This element is normally found in natural waters but can also get into natural water through sewage disposal from sewage plant treatment. It is also found in municipal water when it is used for water treatment to eliminate pathogenic organisms, chlorine itself is not harmful to man up to the concentration of 50ppm. But in water, it forms an active hypochlorite, which reacts with ammonia and organic matters to form chloramines, and chlorinated hydrocarbon, which are carcinogenic (Nelson-Smith, 1986).

2.10.14 Odour and Taste:

The taste and odour problems in water can be due to the presence of actinomycetes and certain species of algae. Odour can also be produced due to anaerobic oxidation of" some compound (e.g., sulphur containing compounds) by biological organisms, e.g., bacteria. These are subjective properties which are difficult to measure and affect the potability of water. However, they are due to dissolved impurities and leachates, often organic in nature,e.g., phenols and chlorophenols.

2.10.15 Biochemical Oxygen Demand:

Biochemical oxygen demand or BOD as it is often referred to, is a major indicator of water quality and is an important factor in water analyses. BOD is a laboratory estimation of the oxygen required for the biochemical breakdown of certain organic matter present in the water.

2.10.16 **Chemical Oxygen Demand (COD)**

The COD can be used to determine the organic load of a water body. It is a measure of the oxygen required when certain portions of organic matter undergo oxidation' by some strong chemical oxidant. Although it would be expected that the value of the ultimate BOD would approximate the COD, this is seldom the case. Some of the reasons for the observed differences are as follows:

(1) Many organic substance can be oxidized chemically but cannot be oxidized biologically;

(2) Inorganic substances that are oxidized by the dichromate increase the apparent organic content of the sample;

(3) Certain organic substances may be toxic to the microorganisms used in the BOD test; and

(4) High COD values may occur because of the presence of interfering substances.

2.10.17 **Fluoride:**

Fluoride is only sparingly soluble and is present in almost all natural waters only in small amounts. Its three major sources are:

(a) Elusion from rocks;

(b) Emission from one smelling and burning of fossils fuel and

(c) Deliberate addition to municipal water supplies.

Some groundwater contains sufficient fluoride to have obvious biological effect, such as mottling and pigmentation of the teeth of children who drinks it over a period of years. Fluoride concentration up to around 1ppm prevents dental decay, however, there is concern over its possible effects on adults. There is evidence that fluoride cause osteoporosis (demineralization) of bones with age. At high concentrations, fluoride is carcinogenic but real evidence is slight (Esca et al., 1995).

2.10.18 Phosphate:

Phosphates like nitrates are utilized by plants and usually found in significant concentrations in surface water. Sources of these anions include fertilizer, dissolution from phosphate rocks, and industrial effluents as wastes. The major sources are the urban and agricultural run off. At a concentration up to 0.01mg/l phosophate aids fish propagation by improving the growth of food organisms. However, at concentration above 0.01mg/l, it promotes algae growth in surface water, leading to entriphications (Linsley et al., 1992).

2.11 Choice of Source of Water Supply:

The choice of water supply to a community, town or city depends majorly on the following factors:

(i) Location;

(ii) Quantity of water;

(iii) Quality of water; and

(iv) Cost

The economic policy may lead to the adoption of both surface and ground water sources of supply of water to very big cities like Akure (Birdie, 1992).

2.12 Ground Water Withdrawal:

For community water supply systems, groundwater should be the preferred source. Surface water sources are very likely to be contaminated and much more subject to seasonal fluctuation. Groundwater withdrawal often can be continued long after drought conditions have depleted the rivers and streams.

The utilization of groundwater for community water supply is most likely and is still very much below its potential in many countries (Hofkes, 1983).

2.13 Pit Latrines:

The data on excreta disposal facilities in our rural and urban areas demonstrated that the problem of sanitation, which has adverse effect on our sanitation and groundwater, is urgent and desirous. As at today, three-quarters of rural and urban population in developing countries are still without good facilities, and therefore exposed to serious health hazard (Pacey, 1981).

The pit latrine is the simplest excreta disposal system, and one of the most efficient for existing rural conditions. It is economical, simple, but if not properly installed, it has varieties of hazards. It consists of three main parts: the dry pit, the superstructure and the squatting plate or slab floor, which is usually made of concrete. A pit measuring 1.0x1.0x4.0 metres (m^3) will accommodate the waste from a family of five people during a 3- 4 years period (Pacey, 1981). A satisfactory pit latrine should have the following quantities:

- Easy clearing;
- Comfortable use;
- Fly control;
- Easy handling;
- Supports for superstructures; and
- Concrete lining.

This method of excreta disposal has various names attached to them as a result of their methods of construction and the improvement carried out on it so far. Among them are:

(a) **The Trench Latrine:**

This is a very crude method of excreta disposal. It consists of a small shallow pit dug in the ground for the purpose of defecation. This is only suitable for emergency and temporary situations, such as temporary military camp and building site (Edwards, 1992).

(b) **Pit Latrine:**

The essential components of the pit latrine are a superstructure, a squat slab, and a pit or hole into which excreta falls. Pit latrine has been reported as the most widely used technique for excreta disposal in developing countries, and the cheapest and simplest option to construct (Parcy, 1981). The pit receives and retains excreta that are biologically digested and eventually rendered harmless (Carroll, 1981).

(c) **Bucket Latrine:**

The bucket latrine consists of a superstructure, a squat slab and a bucket located in a small vault below the slab. The bucket is emptied into a larger collection bucket or the full bucket is replaced with an empty one, for transportation to a treatment depot. The operation of bucket latrine is normally un-sanitary (Edward, 1992). The system may find good application in place where the re-use of excreta is customary (Pacey, 1981).

The British protectorate authorities presented bucket latrine system for urban sanitation in Lesotho in 1930, but this was eradicated in 1993 when people were persuaded to change to VIP latrines) (Blackett, 1994).

(d) **The Overhung Latrine:**

This consists of superstructure and floor built on piles, above water, along the bank of rivers and in coastal areas. It has been reported that overhung latrines were common features on ponds in Asia, Southern China, Indonesia (Edwards, 1992).

(e) **Composting Latrine:**

This is a modified pit latrine, which deals with excreta in a dry.

state. Composting toilet, sometimes referred to as the moulding toilet, needs to be regularly fed with vegetable matter and sometimes with wood ashes (Pacey, 1981). Composting latrine was reported to have been successfully used in Vietnam since 19561(Pacey, 1981).

(f) **Pour-flush Toilet:**

This is an improved pit latrine, with a water seal beneath the squat slab. This water seal entirely separates the pit and the latrine compartment, and prevents smells from getting from one into the other. From the investigation of Cairncross and Feachem (1983), it was discovered that, with pour-flush toilet, the very high water demand of the conventional cistern flushed system could be avoided, so that the toilet is flushed by pouring water from a jug or bucket by hand, with about 1-3 litres per flush as opposed to 10-20 litres per flush for most cistern - flush toilets. This type' of unit is believed to be best suited for public place like schools or community centers

(g) **Vault Latrine:**

This is a version of pit latrine where the removal of night soil or cartage is by buckets, carts or vacuum trucks. Edwards (1992) reported that this system was widely used in Europe and was still being practiced in Asia. In the Indian sub continent, transport was often by bullock-drawn cat, while mechanized transport system was employed for emptying the vaults in Japan, Korea and Taiwan (Pacey, 1981).

(h) **Aqua - privies:**

This system consists of a watertight tank under the squat plate, and the inlet drop pipe in the floor slab. Excreta are deposited directly into the tank. Rather than being flushed along pipe before reaching it. It was reported that aqua-privies were employed in Ibadan, Nigeria comforts stations, to solve sanitation problem (Oluwande, 1981).

(i) **Ventilated Improved Pit (VIP) Latrine:**

This is an improvement on the pit latrine, meant to reduce or eliminate odour and insect nuisance, by adding screened ventilation pipe to the chamber of a basic pit latrine. The advantages of ventilated improved pit latrine have been demonstrated in several countries, and a good many national and regional programmes have been started based on the technology. For instance, VIPs have been successfully developed and tested in Lesotho, Zimbabwe and Botswana. The Blair latrine, a form of VIP latrine, has been developed in Zimbabwe, by the Ministry of Health, as a means of improving the conventional pit latrine (Morgan, 1991).

(J) **Reed Odourless Earth Closet (ROEC):**

This is an off-set dry pit latrine. It was originally developed in South Africa, but has been used in Botswana for over twenty years. ROEC operates with fewer nuisances because of the configuration of a chute, which funnels excreta and urine into a chamber at the rear superstructure.

2.14 Septic Systems:

In developed countries where there is central sewage system, most populated areas are served by the municipal sewage disposal systems, and all their a homebuilder has to do is to tap into pipeline. But in rural and semi-rural areas, municipal sewage service is not available just like in developing countries like our; individual house-owner must install what is called on-site sanitation system, an individual household waste treatment system, a septic tank sanitation system or simply a septic system (Max and Charlotte, 1986).

Septic systems consist of an underground tank and a leach field or drain field that work to cleanse and purify household wastewater.

This practical, safe and effective system is currently used by more than half of the rural and semi- rural homes in the United States and Canada and in most modern homes in Nigeria, system usually requires no attention (there are exceptions caused by unusual site conditions). The tank can last indefinitely, depending upon its construction. The leach field will probably have to be treated or replaced after 10 to 15 years of service, occasionally sooner. The system is buried, odourless If installed and functioning properly, and it rarely has moving parts.

The figure below is an outline of a typical installation.

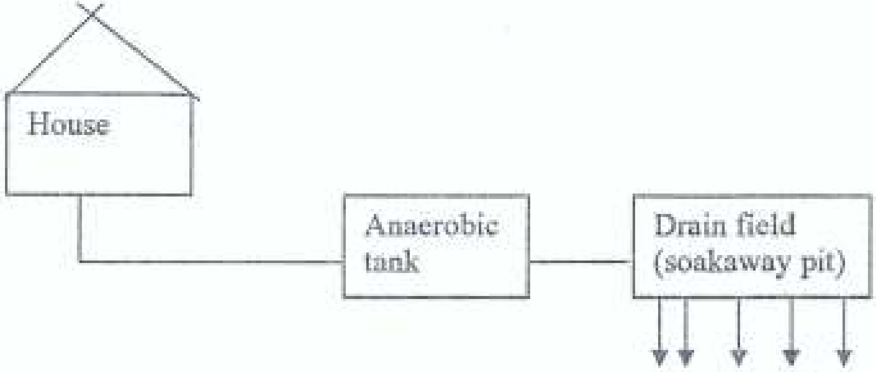


Fig. 2.1 Sketch of septic tank system

Sewage flows by gravity from the house to the tank. There the sewage stands for the time needed for anaerobic bacteria to break down the solids. In coming sewage displaces a like quantity of liquid which flows from the tank outlet by gravity. The displaced liquid is called effluent. The effluent enters the leach field or the soak away tank where it seeps into the surrounding soil. This action filters the liquid while aerobic bacteria further break down into various nutrients and chemicals that support plant life.

Approximately 50 percent of water coming down the sewer pipe is slightly polluted. This is water from the kitchen sink, the shower and the bathroom and this is called gray water. The balance is water used to flush the toilet, this is heavily polluted and it is called black water (Hofkes, 1983).

Humans excrete between 0.25kg and 2kg ounces of feaces everyday on the average. (Hofkes, 1983). The major contaminants are bacteria and nitrates, which are very harmful to man. The septic system, which consists of two-separate apartments or at times joins together with step in-between, is made up of septic tank and the soak-away pit. The common dimension of septic tank is 3.0mx2.4mx2.4m or 3.6mx3.0mx2.4m while that of soak-away pit is 1.2mx1.2mx1.5m. The tank is a large water tight, light tight and relatively airtight container positioned beneath the ground level or sometimes protruding slightly above the ground level (Max and Charlotte, 1986).

The sewage is carried to the tank by an extension of the house main drain, the sewer line. A second pipe leads from the opposite side to the leach field or the soak away pit. The soak away pit consists of loose materials and broken pebbles or blocks to ease the soaking away of the effluents in all the five dimensions. Effluent movement in the pit is by gravity. Whenever there is any sign of odour or usual dampness, it is a mark of failure of the system.

The effluent that flows from the tank outlet is still septic. It contains substances that promote the decomposition of vegetable and animal matter as well as pathogens, bacteria and viruses harmful to man.

The effluent cannot be dumped. It must be treated; or disposed at a safe venue. The soakaway pit serves as a disposal unit, which functions natural water –self-purification system (Max and Charlotte, 1986)

When wells are located close to septic tanks, there is evidence of pollution to a varying degree, which is a function of depth of the well, location of the well relative to these septic tanks systems in terms of distance, topography and the characteristics of the' soil particles. In Akure, Nigeria, where a normal standard plot is 18m x 36m, almost all the wells located in the premises could not satisfy the normal standard distance of 30m from any existing septic system, hence research must be carried out on these wells to ascertain their water quality and determine the level of pollution caused by these on-site sanitation system to safe guard the inhabitants from health hazards that is likely associated with such wells.

2.15 **Dug Wells**

Dug wells constructed by digging a hole in the ground. They are used in many countries with quite satisfactory performance if conditions are right. Usually no special equipment or skills are required for their construction. The diameter of a dug well should be at least 1.2m for two men to work together at the bottom of the well during the digging. For a well serving a single household or farm community, this minimum diameter of 1.2m usually adequate (Hofkes, 1983).

Due to their large diameter and volume, dug wells provide both groundwater withdrawal and storage. Because of the storage capacity, water can be temporarily withdrawn at a higher rate than the recharge inflow into the well. The storage effect is particularly important when the users take the water mostly at peak rates during a few hours in the morning and the evening.

The depth to which a well can and should be dug largely depends on the type of groundwater table. Important factors are the stability of the ground and the costs of digging. Private wells generally are less than 10m deep. Dug wells for communal use are frequently much deeper; 20 - 30m is not unusual and greater depths of 50m and more have been achieved (Hofkes, 1983).

Most dug wells need an inner lining. For this, materials are used such as brick, stone, or pre-cast concrete rings. The lining serves several purposes" During construction, it provides protection against caving-in and collapse and prevents crumbling ground from filling up the dug hole. After completion of the well), it retains the walls. In consolidated ground (e.g., rock) the well may stand unlined but a lining of the upper part is always to be recommended.

In consolidated ground formations, the well should be lined over its entire depth. The section of the well penetrating the aquifer requires a lining with openings or perforations enabling the groundwater to flow into the wells.

In fine sand aquifers, it is impossible to provide a lining with openings or perforations small enough to retain the fine sand and prevent if from passing into the well. In such cases the lining is frequently extended over the entire depth of the well only through the bottom, which is covered with several layers of gravel keeping down the fine sand of the water - bearing formation. For example, three layers of graded gravel, each 15cm thick, may be used with grain sizes of 1-2mm effective if the well is open, because the water in it will then be polluted anyway, especially if the water is drawn using bucket-and-rope. As a minimal provision, the well lining should be extended at least 0.5m above the ground to form a "head wall" around the outer rim of the well. A concrete apron should them be constructed on the ground surface extending about 2m all around the well. The concrete apron also seals any fissures between the well lining and the walls of the excavated hole and so prevents polluted surface water from seeping into the well (Hofkes, 1983).

CHAPTER THREE

METHODOLOGY

3.1 Method of approach:

The following methods of approach were adopted for carrying out the study to meet the objectives of the research work, entailing the following activities:

(i) Reconnaissance survey of the Akure metropolis were carried out in order to collate background data and locations of wells.

(ii) Collection of water samples from the located wells.

(iii) Laboratory examination of collected water samples from wells for physical, chemical and biological analysis.

(iv) Analysis and interpretation of the data obtained and establishment of a model equation.

3.2 Research methodology:

The reconnaissance survey was first carried out after a careful study of Akure metropolis's map. The metropolis was divided into four zones. A total of fifteen wells taken at different locations in each zone where the septic tanks systems were being used and five isolated wells were equally located as control. (Fig. 3.2)

The orientation of the wells and their distances to the on-site sanitation systems were taken. The depth of the wells, the well water levels, environmental and drainage conditions were also measured.

3.3 Collection of water samples:

Sterilized bottles were used to collect water samples and labeled accordingly. The containers were first rinsed with the water and then filled, but not to the brim to prevent air from escaping from the sample and the temperatures were taken on site immediately. Other parameters were subsequently determined at the Regional water Laboratory, a Federal Government Agency at Alagbaka, Akure for physical, chemical and bacteriology analyses.

3.4 Test procedures:

The procedure adopted in the determination of the physical, chemical and biological parameters of the water samples are in accordance with the laid down procedures in the federal Ministry of water Resources (Regional Water Laboratory) handout for physical, chemical and microbiological analysis of water. The handout is an extract of standard method of examination for water and wastewater (Adams,1990 and Eaton,1995).Some of the procedures for examining each parameter are as stated below;

3.4.1 Total hardness:

1. 50ml sample was measured into a 125ml Erlenmeyer flask and 1-2ml drops of buffer solution were added.
2. 1-2 drops of indicator was added, the solution was then titrated with standard EDTA (Ethylene Di-amine Tetra Acetic Acid) solution

slowly, stirring continuously until the solution lost traces of reddish colour.

3. The reading was observed immediately the end-point was reached

3.4.2 Calcium hardness:

1. 50ml sample was measured into a 125ml flask
2. 2ml of 1M NaOH solution was added or a volume sufficient to produce a pH of 12-13.

3.4.3 Chloride:

1. 50ml of sample was measured into a conical flask
2. 0.05ml of K_2Cl0_4 indicator was added and titrated with 0.02 $AgNO_3$
3. The yellow colour of the indicator changed to reddish-brown tinge, which shows the end point. Also a blank test was carried out on the reagent with 5oml of distilled water sample.

3.4.4 Turbidity:

With the help of a turbid meter,the water sample turbidity were carried out, this was done after the turbid meter has been set to zero, with distilled water in the measuring glass The distilled water was poured away and filled with water sample and placed inside the turbid meter comparator. The turbidity value was read off directly from the turbid meter.

3.4.5 Alkalinity:

0.02M of the H_2SO_4 were pipetted into the burette of 50ml mark.50ml of the water sample was measured with the help of a graduated measuring cylinder. Two drops of methyl orange indicator was added to the 50ml water sample in the 250ml conical flask.

3.4.6 Temperature and Conductivity:

Temperature and Conductivity values were measured right at the Sampling points with an instrument known as HYDROCHECK CONDUCTIVITY METER.

3.4.7 Coliform(Bacteriological) test:

There are two basic techniques for counting the numbers of Coli form bacteria present in a sample of water viz:

1. The membrane filtration technique
2. The multiple tube fermentation technique. The former technique was used in this project.

   Media: M-endo agar was used. The medium was prepared according to manufacturer's instruction.

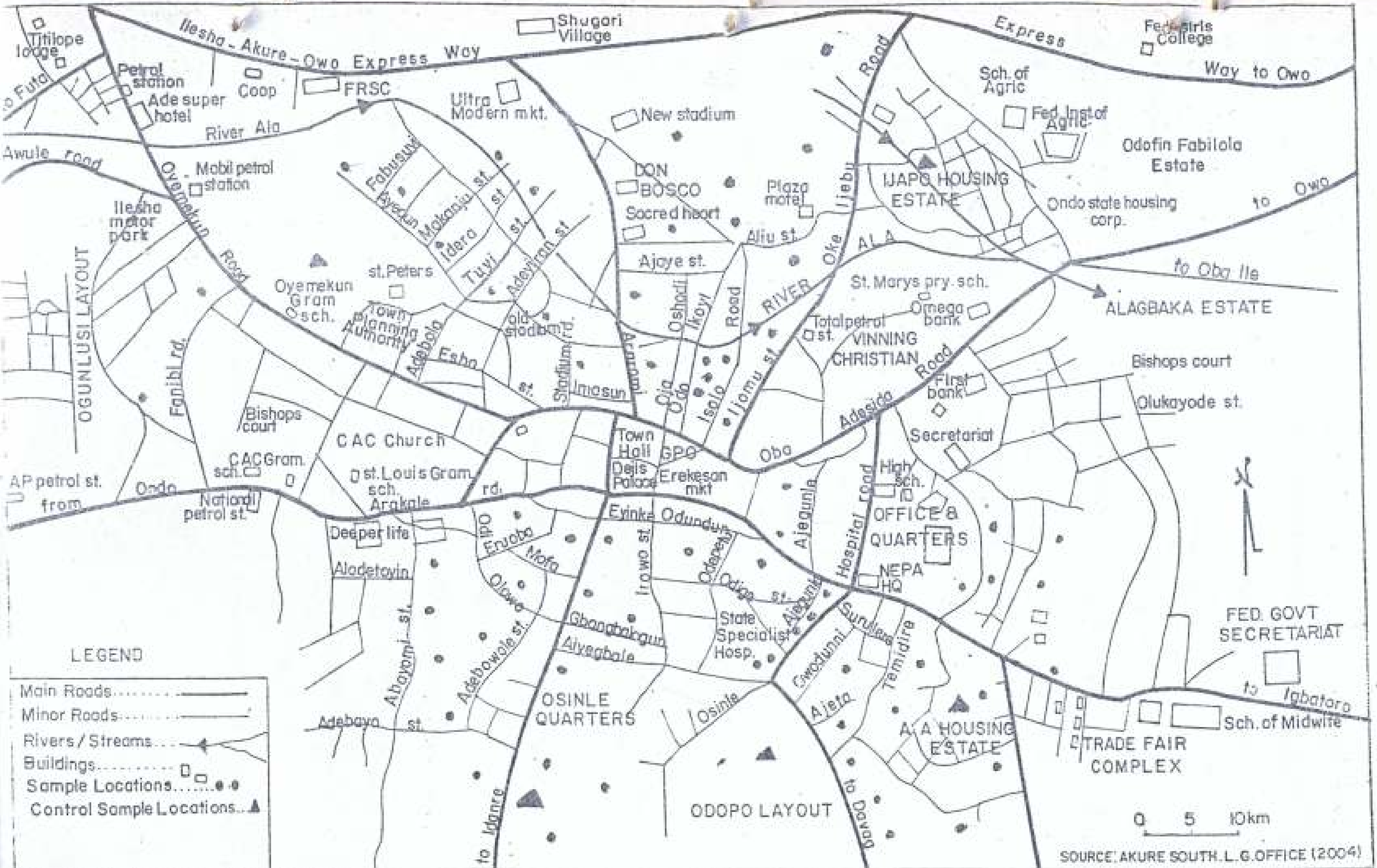


Fig. 3.2: The Location of the Study Area.

3.5 Engineering design of a standard disposal system:

During the reconnaissance survey of the study area for this research work, the dimensions of the septic systems in almost all the houses visited were observed to be similar. No consideration is given to the number or the population of those intended to use the buildings. This had led to the under sizing of some of the septic systems resulting in over-use and subsequent failure. Some have been abandoned for new ones. Investigation at the Ondo State Ministry of Works and Transport, Akure, Town planning Division revealed that inclusion of engineering design of septic systems that is based on population data has never been a condition for plan approval since there have never been an approved number of people that are supposed to occupy certain categories of buildings in any location. Another anonymous officer revealed that even if there was such an approved standard, since there was no monitoring unit to monitor the builders on site to know if the builders built according to the approved standard, such a standard of ensuring appropriate septic task system could not work.

Since over population is a major problem affecting the septic systems in the area, a model of engineering design of a standard septic tank and soak-away system of waste disposal which takes into consideration the likely probable numbers of people recommended for such a systems, is developed and presented in Appendix I

CHAPTER FOUR

DATA ANALYSIS AND RESULTS

4.1 Physical, Chemical and Bacteriological Quality of Sampled Wells:

The results of physical, chemical and bacteriological quality of sampled wells (W_1, W_2..................W_{60}) in Akure metropolis are presented in Appendix III.

The depth of each well and the distance to the on-site sanitation systems were indicated. The results of the samples analyzed were compared with the WHO standard for drinking water. For proper comparison, similar data were obtained for five control wells (W_{c1}, W_{c2}----------W_{c5}) located in different zones.

4.2. Data Analysis and presentation:

The typical result of the various water qualities parameter obtained for the wells are presented graphically in figures 4.1- 4.14. The distance from the sanitation system is considered as the independent variable, while the quality parameters are regressed against it to determine possible influence of the sanitation system on the quality of the well water.

4.3 Interpretation of Results:

4.3.1 pH

The pH values fall within the WHO standard (6.5 -9.2). Low pH of water gives rise to corroding metal containers and may leach mud pot to increase in concentration above permissible level. pH higher than 7.00 shows the presence of carbonates and bicarbonates as a result of contact with rocks and stones.

From the graph of the obtained data (Fig 4.1) there is no trend of pH value with distance. Thus pH of the water is not affected by the proximity of the well to the soakaway system / septic tank.

The pH of the infiltrating effluent may also have been relatively constant throughout the year just as that of the well water.

4.3.2 Temperature:

The values of the temperature obtained are within the WHO permissible level. There is no relationship between the temperature and distance (fig 4.2). Hence the temperature of the water is not affected by the sanitation system. Even the temperature of any hot effluent from the soak-away would have been attenuated through the percolation process before getting to the well.

4.3.3 Conductivity:

Electrical conductivity falls within the WHO standard with exception of well 22 which has a value of 1116mho which is above the permissible level.

However, the values obtained do not show any trend with distance. Therefore the conductivity of the water is not affected by how close the well is to the sanitation system. (Fig.4.3)

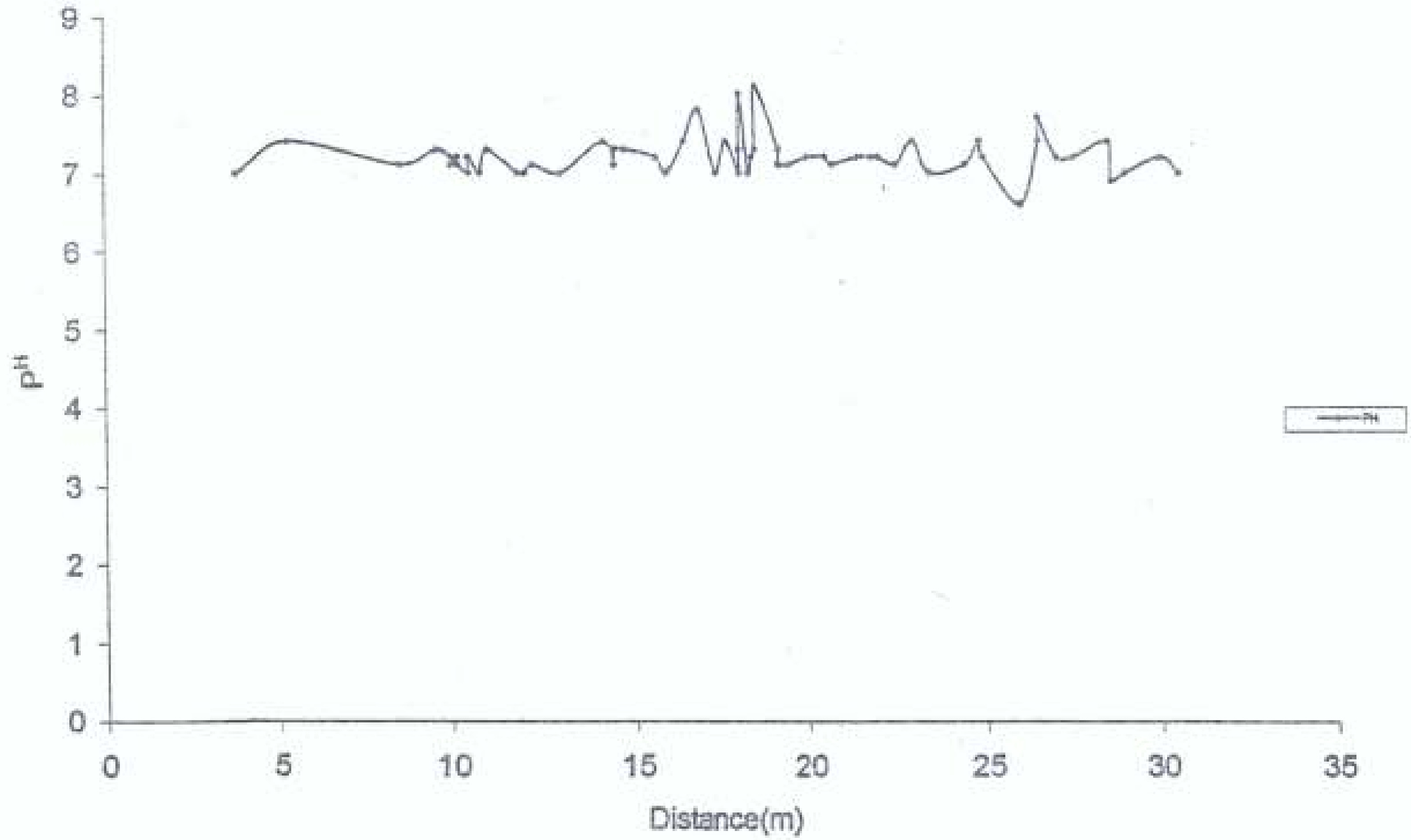


Fig.4.1: P^H vs Distance(m) from the sanitation system for the sampled wells

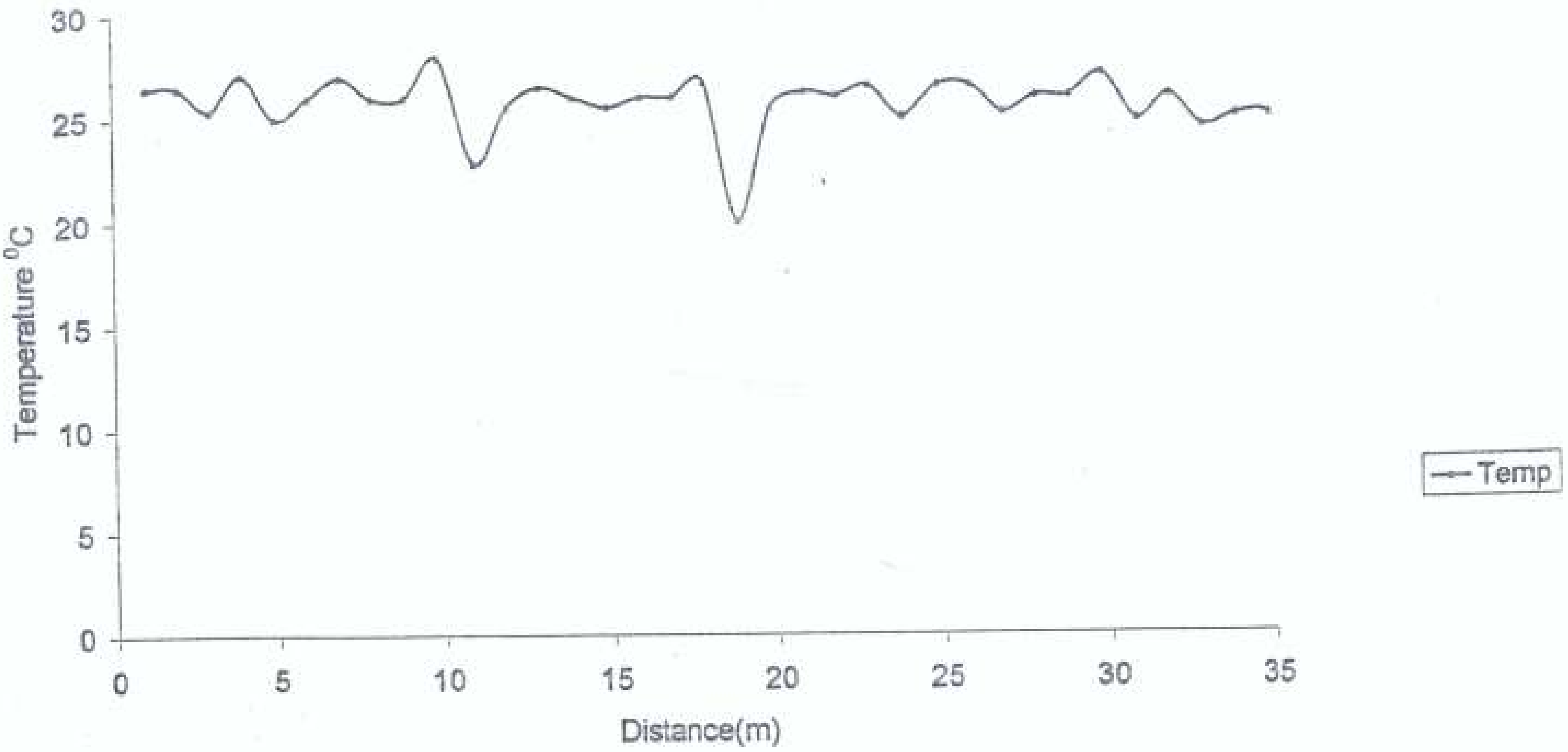


Fig.4.2: Temperature vs Distance(m) from the sanitation system for the sampled wells

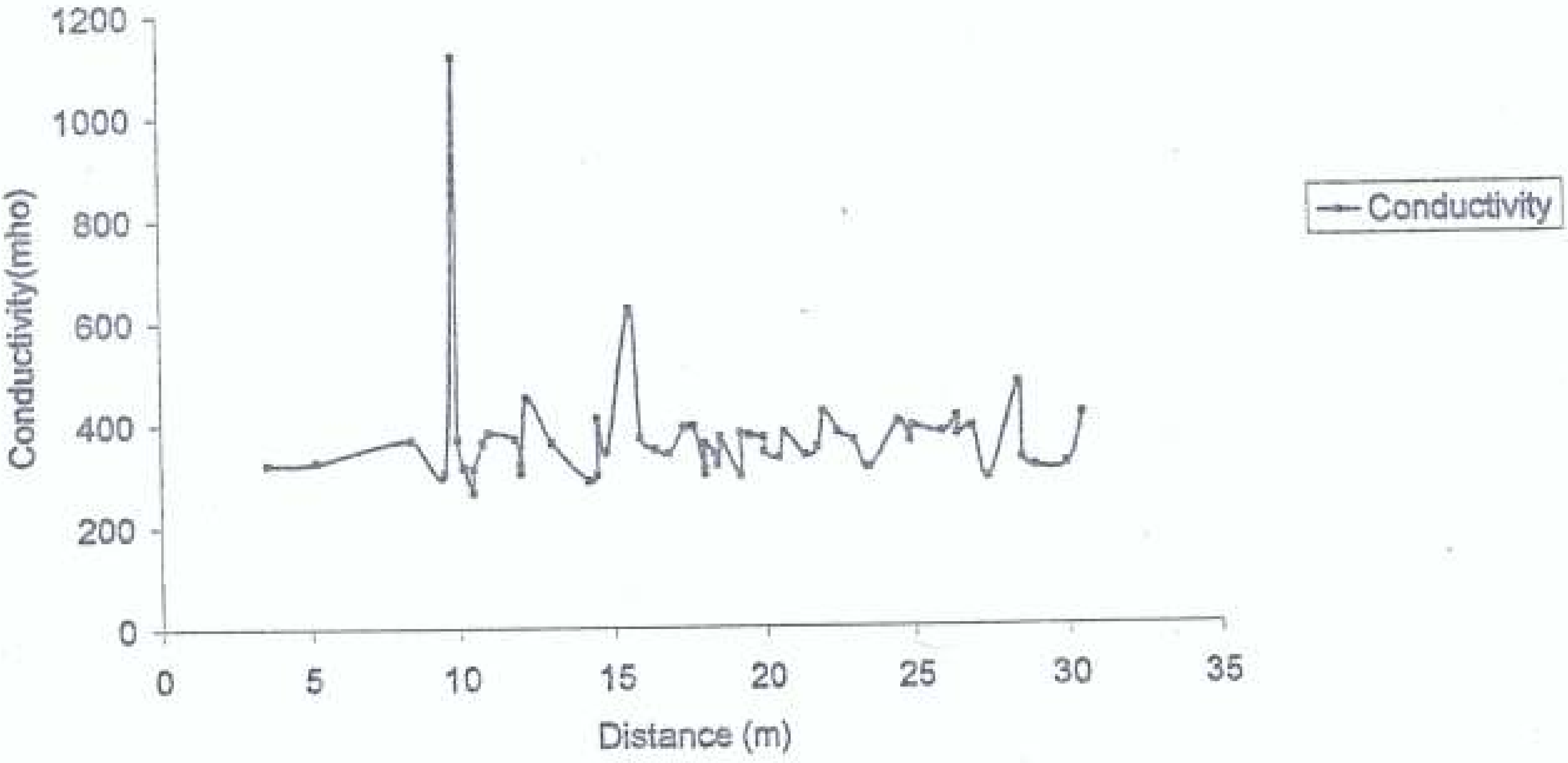


Fig.4.3: Conductivity vs Distance(m) from the sanitation system for the sampled wells

4.3.4 Chloride:

The chloride concentrations of water from the sampled well show that all the wells fall within WHO permissible level (250 – 600mg/l), except wells 1, 36, and 44 which have 629.37mg/l, 611.5mg/l and 793mg/l respectively. These points are nearest to the sanitation systems. The excessive concentrations apart from the natural mineral deposit, is as a result of leachate from sewage effluents which has a large concentration of chloride.

A close observation of chloride concentration of water from the wells versus distance to the sanitation system. Fig 4.4 shows that chloride concentrations of water from the wells are very high when the distance from the soak-away system is between 3.6m and 10.00m. There is a definite trend between chloride value and distance. Hence chloride is affected by distance of the water to the soak-away system, and is therefore a good indicator of the effect of effluent on the well.

4.3.5 Calcium Hardness:

The average results of calcium hardness from the chemical analysis ranges between16.9mg/l and 119.0mg/l, which is within the WHO permissible level. There is no health objection to calcium content in water. The main limitation being made on the ground of excessive scale formation. Its presence and level is an indication of the type of rock through which the water has passed normally in form of carbonate and bicarbonate. Fig 4.5 shows that even though the calcium hardness concentration are within limit in the sampled wells, wells with distances between 3.6m and 10.0m to the soak-away system has relationship in terms of trend between calcium hardness concentrations value and distance. Thus, calcium hardness concentrations are equally affected by the proximity to the soak-away system.

4.3.6 Total Hardness:

Total hardness concentrations of the sampled well water are in the average and fall within the WHO permissible level. It ranges from 30mg/l to 200mg/l.Fig 4.6 shows a similar observation with that of calcium hardness. Thus total hardness also exhibits a trend with the distance. Thus the soak-away effluent affects the well water.

4.3.7 Manganese:

Manganese is one of the earth's most common elements and forms highly soluble salt. It contributes to both carbonate hardness of the water usually at a concentration considerably lower than that of the calcium components. The manganese concentrations fall within the WHO permissible level, except wells 41 and 59 which have the values of 0.71mg/l and 0.61mg/l respectively. Fig 4.7 shows that there is no trend of manganese concentration with distance; hence it is not affected by the distance of the water to the soak-away. One can safely conclude that high manganese concentration is not present in the effluent.

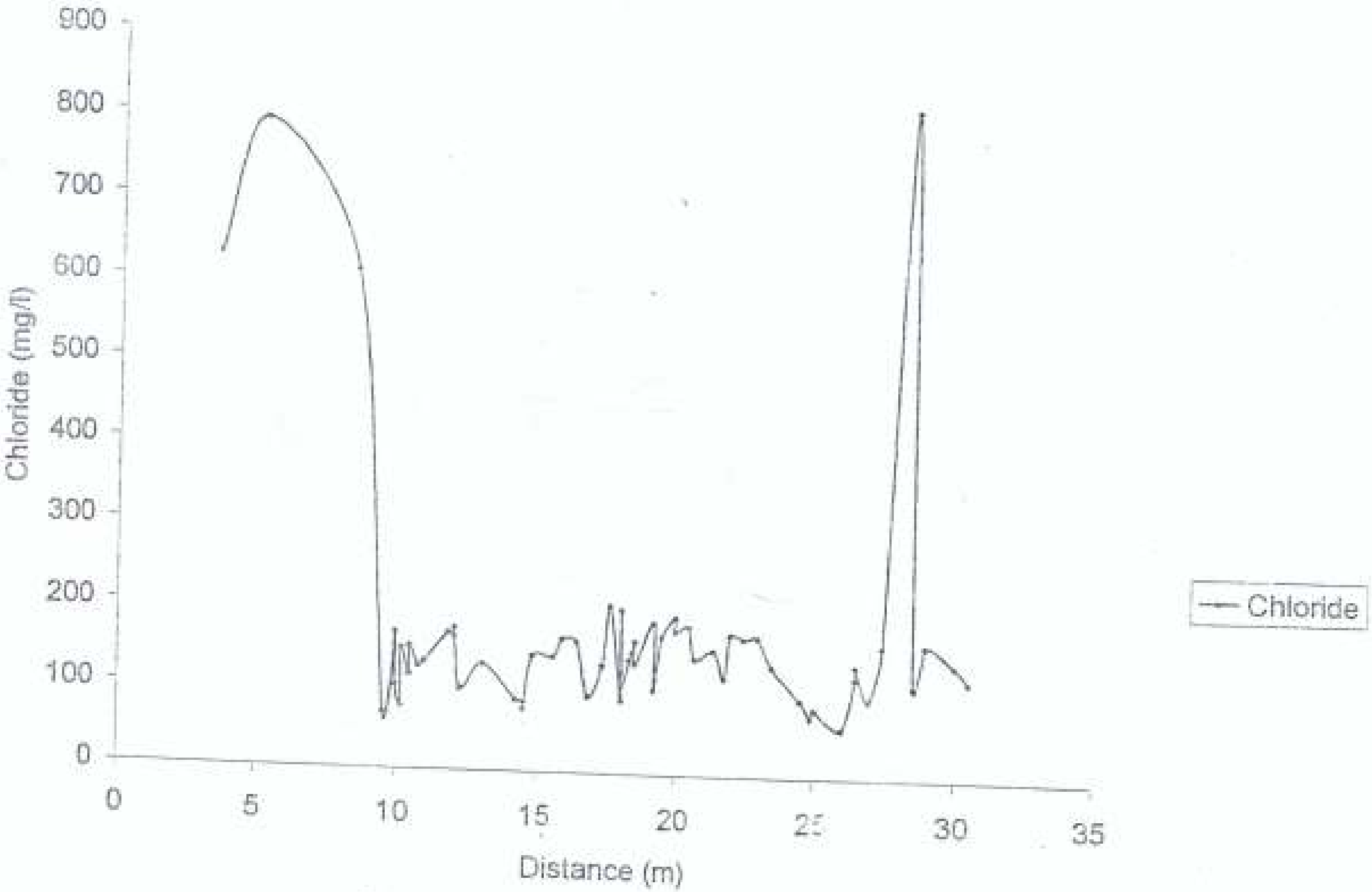


Fig.4.4: Chloride versus Distance(m)

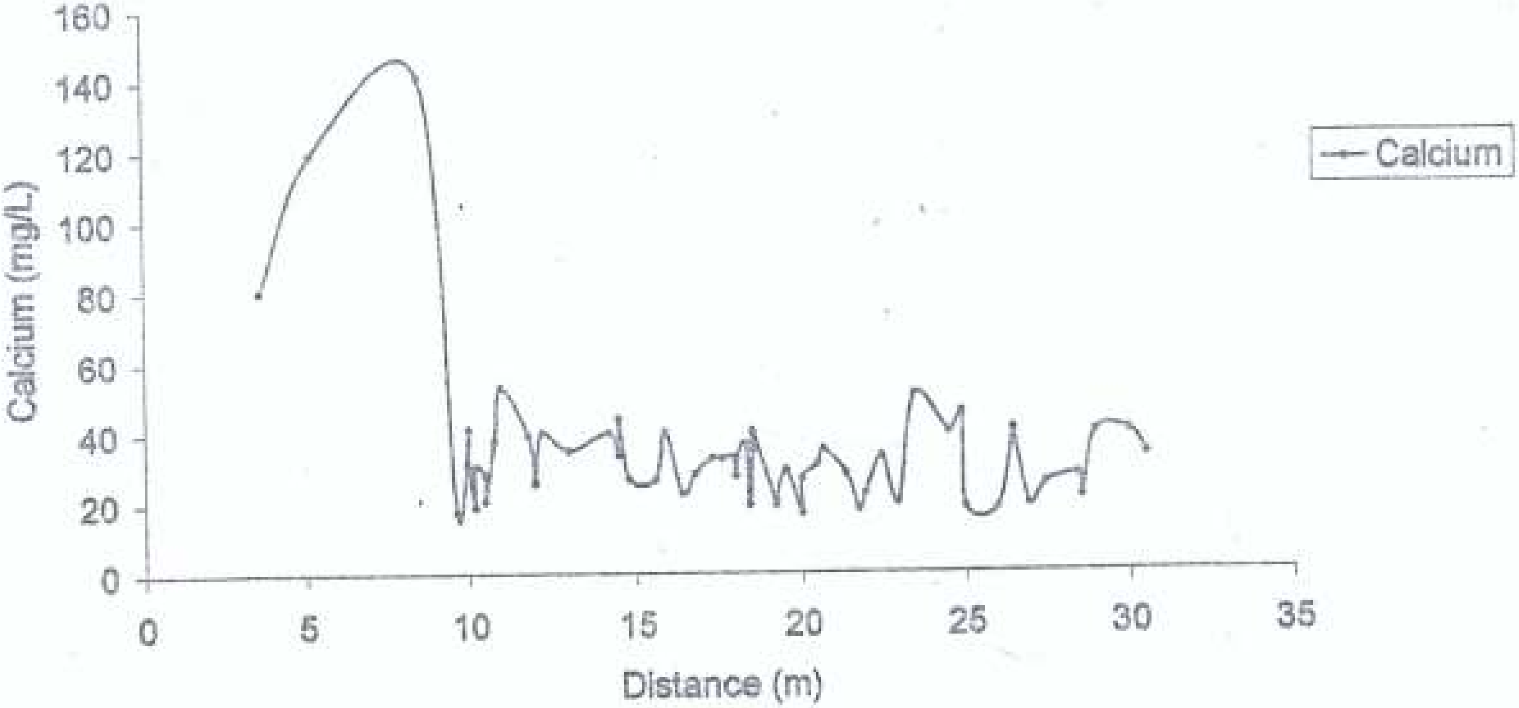


Fig.4.5: Calcium vs Distance(m) from the sanitation system for the sampled wells

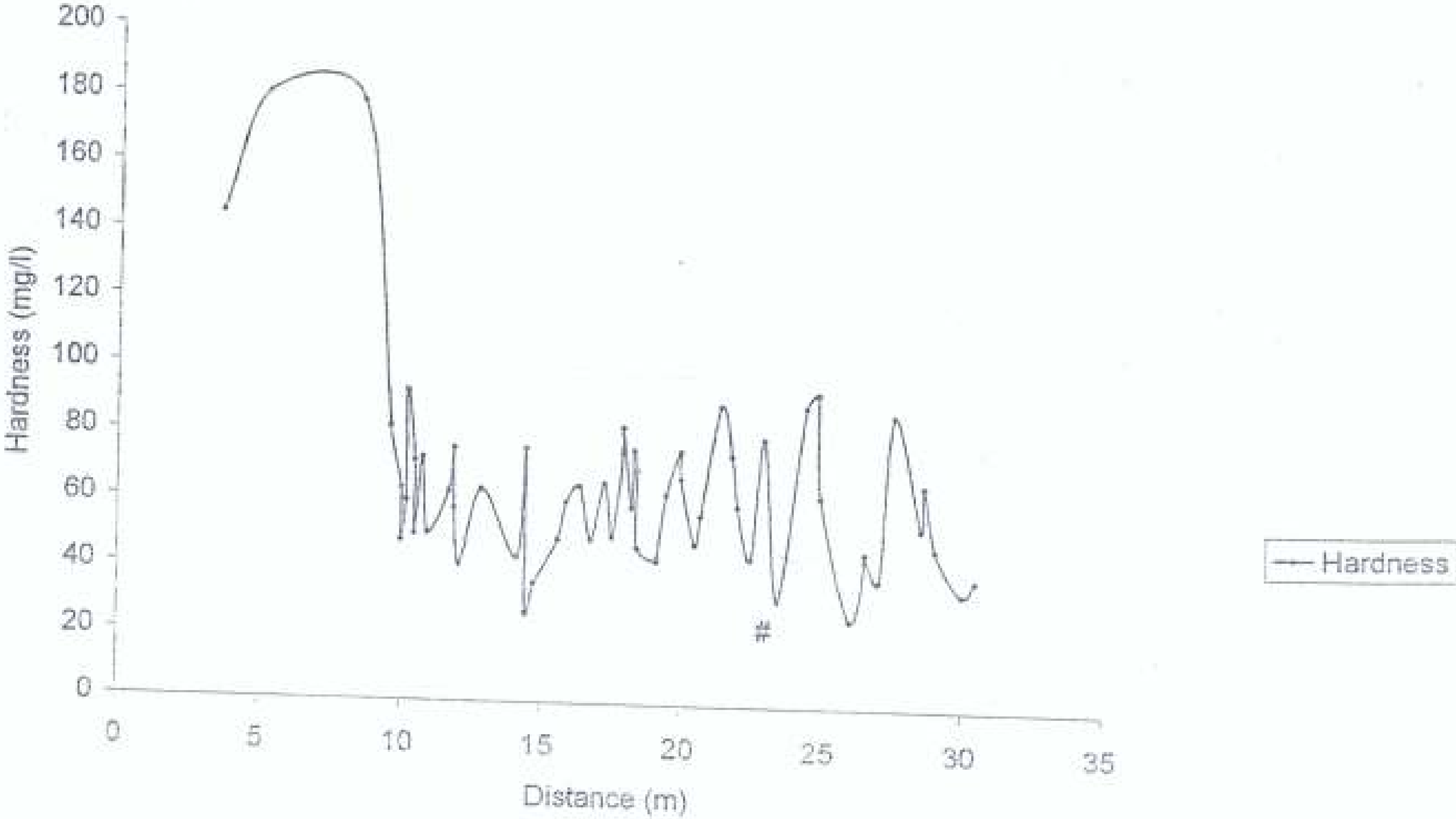


Fig.4.6: Hardness vs Distance(m) from the sanitation system for the sampled wells

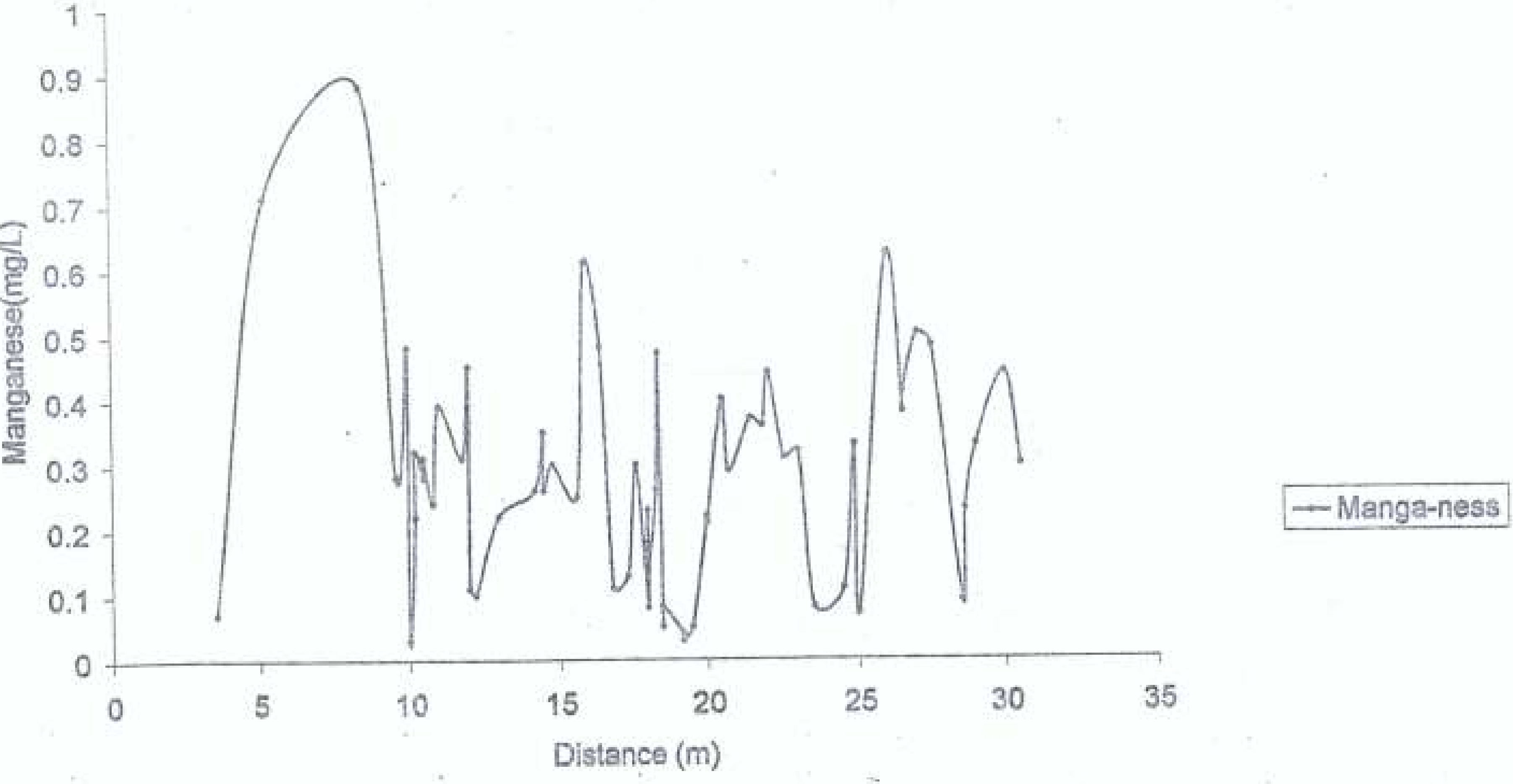


Fig.4.7: Manganess vs Distance(m) from the sanitation system for the sampled wells

4.3.8 Turbidity:

The average results of Turbidity from the chemical analysis ranges from 1.0mg/l to 10.0mg/l, which is within the WHO permissible level. Fig. 4.8 shows that there is no relationship with distance. Therefore the turbidity of the water is not affected by the distance.

4.3.9 Sulphate:

The overall results of the sampled well water show that three wells, wells 1, 36 and 44 have higher concentrations above the permissible level of the WHO standard with all other wells having their concentrations fall within. (it has values ranges between 1.0mg/l and 3.11mg/l). The higher concentrations of 435mg/l, 437mg/l and 471mg/l respectively is an indication of pollution from septic systems and detergent from the laundry activities which percolated and found its way into the wells. There is a definite trend between the sulphate concentration value and distance as shown in Fig 4.9. Hence, Sulphate concentration in the well is affected by the promixity to the soakaway system up to a distance of 10.0m.

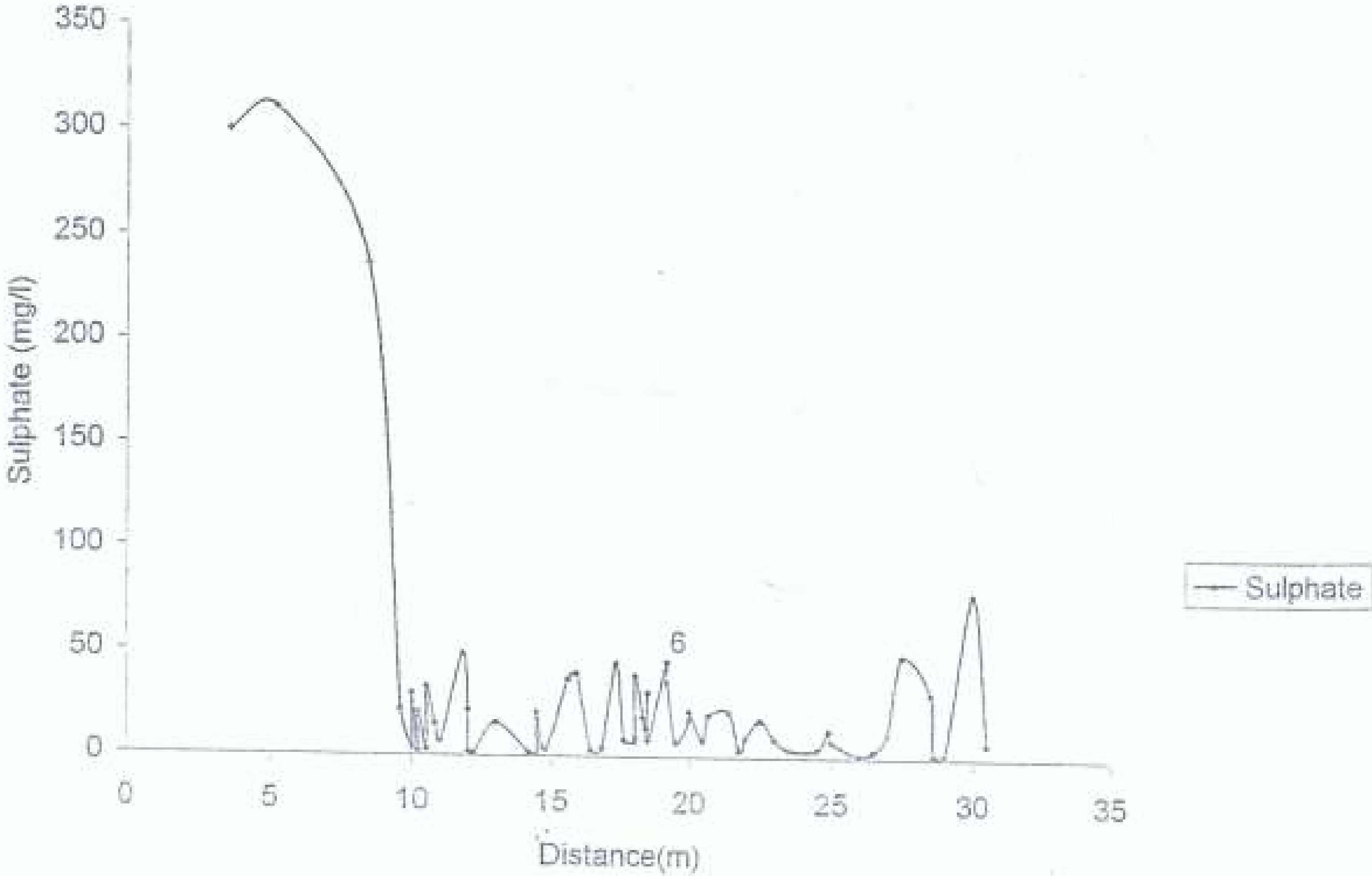


Fig.4.8: Sulphate vs Distance(m) from the sanitation system for the sampled wells

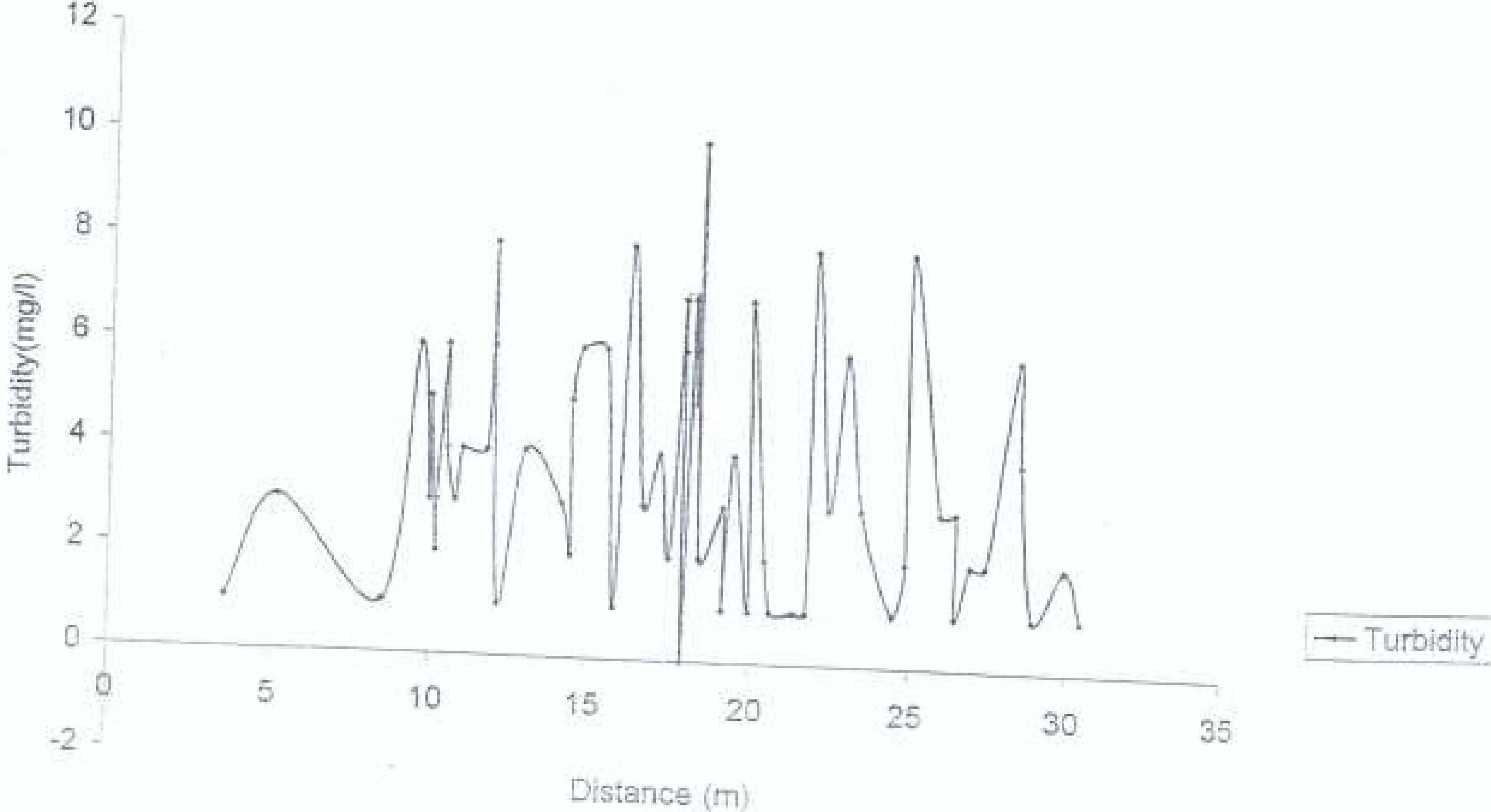


Fig.4.9: Turbidity vs Distance(m) from the sanitation system for the sampled wells

4.3.10 Nitrate:

The desirable level of Nitrate for public water supply is 50mg/l highest desirable level and 100mg/l as the maximum permissible level recommended by WHO.

In all the sampled wells, all fell within the WHO permissible level, except wells 1, 36 and 44, which have nitrate concentrations of 108mg/l, 110mg/l and 140mg/l respectively. This is an indication of nitrate pollution from the sewage and effluent from soak-away system which could have health hazard unless such wells are treated. There is a trend of nitrate concentrations with distance. The value of nitrate concentrations is affected by the proximity of the well water to the septic tanks. Fig 4.10 shows that there is trend of relationship as nitrate concentration relatively not seen from 14.0m distance and above to the septic tanks.

4.3.11 Phosphate:

The results of the chemical analysis shows that the phosphate concentrations in the sampled wells fell within the WHO permissible level except wells 1, 36, 44 and 51 which have 3.0mg/l, 3.0mg/l, 2.8mg/l and 0.07mg/l respectively. The presence of high phosphate will stimulate growth of algae, which can interfere with water treatment. The high phosphate level can be associated with leaching or movement of detergent through routine laundry activities and other household washing around the wells areas.

4.3.12 Colour:

The values obtained measured in TCU fall within the highest desirable level and the maximum permissible level of WHO standard. Fig 4.12 shows that there is no trend of colour value with the distance, hence, it is not affected by the distance to the sanitation system.

4.3.13 Coliform count:

The desirable level of coliform count for drinking water is 3.0 pcu highest desirable level and 10.0pcu as the maximum permissible level.

The results of the feacal coliform analysis shows that wells 1, 36 and 44 exceeded the maximum permissible level as recommended by the WHO with 15.0pcu, 15.1pcu and 18.5pcu respectively. The high level presence of coliform count is due to feacal contamination from the septic system. This was equally confirmed to be from the results of nitrate concentrations obtained from these wells.

There is a relationship in terms of trend between the coliform count value and distance. This coliform count of the sampled wells is affected by the distance of the water to soak-away system. Fig 4.15 shows that the coliform count is a function of distance up to 14.0m beyond which no trace is further observed.

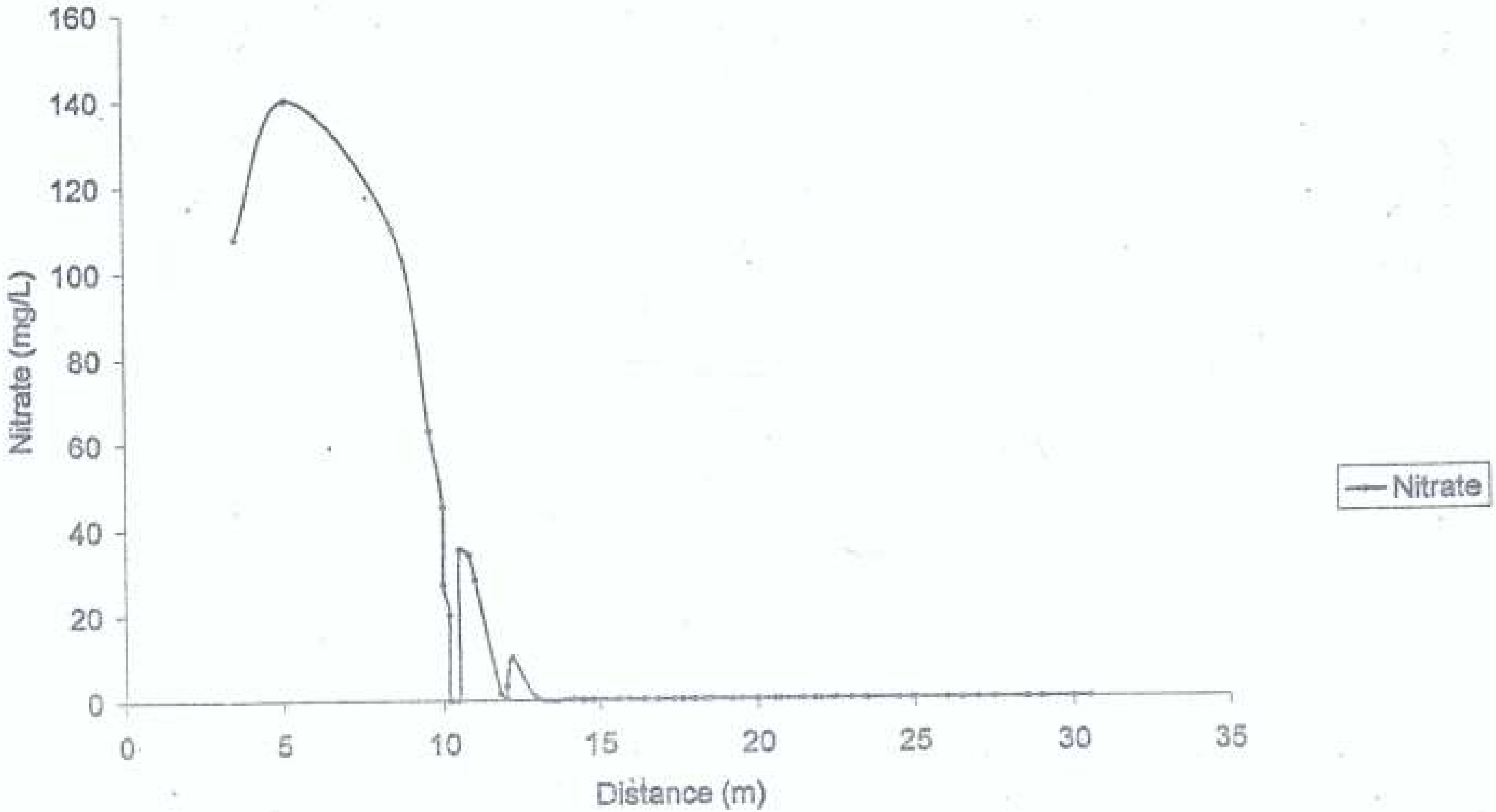


Fig:4.10: Nitrate vs Distance(m) from the sanitation system for the sampled wells

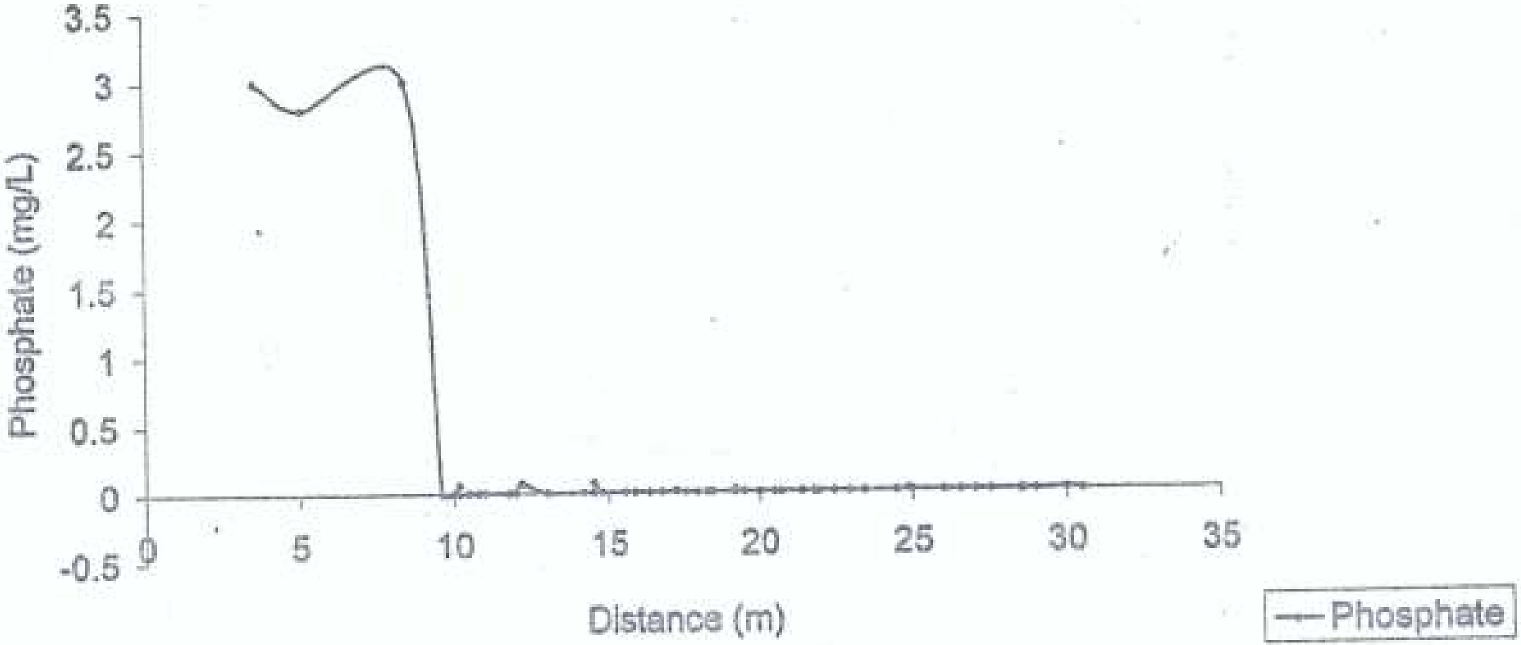


Fig.4.11: Phosphate vs Distance(m) from the sanitation system for the sampled wells

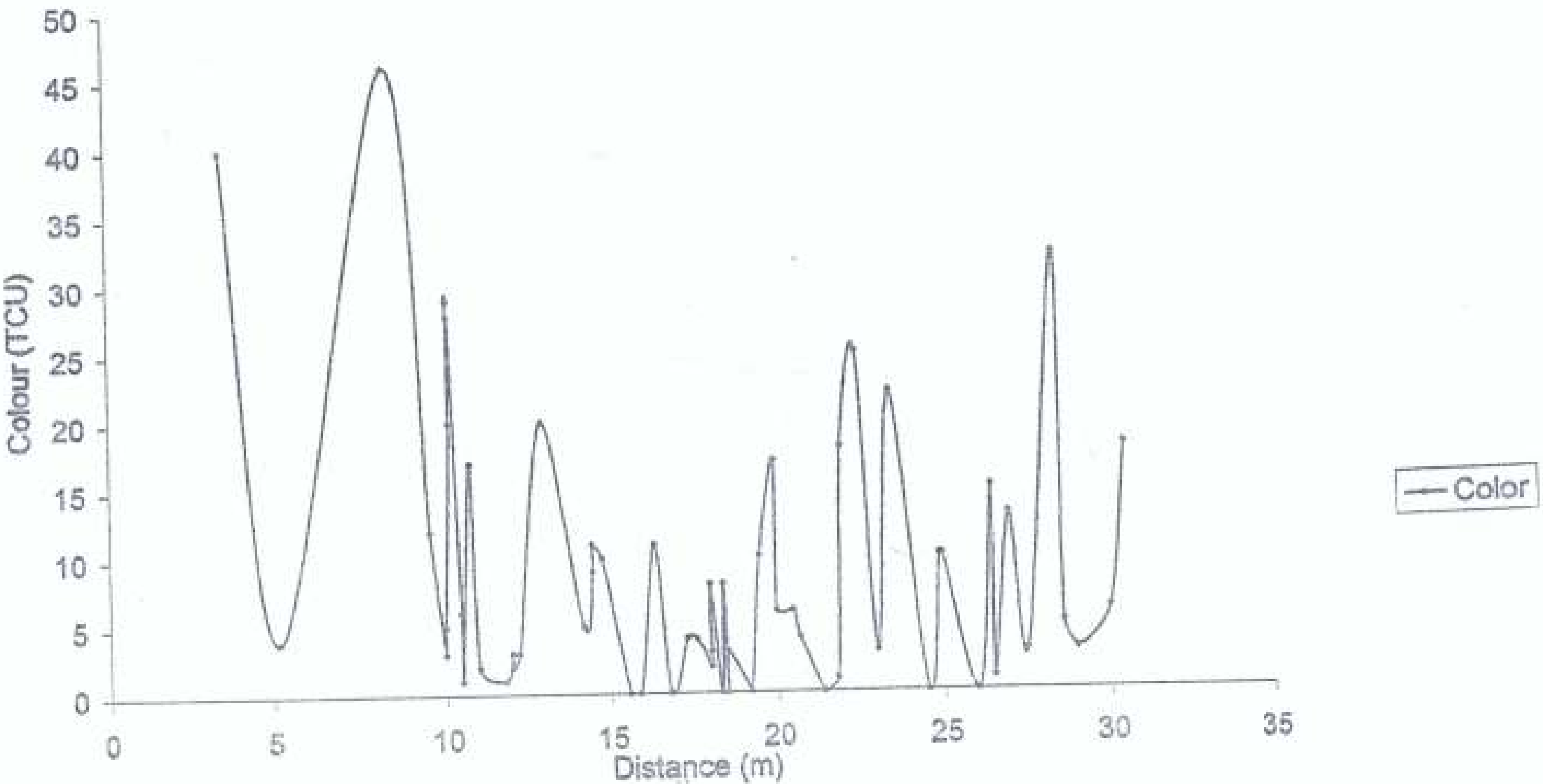


Fig.4.12: Colour vs Distance(m) from the sanitation system for the sampled wells

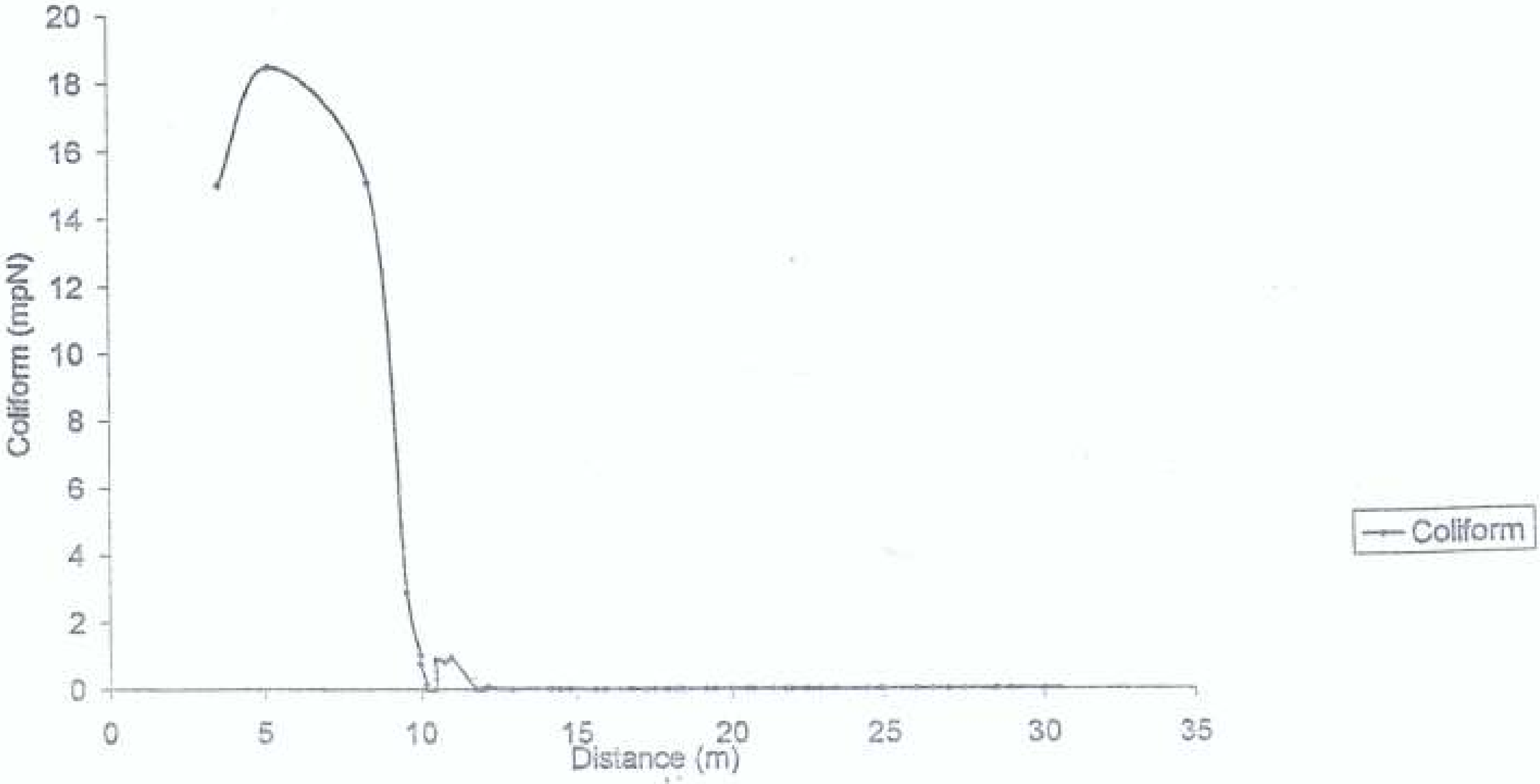


Fig.4.13: Coliform vs Distance(m) from the sanitation system for the sampled wells

4.3.14 Iron:

The WHO standard recommends 0.1mg/l as the highest desirable level and 1.0mg/l as the maximum permissible level. In all the sampled wells, the results of chemical analysis revealed that the Iron concentrations are within the permissible level of WHO. Fig. 4.14 shows that there is no relationship between the Iron concentrations and distance to the sanitary system. Hence the Iron concentration of the water is not affected by the sanitation system.

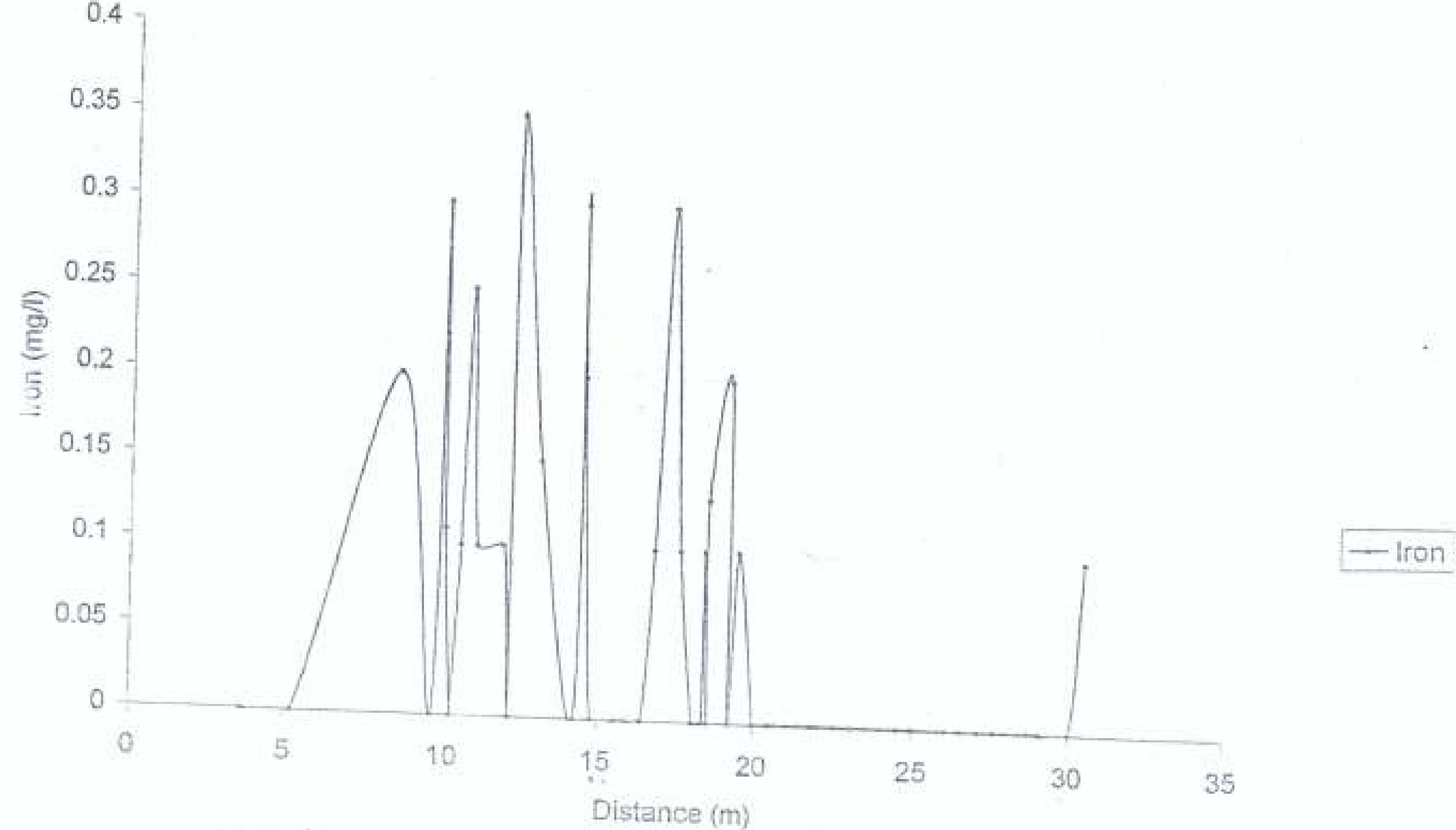


Fig.4.14: Iron vs Distance(m) from the sanitation system for the sampled wells

4.4 Formulation of Model Equations for Quality of well water vs Distance from the septic tanks:

Of all the parameters, nitrate, calcium, hardness, sulphate, chloride phosphate and coliform appear to give best indications of the relationship of proximity effect of the septic tanks. They are most amenable to modeling. The concentrations of these contaminants were used to formulate mathematical relationships with distance to the septic tanks for each well and model equations were obtained.

4.4.1 Nitrate;

Nitrate concentration has been used to formulate a mathematical relationship between concentration and distance. From the data obtained on nitrate concentrations in each well and its distance to the septic tanks, a model equation was formulated which follows a 3rd order polynomial distribution pattern in the form of

$Y = ax^3 + bx^2 + cx + d$... (4.1)

Where; y is the concentration of the well water and x is the distance of the well from the sanitation system.

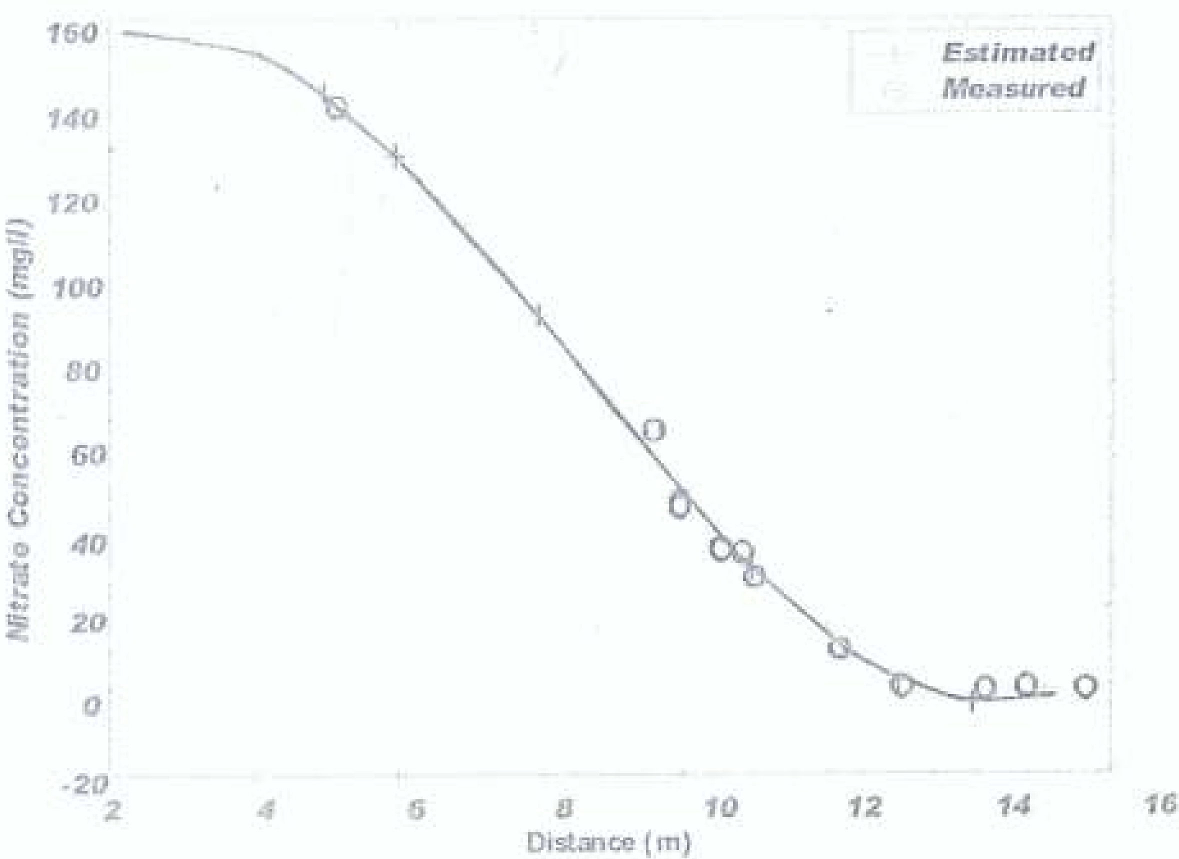
Regression analysis of the data gives the parameters of the equation as:

a = 0.2177, b = -5.6297, c = 27.3965, d = 119.5038

The coefficient of determination, $R^2 =$ 0.9025

The high value of R^2 shows that more than 95% of the variation can be explained by this relationship.

It can be inferred from the graph that the concentration distribution with respect to distance follows a 3rd order polynomial distribution pattern. (Fig. 4.15). It is also established that shallow wells located from 14.0m and above to the septic system are relatively free from pollution associated with the septic system.



Measured and estimated nitrate concentration Vs distance

Fig. 4.15

4.4.2 Chloride;

From the data obtained on chloride concentrations in each well and its distance to the septic tanks, a model equation was formulated which follows a 3rd order polynomial distribution pattern in the form of

$Y = ax^3 - bx^2 + xc - d$..(4.2)

Where; y is the concentration of the well water and x is the distance of the well from the septic tanks.

Regression analysis of the data gives the parameters of the equation as:

a = 3.11, b = - 80.657, c = 562.33, d = - 452.24

It is established that shallow wells located from 12.0m and above to the septic tank system are relatively free from pollution associated with the septic system. (Fig.4.16).

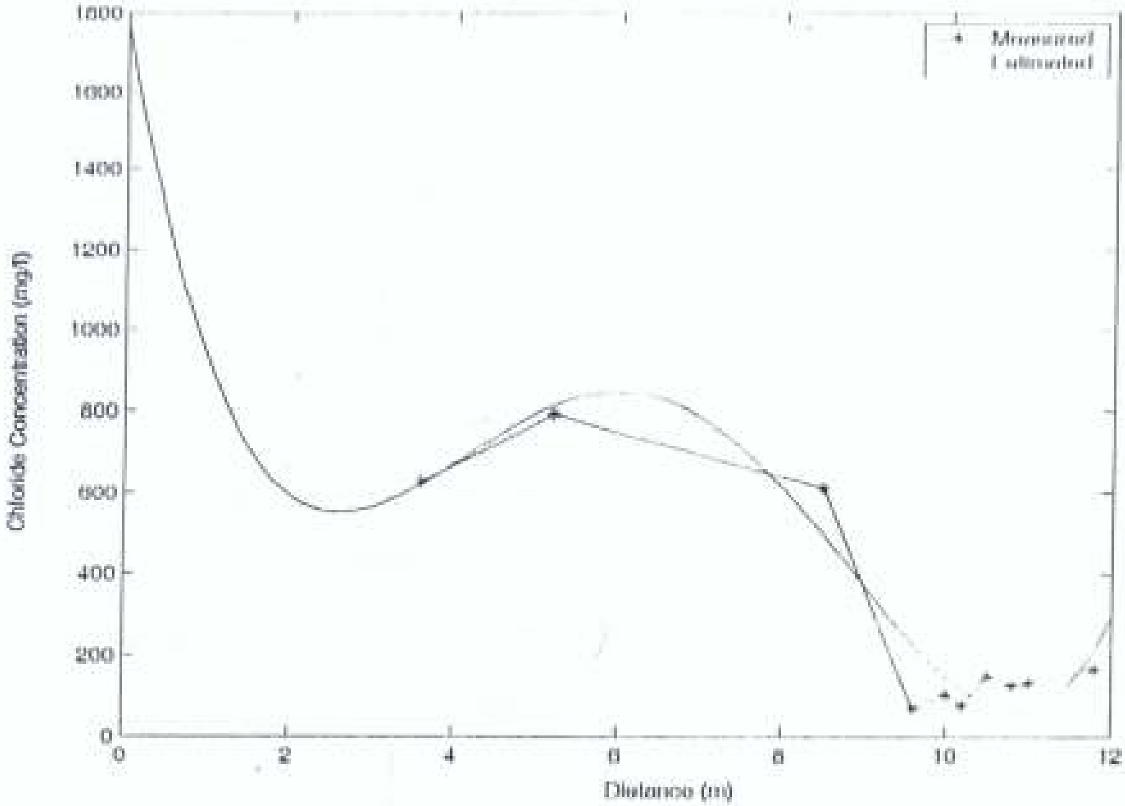


Figure 4.16; Measured and Estimated Chloride Concentration vs Distance

4.4.3 Hardness;

A model equation was formulated from the obtained data which follows a 3rd order polynomial distribution pattern in the form of

$Y = ax^3 - bx^2 + cx - d$..(4.3)

Where; y is the concentration of the well water and x is the distance of the well from the septic tank system.

Parameters of the equation as obtained from regression analysis are:

A = 0.7555, b = - 20.568, c = 157.38, d = - 187.49.

It is established that shallow wells located from 11.80m and above to the septic tank are relatively free form pollution associated with the septic tank system. (Fig. 4.17).

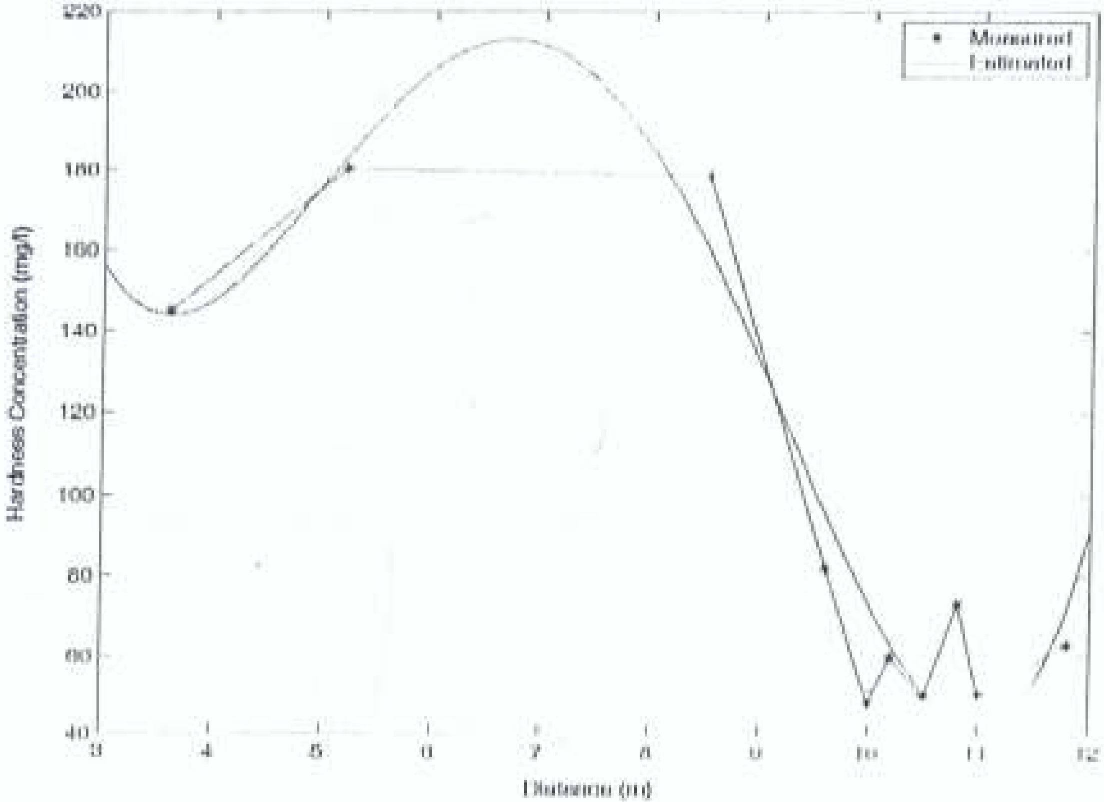


Figure 4.17; Measured and Estimated Hardness Concentration vs Distance

4.4.4 Sulphate;

Sulphate concentration was used to formulate a mathematical relationship between concentration and distance which gives a model equation which follows a 4th order polynomial distribution pattern in the form of

$$Y = ax^4 - bx^3 + cx^2 - dx + e \quad (4.4)$$

Where; y is the concentration of the well water and x is the distance of the well from the septic tank system.

The regression of the above equation gives

a = 1.1, b = - 30, c = 291, d = - 116.1, e = 1924.

It is established that shallow wells located from 11.80m and above to the septic tanks relative free from contamination associated with the septic tank system. (Fig 4.18).

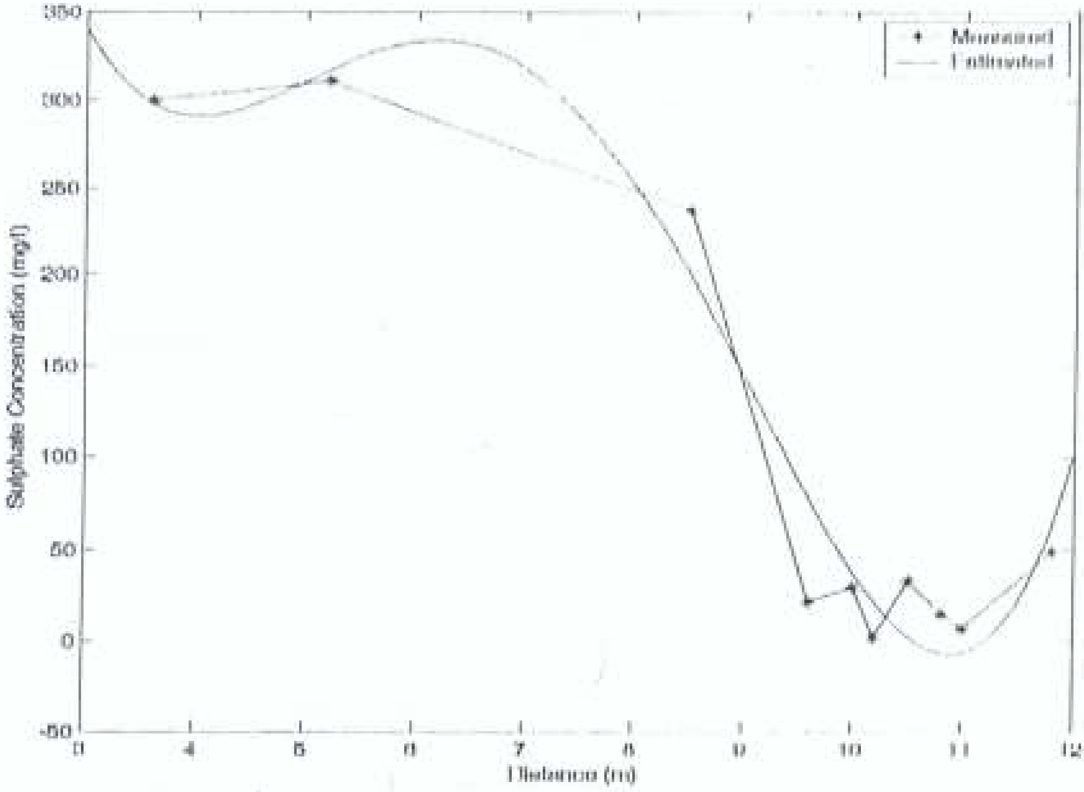


Figure 4.18: Measured and Estimated Sulphate Concentration vs Distance

4.4.5 Phosphate;

Phosphate concentration has been used to formulate a mathematical relationship between concentration and distance which gives rise to a 5^{th} order polynomial distribution pattern in the form of

$Y = - ax^5 + bx^4 - cx3 + dx^2 - ex + f$.................... (4.5)

Where, y is the concentration of the well water and x is the distance of the well from the septic tank system.

The regressed equation gives the parameters below:

A = - 0.0026, b = 0.1154, c = - 1.946, d = 15.32, e = - 56.14, f = 79.385.

From the graph, it is established that shallow wells located from 11.80m and above are relatively free from contamination associated with the septic tank system. (Fig. 4.19).

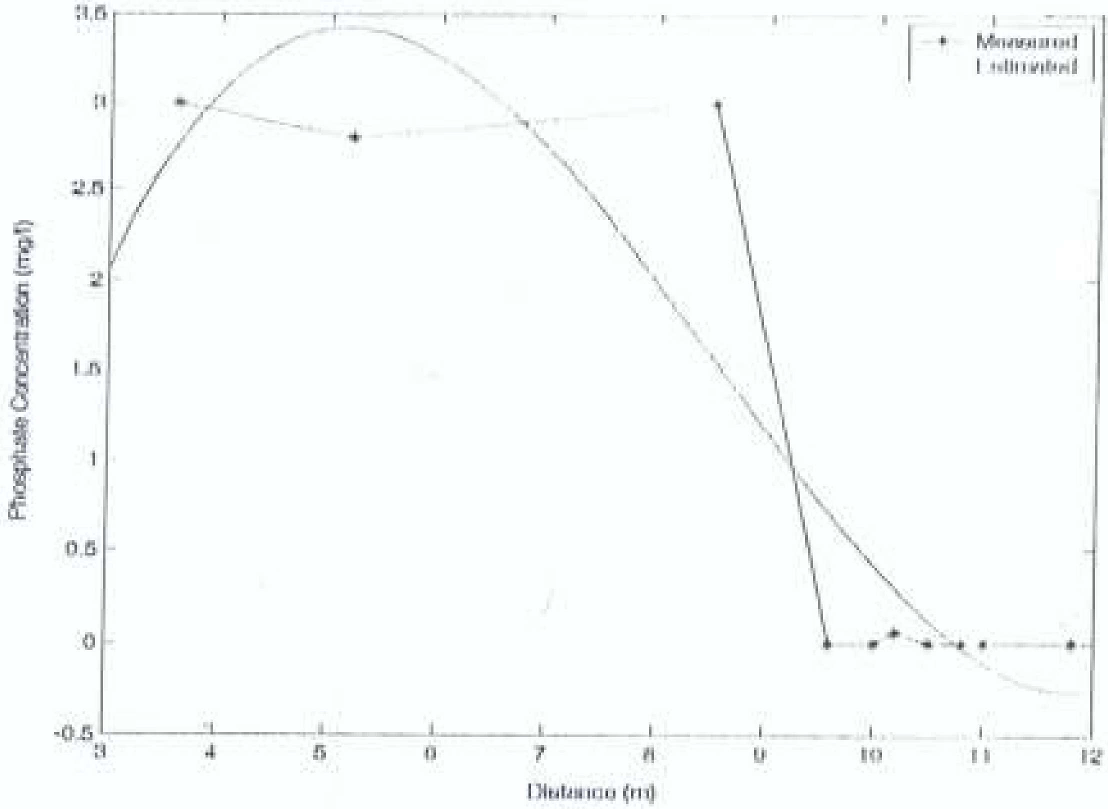


Figure 4.19: Measured and Estimated Phosphate Concentration vs Distance

4.4.6 Coliform;

From the data obtained on coliform concentration in each well and its distance to the septic tanks, a model equation was formulated which follows a 2nd order polynomial distribution pattern in the form of

$Y = ax^2 + bx + c$ ....(4.6)

Where, y is the concentration of the well water and x is the distance of the well from the septic tanks.

Regression analysis of the data gives the parameters of the equation as:

a= 0.094439, b = - 3.682, c = 30.927.

It is established that shallow wells located form 11.80m and above to the septic tanks are relatively free form pollution associated with the septic tanks. (Fig. 4.20).

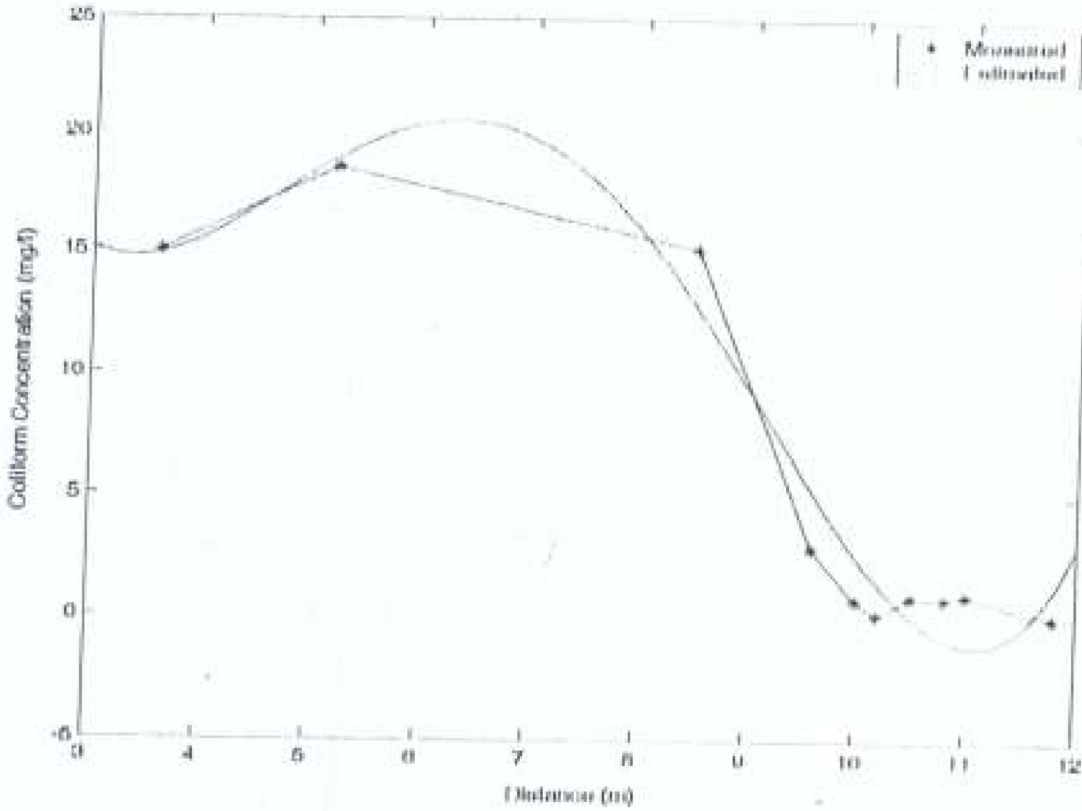


Figure 4.20; Measured and Estimated Coliform Concentration vs Distance

4.4.7 Calcium;

Model equation was formulated form the obtained data which follows a 3rd order polynomial distribution pattern in the form of

$Y = ax^3 + bx^2 + cx - d$........... ....(4.7)

Where, y is the concentration of the well water and x is the distance of the well from the septic tanks.

Regression analysis of the above equation gives the parameters as:

A = 0.7321, b = - 19.793, c = 155.17, d = 254.24.

From the graph, it is established that wells located from 11.80m and above to the septic tanks are relatively free from pollution associated with the septic tanks. (Fig. 4.7).

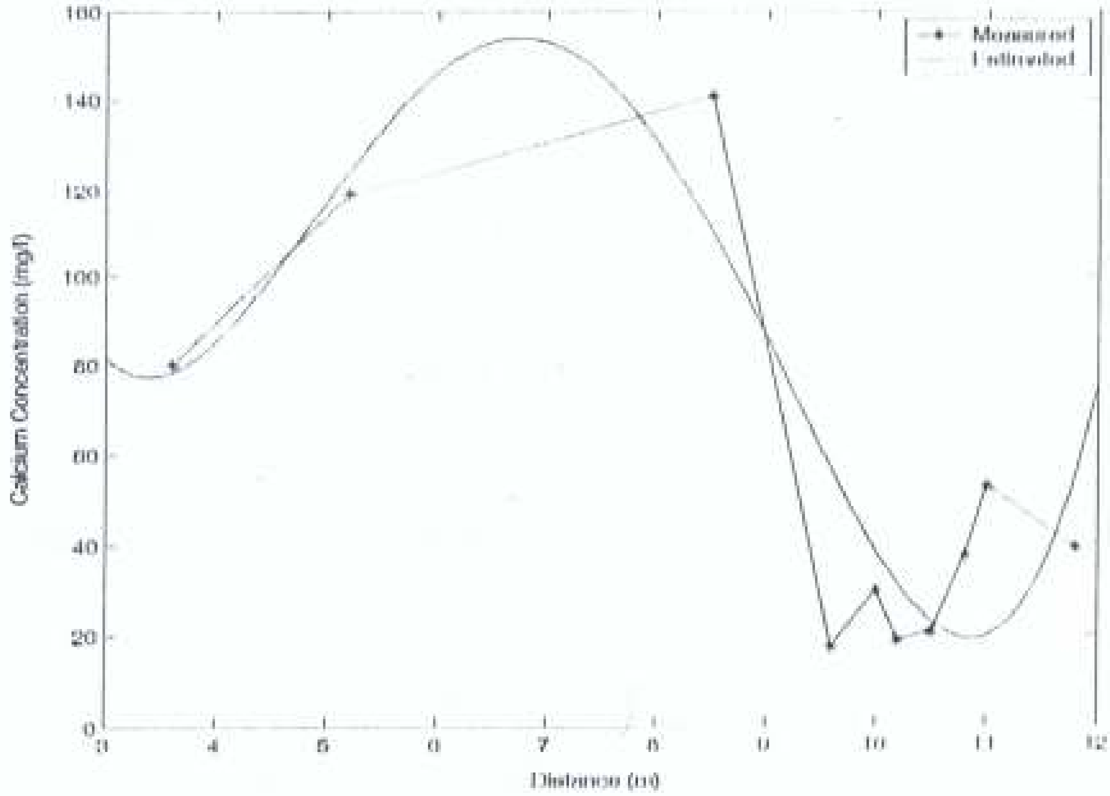


Figure4.21; Measured and Estimated Calcium Concentration vs Distance

CHAPTER FIVE

5.0 CONCLUSIONS AND RECOMMENDATIONS:

5.1 Conclusion

The objective of this project has been an exclusive study of groundwater contamination by septic tank systems of Akure metropolis in Akure South Local Government of Ondo State.

A comparison of the results obtained in the sixty-five sampled wells with the International Standard on potable water WHO, shows that wells 6, 11, 13, 14, 17, 19, 21, 22, 25, 27, 31, 41, 53 and 55 are contaminated, but the level of contamination is within limit with exception of wells 1, 36 and 44 which have contaminant concentrations exceeding the maximum permissible limit. These wells are closer to the septic tanks; they are located at lower elevations at relative short distances of 3.6m, 8.5m and 5.2m respectively. Hence leachate could easily migrate into them. Finally, seepage of untreated effluent migrated through the unlined, poorly constructed and poorly maintained wells.

5.2 Recommendations

In order to protect the general public from the health hazard. Associated with these contaminants, the following principles should serve as technical guides.

(i) From the model equation obtained, it shows that from 14.0m and above, no trace of nitrate pollution is seen on the sampled wells. Hence, it is recommended that a minimum distance of 14.0m should be allowed as the distance between the septic systems and wells in Akure metropolis.

(ii) Wells without concrete ring should be discouraged. Many have concrete ring lining, but the annular space between the ring and the well hole is not usually closed with cement mortar, such hole should be filled up.

(iii) Siting of wells within an adjoining buildings should be monitored and controlled so that wells will not be too close to latrines, soakaways or refuse dumping sites from the adjoining site or building.

(iv) As a minimal provision, the well lining should be extended to at least 1.0rn above the ground to form a "head wall" around the outer rim of the well. A concrete apron should be constructed on the ground surface extending about 2.0m all around the well to prevent polluted water *from* Seeping into the well.

(v) Since the analyzed samples require mild treatment in many cases, well chlorination should be encouraged and well monitored at a regular interval.

(vi) There is need to improve refuse collection and disposal management currently undertaken by the State Government in order to avert the long term ,risks of chemical pollution that may arise due to leaching and movement of refuse to water sources.

REFERENCES

Ababio, O. Y. (2002) New School Chemistry, senior Secondary Science series Africana – Feb Publishers Limited, Onitsha, Nigeria.

Abdel –Aziz, I. K. (1987). "Groundwater Engineering". McGraw Book Company, 2nd Edition. Pp 81 – 147

Arnold, P. (Edit) (1981). " Sanitation in Developing Countries" John Wiley and Sons Ltd. Chichester, England. pp 1 – 8

Cairncross, S. and Feachem, R. G (1983), Environmental health Engineering in the tropic: An introductory text.John Wiley and Sons L. t.d. Chichester, England.

Cartwight, K., Gilkeson, R. H., Griffin, R. A., Johnson, T. M., Lindorff, D. E., and Dumontelle, P. B. (1981). "Hydrogeologic Considerations in Hazardous Wastes Disposal in Illinosis", Illinois State Geological Survey, Environmental Geological. Note 94, 20 pp.

Darren, S. (1997). "Practical Development of Strategic Sanitation Concept". Pit Latrtine Network News Letter. Issue 3, November, GARNET, United Kingdom. p1.

Duncan, M. (1984) . " The Design of Ventilated Improved Pit Latrines" the World Bank, 1818H Street, NW Washington, DC, USA.

Edwards, P. (1992), Re-use of Human Wastes in Aquaculture: A Technical Review: UNDP-World Bank water and sanitation programme. Washington D. C. USA.

Eales, K. (1997). "Evaluation Indication for Projects." Pit Latrine Network News Letter Issue 3rd November. GARNET, United Kingdom.

Esca, B. (1995). "Analysis of Trace Elements in water" Electron Spectroscopic relant Phenol, pp 343-347.

Escritt, L. B (1972). " Public Health Engineering Practice" Fourth Edition, Volume II: Sewage Disposal. Macdonald and Evan Ltd., London.

Ehler, Z. H. and Steel, C. O. (1978). "Municipal and Rural Sanitation". McGraw Book Company United State of America, 6th Edition pp 201-305.

Fair, G. M. J, Gayer, J. C. and Okun, D. A. (1988), Water and Wasterwater Engineering, John Willey and Sons, New York, vol. 5 and 11.

Feachem, R., McGay, M., and Mara, D. (1978). "Water Wastes and Health in Hot Climate". John Wiley and Sons Ltd., Chichester, England

Fuhriman, D. K. and **Barton, J. R.** (1999) "Groundwater pollution in Arizona, California, Nevada and Utah", Report No 1600, E. R.U, for the Office Of Research and Monitoring, U. S. E. P. A., 249 pp.

Funk, G and **McClenaghan, W. A.** (1980). "Water Wells and Groundwater Supply". I. N. Onatario Inc., pp. 196 – 203.

Freeze, R. A. and Cherry, J. A., (1980). "Underground Water Quanlity Summary, Prepared by Illinois State water Survey, for the Illinois Environmental Protection Agency. 120pp

Hamil, L. and Bell, F. G. (1986), Groundwater Resources, Development, University Press Cambridge, U.K

Hamil, L. and Bell, F. G. (1986), Groundwater Resources, Development, University Press Cambridge, U.K

Hammer, M. J. (1977) "Water and Waste Water Technology". John Willey and Sons Inc. pp 99 150.

Hofkes, E. H. (1983). "Small Communities Water Supplies" International Reference Center for Community Water Supplies and Sanitation, Hague, Netherlands.

Howard, S. P., Donald, R. R. and **George,T.** (1985). "Environmental Engineering. McGraw Hill Book Company, New York.

John, M. K., DeAnne, S. J. and **Charles, G. G.** "Appropriate Technology for Water Supply and Sanitation" Issue, December 1990. International Water Supply and Sanitation Decade.

Krisno, N. (1981). "Criteria for Evaluating Excreta Disposal Tecchniques" Sanitation in Developing Countries. John Willey and Sons Ltd., Chichester, England. pp 43 – 48.

Krusenan, G.P (1995), Exploration and Development of Groundwater: A Water Resources of Reclamation, Washington.

Lindorff, D. E. and **Cartwright, K.** (1977). "Groundwater Contamination: Problem and Remedial Actions". Environmental Geological Notes II 81, Illinois State Geological Survey, 58 pp.

Linsley, R. K., Franzini, J. B., Freyberg, D. L and Tchobanoglous, G. (1992), Water Resources Engineering, McGraw Hill Inc. New York, 4th Edition).

Mara, D. (1976). "Sewage Treatment in Hot Climates". John Wiley and Sons Ltd., Chi Chester, England.

Max, P. and Charlotte, A. (1996) "Wells and Septic Systems". Tab Book **Ltd.,** 2nd Edition pp 3 – 10; 95 – 119, 171 – 185.

Millipore "Coliform Analysis" (1979). Millipore Corporation Bedford, Massaachusetts.

Moriber, G. (1988), Environmental Science, Allyn and Bacon Inc. Boston.

Morgan, P. (1991) "Rural Water Supplies and Sanitation. Macmillan Education Ltd., London.

Nelson – Smith, A. (1986), Water Pollution and Marine Ecology, Paw Eleck Scientific Books Ltd England.

Nigeria Water Sanitation Association. (2003) Manual on Waterfront and municipal Waste management, vol. 5.

Oluwande, P. A.. (1981), "The Potential of the Aqua-Privy: Nigerian Experience." Sanitation in Developing Countries. John Wiley and Sons Ltd. Chichester, England. pp 88 – 91.

Oteze, G. A. (1983), "Groundwater level and Groundwater movement", in Tropical Soils of Nigeria in Engineering Practice, by Ola, S. A. Bulking A. A. Publishing Ltd, Nigeria.

Palanichami, S. (2002) "Environmental and Groundwater Monitoring" A Journal of Ecotoxicology and Environmental Pollution, vol. 198, Washington D.C. 120 pp

Parcey, A (1981), Sanitation in Developing Countries. John Wiley and Sons, Ltd, Chichester, England.

Steiner, R. C., Fungaroli, A. A., Schoenberger, R. J and Purdonm, P. W., (1979), "Criteria for Sanitary Landfill Development, California Bureau of Public Works, vol. 102 (2), 79 Pp

Tchobanoglous, G. H and Theisen, R. E, (1977), Solid Wastes: Enginewering Principles and Management Issues, McGraw-Hill Inc. New York.

Tebutt. T. H. Y. (1983). "Principle of Water Quality Control" Pergamon Press, Toronto. 3rd Edition, pp. 42 – 79

Warren, L. J. (1981), "Contamination of sediments by Lead, Cadmium and Zinc. A review: Environmental Pollution", CRL Press Inc., USA,

Waterfront. Issue, April 1982 UNICEF Water Environmental Sanitation Team.

Watsan (2002), Profile of Akure metropolis.

WHO (1992), International Standard for Drinking water, World Health Organization, Geneva

WHO (1992), Drinking Sanitation: A Way of Health, World Health Organization, Geneva

Witold. R., Chongrak P. and Micheal. M. "Appropriate Technology for Water Supply and Sanitation" Issue, February 1982. International Drinking Water Supply and Sanitation Decade pp. 7 – 71.

Wright, A. M., Onusu, S. E and Handa, V. K. (1981). "Availability of Latrines in a Developing Country", John Wiley and Sons Ltd., Chichester, England.

Unran, G. O. (1981), "Water Seal Pit Latrine. Sanitation in developing Countries. John Wiley and Sons Ltd. Chichester, England pp. 104-106

APPENDICES

APPENDIX I

Design of ventilated improved pit latrines:

A.1.1 Introduction:

Excreta - related diseases are responsible for a large proportion of the morbidity and mortality in developing countries, especially among low - income communities in urban fringe and rural areas, where adequate water supplies and sanitation facili1ties are typically absent. Excreta control is thus of paramount importance in the incidence of these disease is to be reduced. (Mara, 1976) Excreta research sponsored by the World Bank has clearly shown that excreta - related diseases can be greatly reduced by:

(a) The provision of sanitary toilets of whatever type, which people of all ages will use and keep clean;

(b) The effective treatment of excreta or sewage prior to discharge or reuse;

(c) The provision of an adequate water supply so that water consumption is in the region of 30 to 50 litres per capita per day which is normally the minimum requirement for control of those excreta - related infections which have a water - washed mode of transmission; and

(d) An effective and sustained programme of personal hygiene education by the responsible local authority (Mara, 1976).

A.1.2 The Design:

(a) Volume:

The required pit volume depends on the solids accumulation rate, the number of users and the desired life of the pit. In practice, the pit must not be allowed to fill up completely (~ to the underside of the cover slab), so a small free space at the top of the pit must be allowed for in the design; usually 0.5m is sufficient. The effective pit volume m^3, which is the total volume less the free space volume, is calculated as;

$V = CPN$ .... (A1.1)

Where

V = Volume of the pit (m^3)

C = Pit design capacity or solids accumulation rate, (m^3/person/year)

P = Expected population or Number of users per pit

N = Number of Years the pit is to be used before emptying or design life span

Generally, the solids accumulation rate for design purpose in dry region has a design factor of $0.03m^3$/person/year.

For economic purpose, 5years should be considered desirable.

For 30 people

$V=CPN$

$= 0.03 \times 30 \times 5$

$= 4.5 \text{ W } m^3$

This design value should be increased by 50% if there is likelihood of using bulky anal cleansing materials like cement paper, corncobs, etc.

Therefore, the volume is 6.75 m^3

Provide V = 1.2 x 2.5 x 2.3 = 6.90m^3

Top area of the pit = 1.2m x 2.5m

Depth - 2.30m

Free space = 0.5m

Depth of excavation = 2.80m

(b) **Top slab design:**

To withstand two 100kg men standing at the center

M = PL/4 .... (A I.2)

where

M = Mid-span moment (Nm)

P = Design load (N)

L = Span (m)

Effective length or span:

$$= 2.5 - \frac{0.225}{2} - \frac{0.225}{2}$$

L = 2.5 - 0.225

L = 2.275m

M = 2 x 100 x 9.8 x 2.275/4

= 1114.75Nm

Using the limit state method (BS 8110)

As = 1396.5 mm^2

Main reinforcement:

Provide 8Y10 @ 150 mm $^c/_c$ (A_S = 1609 mm^2)

Distribution bars:

Provide 8Y 10 @ 200 mm $^c/_c$ (A_S = 942 mm^2)

APPENDIX II

A2 Design of septic tank and soak-away pit:

(A 2.1) **Septic Tank:**

Generally, $V = QNT$ .... (A 2.1)

Where

V = Volume of septic tank (m^3)

Q = Waste flow ($/m^3hd$)

$=0.075(/m^3hd)$

N = Population

Tr = Detention time (usually 3 days)

For a limiting ratio of 30 people per facility

If 75% of water used as waste

$V = 0.075 \times 30 \times 3$

$= 6.75m^3$

Provide

B = Width = 1.8m

L = Length = 2.8m

H = Height = 1.8m

Structural dimension

$2.8 \times 1.8 \times 1.8 = 9.072\ m^3$ O.K

(a) Excavation dimension:

Provide 0.5m as free space

Hence;

$H = 1.8 + 0.5$

$= 2.30m$

Provide

$2.8 \times 1.8 \times 2.3m$

(b) **Soak-away pit:**

Generally, $A = NQ/I$ .... (A 2.2)

A = Infiltration area (m^3)

N = Population

Q = Waste flow (l/hd)

I = Infiltration rate (l/m^2d)

For a limiting population of 30 people per facility at the infiltration rate of 50 l/m^2d

$$A = \frac{30 \times 75}{50 \times 100}$$

$=0.45m^2$

Provide

$L = 1.5m$

$B = 1.2m$

Dimension: $1.5 \times 1.2m = 1.8m^2$

Height of excavation

Use $h = 1.2m$

Free-space = 0.3m

Excavation height = 1.2 + 0.3

= 1.5m

Excavation dimension

1.5m x 1.2 m x 1.5m

APPENDIX III

Laboratory analysis of the Physical, Chemical and Bacteriological Quality of Sampled Wells

		WELLS				WHO Recommendation limit	
Parameter	Units	W_1	W_2	W_3	W_4	Highest desirable level	Maximum permissible level
pH	-	7.0	7.4	6.6	7.1	6.5	9.2
Temperature	^0C	26.5	25	24.8	25.4		29^0c
Conductivity	µmho	320	473	380	400		400
Chloride	mg/l	629.37	280.61	60.13	94.75	250	600
Total hardness	mg/l	145.2	54.0	26.4	90	30	200
Calcium hardness	mg/l	80	27.4	18.10	10.0	75	200
Manganese	mg/l	0.07	0.09	0.62	0.11	0.05	0.5
Turbidity	NTU	1	6	3	1	5	25
Sulphate	mg/l	300	31	1	4	200	300
Iron	mg/l	0	0	0	0	0.1	0.1
Nitrate	mg/l	108	0	0	0	50	100
Phosphate	mg/l	3.0	0	0	0.01		0.03
Colour	TCU	40	32	0	0	5	50
Coliform count	MPN	15.0	0.0	0.0	0.0	3	10
Well distance to soak-away	M	3.6	28.5	26.0	24.5		
Depth of well	M	6.0	11.7	11.7	9.9		

Laboratory analysis of the Physical, Chemical and Bacteriological Quality of Sampled Wells

		WELLS				WHO Recommendation limit	
Parameter	Units	W_5	W_6	W_7	W_8	Highest desirable level	Maximum permissible level
pH	-	7.2	7.0	7.3	7.3	6.5	9.2
Temperature	^0C	26	26	25	24.5		29^0c
Conductivity	µmho	315	303	297	365		400
Chloride	mg/l	140	163.5	186	163	250	600
Total hardness	mg/l	35	76	43	70	30	200
Calcium hardness	mg/l	40	26.3	19.10	35.0	75	200
Manganese	mg/l	2	8	3	10	5	25
Turbidity	NTU	2	8	3	10	5	25
Sulphate	mg/l	79	22	46	31	200	400
Iron	mg/l	0.10	0.0	0.20	0.0	0.1	1.0
Nitrate	mg/l	0	0.8	0	0	50	100
Phosphate	mg/l	0.01	0.0	0	0		0.03
Colour	TCU	6	3	0	0	5	50
Coliform count	MPN	0.0	0.01	0	0	3	10
Well distance to soak-away	M	30.0	12.0	19.2	18.5		
Depth of well	M	10.8	9.0	9.0	9.0		

Laboratory analysis of the Physical, Chemical and Bacteriological

Quality of Sampled Wells

		WELLS				WHO Recommendation limit	
Parameter	Units	W_{13}	W_{14}	W_{15}	W_{16}	Highest desirable level	Maximum permissible level
pH	-	7.0	7.0	7.1	7.2	6.5	9.2
Temperature	^0C	25.5	26.5	23.2	27		29^0c
Conductivity	µmho	320	369	375	388		400
Chloride	mg/l	175	169	103.4	96	250	600
Total hardness	mg/l	58	63	44.1	38.5	30	200
Calcium hardness	mg/l	25.6	39.4	20.8	19.30	75	200
Manganese	mg/l	0.11	0.31	0.03	0.50	0.05	0.5
Turbidity	NTU	6	4	1	2	5	25
Sulphate	mg/l	2	49	38	11	200	400
Iron	mg/l	0.0	0.1	0.0	0.11	0.1	1.0
Nitrate	mg/l	3.2	1.6	0	0	50	100
Phosphate	mg/l	0.01	0	0.02	0		0.03
Colour	TCU	2	1	0	13	5	50
Coliform count	MPN	0.01	0.01	0	0.0	3	10
Well distance to soak-away	M	12.0	11.8	19.2	27.0		
Depth of well	M	9.0	7.2	8.1	8.1		

Laboratory analysis of the Physical, Chemical and Bacteriological Quality of Sampled Wells

		WELLS				WHO Recommendation limit	
Parameter	Units	W_{17}	W_{18}	W_{19}	W_{20}	Highest desirable level	Maximum permissible level
pH	-	7.2	7.2	7.1	7.0	6.5	9.2
Temperature	^{0}C	27	26	26	26		$29^{0}c$
Conductivity	µmho	314	390	450	300		400
Chloride	mg/l	77	83.4	99.6	90.0	250	600
Total hardness	mg/l	60	63	41.2	75	30	200
Calcium hardness	mg/l	19.0	18.3	40.0	33	75	200
Manganese	mg/l	0.22	0.07	0.10	0.08	0.05	0.5
Turbidity	NTU	2	8	1	7	5	25
Sulphate	mg/l	80	14	3	69	200	400
Iron	mg/l	0.0	0.1	0.35	0	0.1	1.0
Nitrate	mg/l	20	0	10	0	50	100
Phosphate	mg/l	0.06	0	0.07	0		0.03
Colour	TCU	20	10	3	2	5	50
Coliform count	MPN	0.15	0.0	0.06	0.0	3	10
Well distance to soak-away	M	10.2	25.0	12.2	18.0		
Depth of well	M	4.5	5.4	7.2	8.0		

Laboratory analysis of the Physical, Chemical and Bacteriological Quality of Sampled Wells

		WELLS				WHO Recommendation limit	
Parameter	Units	W_{21}	W_{22}	W_{23}	W_{24}	Highest desirable level	Maximum permissible level
pH	-	7.3	7.2	7.2	7.2	6.5	9.2
Temperature	^0C	25.5	25.0	26.0	26		29^0c
Conductivity	µmho	382	1116	623	350		400
Chloride	mg/l	133	168.2	141	120	250	600
Total hardness	mg/l	50.4	63.8	49	75	30	200
Calcium hardness	mg/l	53	41	26.6	18.10	75	200
Manganese	mg/l	0.39	0.48	0.25	0.36	0.05	0.5
Turbidity	NTU	4	3	6	1	5	25
Sulphate	mg/l	7	4	37	3	200	400
Iron	mg/l	0.1	0.3	0.0	0.0	0.1	1.0
Nitrate	mg/l	28	45	0	0	50	100
Phosphate	mg/l	0	0	0	0		0.03
Colour	TCU	2	3	0	1	5	50
Coliform count	MPN	0.95	1.01	0.0	0.0	3	10
Well distance to soak-away	M	11.0	10.0	15.6	21.8		
Depth of well	M	8.5	9.0	9.9	8.1		

Laboratory analysis of the Physical, Chemical and Bacteriological Quality of Sampled Wells

		WELLS				WHO Recommendation limit	
Parameter	Units	W_{25}	W_{26}	W_{27}	W_{28}	Highest desirable level	Maximum permissible level
pH	-	7.3	7.4	7.4	7.0	6.5	9.2
Temperature	^0C	27.1	27.2	26.7	26.5		29^0c
Conductivity	µmho	303	362	288	390		400
Chloride	mg/l	69	74	88.5	132	250	600
Total hardness	mg/l	82	94	43.5	66	30	200
Calcium hardness	mg/l	17.5	45.2	40	32.5	75	200
Manganese	mg/l	0.28	0.33	0.26	0.13	0.05	0.5
Turbidity	NTU	6	2	3	4	5	25
Sulphate	mg/l	22	13	2	45	200	400
Iron	mg/l	0.0	0.0	0.0	0.3	0.1	1.0
Nitrate	mg/l	63	0	0.22	0	50	100
Phosphate	mg/l	0	0	0	0.01		0.03
Colour	TCU	12	10	5	4	5	50
Coliform count	MPN	2.9	0.00	0.01	0.0	3	10
Well distance to soak-away	M	9.6	24.9	14.2	17.3		
Depth of well	M	10.8	10.8	8.5	6.3		

Laboratory analysis of the Physical, Chemical and Bacteriological Quality of Sampled Wells

		WELLS				WHO Recommendation limit	
Parameter	Units	W_{29}	W_{30}	W_{31}	W_{32}	Highest desirable level	Maximum permissible level
pH	-	7.1	7.2	7.0	7.0	6.5	9.2
Temperature	^{0}C	26	26	26	25.5		$29^{0}c$
Conductivity	µmho	315	420	265	311		400
Chloride	mg/l	148.6	173	116	163.8	250	600
Total hardness	mg/l	93.0	60	72	48	30	200
Calcium hardness	mg/l	30.1	22.5	28.1	39.6	75	200
Manganese	mg/l	0.32	0.44	0.28	0.33	0.05	0.5
Turbidity	NTU	3	8	6	1	5	25
Sulphate	mg/l	21	9	3	2	200	400
Iron	mg/l	0.0	0.0	0.01	0.6	0.1	1.0
Nitrate	mg/l	0.11	0	0	0	50	100
Phosphate	mg/l	0.0	0	0	0		0.03
Colour	TCU	29	18	6	3	5	50
Coliform count	MPN	0.0	0	0	0.00	3	10
Well distance to soak-away	M	10.2	22.0	10.5	29.0		
Depth of well	M	11.7	10.8	11.7	11.7		

Laboratory analysis of the Physical, Chemical and Bacteriological Quality of Sampled Wells

		WELLS				WHO Recommendation limit	
Parameter	Units	W_{33}	W_{34}	W_{35}	W_{36}	Highest desirable level	Maximum permissible level
pH	-	7.0	7.1	7.1	7.1	6.5	9.2
Temperature	^{0}C	25	26	24.0	25.4		$29^{0}c$
Conductivity	µmho	310	380	375	368		400
Chloride	mg/l	136	143	169	611.5	250	600
Total hardness	mg/l	36	57	63	178.5	30	200
Calcium hardness	mg/l	50.5	35.0	29.0	140.8	75	200
Manganese	mg/l	0.08	0.29	0.05	0.88	0.05	0.5
Turbidity	NTU	3	1	4	1	5	25
Sulphate	mg/l	4	20	7	237	200	400
Iron	mg/l	0.0	0.0	0.1	0.2	0.1	1.0
Nitrate	mg/l	0	0	0	110	50	100
Phosphate	mg/l	0	0	0	3.0		0.03
Colour	TCU	22	4	10	46	5	50
Coliform count	MPN	0	0	0	15.1	3	10
Well distance to soak-away	M	23.5	20.7	19.5	8.5		
Depth of well	M	10.8	9.9	11.7	3.5		

Laboratory analysis of the Physical, Chemical and Bacteriological Quality of Sampled Wells

		WELLS				WHO Recommendation limit	
Parameter	**Units**	W_{37}	W_{38}	W_{39}	W_{40}	**Highest desirable level**	**Maximum permissible level**
pH	-	7.2	7.2	7.2	7.2	6.5	9.2
Temperature	^{0}C	27.9	26	27	26		$29^{0}c$
Conductivity	µmho	312	318	370	342		400
Chloride	mg/l	152	149	193	176	250	600
Total hardness	mg/l	50	76	76	68	30	200
Calcium hardness	mg/l	20.8	19.3	169	26.7	75	200
Manganese	mg/l	0.31	0.47	0.22	0.21	0.05	0.5
Turbidity	NTU	4	5	1	7	5	25
Sulphate	mg/l	33	14	18	22	200	400
Iron	mg/l	0.10	0.30	0.0	0.0	0.1	1.0
Nitrate	mg/l	35	0	0	0	50	100
Phosphate	mg/l	0	0	0	0		0.03
Colour	TCU	1	8	17	6	5	50
Coliform count	MPN	0.89	0	0	0	3	10
Well distance to soak-away	M	10.5	18.4	20.0	20.0		
Depth of well	M	9.0	9.0	10.8	10.8		

Laboratory analysis of the Physical, Chemical and Bacteriological Quality of Sampled Wells

		WELLS				WHO Recommendation limit	
Parameter	**Units**	**W_{41}**	**W_{42}**	**W_{43}**	**W_{44}**	**Highest desirable level**	**Maximum permissible level**
pH	-	7.1	8.1	7.4	7.4	6.5	9.2
Temperature	^0C	26	25	25	26.5		29^0c
Conductivity	µmho	369	37111	349	325		400
Chloride	mg/l	103.5	135	161	793	250	600
Total hardness	mg/l	48	47	65	180.5	30	200
Calcium hardness	mg/l	30.1	40.2	22.6	119.0	75	200
Manganese	mg/l	0.03	0.08	0.48	0.71	0.05	0.5
Turbidity	NTU	5	2	8	3	5	25
Sulphate	mg/l	30	8	3	311	200	400
Iron	mg/l	0.11	0.13	0.0	0.0	0.1	1.0
Nitrate	mg/l	27.0	0	0	140.0	50	100
Phosphate	mg/l	0	0	0	2.8		0.03
Colour	TCU	5	3	11	3.9	5	50
Coliform count	MPN	0.75	0	0	18.5	3	10
Well distance to soak-away	M	10.0	18.5	16.4	5.2		
Depth of well	M	12.6	12.6	11.7	7.2		

Laboratory analysis of the Physical, Chemical and Bacteriological Quality of Sampled Wells

		WELLS				WHO Recommendation limit	
Parameter	Units	W_{45}	W_{46}	W_{47}	W_{48}	Highest desirable level	Maximum permissible level
pH	-	7.4	7.0	7.4	7.7	6.5	9.2
Temperature	^0C	25	24.8	25.2	25.5		29^0c
Conductivity	µmho	364	339	393	374		400
Chloride	mg/l	171	140	206	137	250	600
Total hardness	mg/l	80.3	59	50	46.5	30	200
Calcium hardness	mg/l	19.8	36.8	32.6	40.5	75	200
Manganese	mg/l	0.32	0.26	0.30	0.41	0.05	0.5
Turbidity	NTU	6	7	2	1	5	25
Sulphate	mg/l	9	19	8	3	200	400
Iron	mg/l	0.0	0.0	0.10	0.0	0.1	1.0
Nitrate	mg/l	0	0	0	0	50	100
Phosphate	mg/l	0	0	0	0		0.03
Colour	TCU	3	0	4	1	5	50
Coliform count	MPN	0	0	0	0	3	10
Well distance to soak-away	M	23.0	18.3	17.6	26.5		
Depth of well	M	10.8	9.9	12.6	11.7		

Laboratory analysis of the Physical, Chemical and Bacteriological Quality of Sampled Wells

		WELLS				WHO Recommendation limit	
Parameter	Units	W_{49}	W_{50}	W_{51}	W_{52}	Highest desirable level	Maximum permissible level
pH	-	7.1	7.8	7.3	7.0	6.5	9.2
Temperature	^0C	20.0	26.5	25.4	25		29^0c
Conductivity	µmho	299	340	409	413		400
Chloride	mg/l	86	93.4	76.8	120	250	600
Total hardness	mg/l	76	49.0	26.8	39.2	30	200
Calcium hardness	mg/l	33.4	28.2	44.0	33.2	75	200
Manganese	mg/l	0.35	0.11	0.26	0.30	0.05	0.5
Turbidity	NTU	2	3	5	1	5	25
Sulphate	mg/l	1	4	21	7	200	400
Iron	mg/l	0.30	0.10	0.20	0.0	0.1	1.0
Nitrate	mg/l	0	0	0	0	50	100
Phosphate	mg/l	0	0	0.07	0		0.03
Colour	TCU	9	0	11	18	5	50
Coliform count	MPN	0	0	0	0	3	10
Well distance to soak-away	M	14.5	16.8	14.5	30.5		
Depth of well	M	10.8	10.8	10.8	6.5		

Laboratory analysis of the Physical, Chemical and Bacteriological Quality of Sampled Wells

		WELLS				WHO Recommendation limit	
Parameter	Units	W_{53}	W_{54}	W_{55}	W_{56}	Highest desirable level	Maximum permissible level
pH	-	7.0	6.9	7.3	7.2	6.5	9.2
Temperature	^0C	22.8	26.5	26.2	26		29^0c
Conductivity	µmho	362	320	344	330		400
Chloride	mg/l	127.3	113	141.7	182	250	600
Total hardness	mg/l	73.0	67	36	48.3	30	200
Calcium hardness	mg/l	37.9	21.4	26.8	30.9	75	200
Manganese	mg/l	0.24	0.23	0.30	0.40	0.05	0.5
Turbidity	NTU	3	4	6	2	5	25
Sulphate	mg/l	15	2	3	8	200	400
Iron	mg/l	0.25	0.1	0.0	0.0	0.1	1.0
Nitrate	mg/l	34	0	0.16	0	50	100
Phosphate	mg/l	0	0	0	0		0.03
Colour	TCU	17	5	10	6	5	50
Coliform count	MPN	0.80	0.0	0.01	0.0	3	10
Well distance to soak-away	M	10.8	28.6	14.8	20.5		
Depth of well	M	7.2	9.0	8.1	10.8		

Laboratory analysis of the Physical, Chemical and Bacteriological Quality of Sampled Wells

		WELLS				WHO Recommendatio limit	
Parameter	Units	W_{57}	W_{58}	W_{59}	W_{60}	Highest desirable level	Maximum permissible level
pH	-	7.3	8.0	7.0	7.1	6.5	9.2
Temperature	^0C	26	27	26.5	25.3		29^0c
Conductivity	mho	311	358	371	379		400
Chloride	mg/l	201	107.8	164	169	250	600
Total hardness	mg/l	76.5	83	60.1	44.3	30	200
Calcium hardness	mg/l	27.6	32.0	40.1	33.0	75	200
Manganese	mg/l	0.23	0.14	0.61	0.31	0.05	0.5
Turbidity	NTU	6	0	1	3	5	25
Sulphate	mg/l	9	39	40	18	200	400
Iron	mg/l	0.0	0.0	0.10	0.0	0.1	1.0
Nitrate	mg/l	0	0	0	0	50	100
Phosphate	mg/l	0	0	0	0		0.03
Colour	TCU	3	8	0	25	5	50
Coliform count	MPN	0	0	0	0	3	10
Well distance to soak-away	M	18.0	18.0	15.9	22.5		
Depth of well	M	10.6	8.1	7.2	11.7		

APPENDIX IV

Laboratory analysis of the Physical, Chemical and Bacteriological Quality of control Sampled Wells

		WELLS					WHO Recommendation limit	
parameter	Unit	Wc_1	Wc_2	Wc_3	Wc_4	Wc_5	Highest desirable level	Maximum permissible level
pH	-	6.8	7.0	7.4	7.1	7.1	6.5	9.2
Temperature	^0C	26	26.5	25.5	25.0	25.4		29^0c
Conductivity	µmho	252	165	318	249	314		400
Chloride	mg/l	130.8	289.6	73.2	60.3	93.6	250	600
Total hardness	mg/l	145.2	26.40	90.0	45.2	103.8	30	200
Calcium hardness	mg/l	0.03	0.04	0.01	0.0	0.1	75	200
Manganese	mg/l	55	24	33	40	88	0.05	0.5
Turbidity	NTU	2	1	3	7	5	5	25
Sulphate	mg/l	38	63	11	18	31	200	400
Iron	mg/l	0	0	0	0	0.05	0.1	1.0
Nitrate	mg/l	0	0	0	0	0	50	100
Phosphate	mg/l	0	0	0	0.01	0		0.03
Colour	TCU	1	3	13	0	0	5	50
Coliform count	MPN	0	0	0	0	0	3	10
Depth of well	M	3.6	6.0	4.5	9.0	7.2		