CHEMICAL ANALYSIS OF WELL WATER IN SAMARU, ZARIA.

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DECLARATION

I hereby declare that this thesis has been written by me and that it is a record of my own research work. It has not been presented in any previous application for a higher degree. All quotations are indicated and the sources of information are specifically acknowledged by means of references.

Hilary Chikezie Alaribe

Date: 20/2/84

DEDICATION

To my beloved wife

Bertha

for her untiring support
and care throughout my stay
in this University.

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ABSTRACT

Inadequate supply of treated water in Samaru has made people resort to the use of well water for domestic purposes. Some of these well waters contain substances that are injurous to health. The quality of these well waters in Samaru, Zaria has been studied. The samples for the study have been collected from ten different wells located at different places in Samaru village and Ahmadu Bello University, main campus, Zaria.

The wells are chosen after careful consideration which include the number of people fetching water from the wells and the frequency at which they do that. The quality of the water has been ascertained by carrying out chemical analyses which include – the determination of total hardness, calcium hardness, magnesium hardness, non~carbonate hardness, electrical conductivity, pH, alkalinity, chloride, total residue, sulphate, total organic nitrogen, total phosphate, dissolved oxygen, temperature and some metal ions.

Flame photometric technique has been used to determine sodium, potassium and calcium while magnesium lead, zinc, iron, manganese, cadmium, copper, arsenic and nickel have been determined by atomic absorption spectrophotometry.

The results obtained have been compared with International Standards for Drinking Water as recommended by World Health Organisation (WHO).

All the metal ions have been found to be within the tolerable limit, while total solids, dissolved oxygen, pH and total hardness have been found to bo outside the recommended limits in some wells.

In order to reduce the amount of total solid in the well water (particularly wells 1 - 7) , the use of a chemical coagulant, alum has been studied. The minimum amount of alum required to treat a bucket containing about 8 litres of water has been found to be 2.5g.

To suppress the activity of harmful micro-organ likely to be present in the water, five table spoons full of milton, a chemical disinfectant has been recommended for treatment of a bucket full of the water

Finally, as some of the wells are net properly maintained, suggestions has been made to the Local Government Authority as to how these wells could be maintained.

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ABBEVIATIONS

(i)	ppm	-	parts per million
(ii)	EDTA	-	Disodium ethylenediaminetetraacetate dihydrate.
(iii)	ABU	-	Ahmadu Bello University
(iv)	WHO	-	World Health Organisation
(v)	AWWA	-	American Water Works Association.
(vi)	APHA	-	American Public Health Association.
(vii)	NAPRI	-	National Animal Production Research Institute.

CHAPTER 1

I N T R O D U C T I O N

1.1 Importance of water in Life.

The basic material for man's existance has always been water. Water is a unique substance and forms an integral part of man's life. There seems to be no end to the purposes for which it is put - drinking, cooking, agriculture, transport, industry and recreational activities, all these need water. Water is used in industries as a basic material for mixing, washing and finishing processes and also for generation of electricity. Without water, there will be no life and no industry will function hence water can be regarded as the most important material of civilization. The concept of water as a natural resource is essential, as growing populations and industrial developments demand ever - increasing supplies of water.

1.2 Quality of water.

The characteristics of water which entitles it to be designated "good quality" are directly dependent upon the use to which the water is to be put (1). It has long been recognised that its suitability for that purpose can be affected by substances dissolved and/or suspended in water. For instance a warm and corrosive water would be "of poor quality" for use in condensing

steam; similarly a turbid water would be considered unacceptable for paper manufacturing and hard water would not be accepted for use in Laundries or textile mills. As for human consumption, regardless of its clarity, turbidity, its hardness or softness, no water polluted by or exposed to pollution by sewage can be considered "of good quality". In general the quality of water depends on its orgin; natural waters show qualities which characterise their sources (2).

1.3 Sources of water.

For convenience, the sources of water available in the hydrologic cycle can be classified as follows.

(a) Rain water.
(b) Surface water - which includes streams, natural ponds and lakes.
(c) Ground water - which includes springs, and we

1.4 The Wells.

Wells may be classified as shallow wells or deep wells. Shallow wells are those developed in surface deposits of previous materials overlying an impervious stratum. Arbitrarily any well deeper than 20 metres may be considered as a "deep well" (2). Generally the gathering ground for deep wells is extensive. This means that the ground water will have long paths of

travel and long time of contact with the rock and soil formation. Deep well waters are likely to be more mineralized than shallow wells. They are usually clean and colourless but often contain iron or manganese or both whereas shallow well waters are usually coloured which means they contain a lot of dissolved substances, some of which may be very hazardous. In general no two well waters are exactly alike and even the same well may produce water of widely varying quality at different times (3). Thus it must be emphasised that each well must be studied by itself when measures for its treatment are under consideration.

Here in Zaria, all the wells are shallow wells as none of them is deeper than 10 metres and as such are prone to contamination and pollution. The walls of some of these wells are cemented from the bottom to about 1 metre above the ground level and are well covered, while some are not. During the rainy season, some of these wells are as deep as 2.5 metres.

1.5 The Parameters Affecting the Quality of Well Water for Domestic Uses.

As pointed out earlier, the characteristics of water which entitles it to be designated "good quality" are directly dependent upon the use to which the water is to be put.

As regards water for domestic use, certain parameters make some water unsuitable for domestic uses. These include:-

(a) Turbidity:

Turbidity is caused by the presence of suspended matter in water. Turbid waters are objectionable to sight and when algae, diatoms and other forms of life are visible, the appearance may be alarming; such materials may be irritating to the bowels and if ova are present, they may develope into worms in the intestines of people drinking such water (4). Obviously such waters need treatment with a chemical coagulant such as alum, $[K_2SO_4.Al_2(SO_4)_3.24H_2O]$ to remove the suspended materials in the water before using it.

(b) Colour:

Colour in water is caused by minerals such as iron, manganese or by biological agents such as humus, tannins, algae, weeds, protozoa etc (5). In addition wastes from a number of man's activities impart colour to waters receiving them. Coloured waters are always objectionable and in as much as the colour can be removed, it should be removed at least to such an extent that it is not obvious in an ordinary clean tumbler before it is considered for domestic uses.

(c) Odour and Taste:

Any well water with any type of odour and/or taste should be considered impure. Odours in well water may come from natural sources e.g. odoriferous compounds, microscopic organisms, decaying vegetation and other organic matter present in the water. Tastes are closely related to odours, although certain non-volatile substances can cause tastes without causing odours. A study of some well waters showed that snails, mussels, and crustacae cause odour and taste problems when they die and decompose (6).

Although the odour and taste levels do not directly measure the safety of a drinking water, they are related to the consumer's acceptance of the water. If water has an objectionable odour and taste, people may turn to less safe alternative supplies.

(d) Electrical conductivity:

Electrical conductivity is the ability of a solution to conduct electricity. The electrical conductivity of well water is a measure of the mineral constituents dissolved in the water. In very dilute solution it is proportional to the total dissolved solid. It does not give an indication of the nature of the mineral salts present but its high value is an indication of a large amount of mineral salts present.

(e) pH.

The pH of a solution isolution is a measure of the intensity of acidity or alkalinity of a solution. The pH scale extends from zero which is extremely acidic through 7, which is neutral, to 14 which is extremely alkaline. The recommended pH of water for domestic uses is 6.5 to 9.2 (7). Any well water with pH outside this range should be considered unsafe.

(f) Naturally Occuring Metals Ions found in Well Waters.

(i) Calcium:

Calcium is the primary element concerned with hardness of water. It is the most aboundant mineral constituent of human body and an adequate intake is essential for normal growth and health. The minimum average daily requirement of calcium is probably one to two grammes, larger amount is required by pregnant or lactating women and growing children (8). It is very essential for bones and teeth formation. Since calcium is the primary element concerned with hardness in water, excess of it would be undesirable because when such water is used for laundry a lot of soap will be needed to cause lather. It is on the basis of this that World Health Organisation (1971) set 200 ppm as the maximum permissible level of calcium in water for domestic uses. Calcium occurs in most well waters in the form of bicarbonate, carbonate, sulphate and chloride.

(ii) Magnesium:

Magnesium is the second element concerned with hardness and invariably occur in smaller quantities than calcium. Although magnesium is not known to produce toxic effects, a maximum permissible level of 150 ppm in drinking water has been recommended. This limitation is based on the fact that in high concentrations magnesium salts have pronounced laxative effect (9). Secondly since magnesium is the second element concerned with hardness of water, its high concentration is undesirable in water for domestic uses.

(iii) Sodium:

Sodium compounds are very common in the environment, and constitute 2.83% of the earth's crust. Sodium occurs as carbonate, bicarbonate, nitrate, chloride or sulphate and most of these salts are extremely soluble in water. When sodium occurs as chloride, concentration up to 300 ppm can be tolerated except when it arises from sewage pollution. While sodium in drinking water is not known to cause harm to healthy people, it can impose a serious problem to people suffering from hypertension (10). Sodium - restrictive diets are essential in treating congestive cardiac failure, hypertension, renal disease, cirrhosis of the liver and toxaemicas of pregnency.

(iv) Potassium:

Potassium constitutes a minor element in well water and quantities present are usually a small fraction of the amount of sodium present.

(v) Nitrate and Nitrite:

Nitrates are present in most well waters but high concentration of nitrate may be due to pollution by sewage or manure since these nitrates may be derived from the oxidation of nitrogenous organic matter of animal origin (11).

High nitrate levels in water are of great concern because methaemoglobinaemia in infants has been associated with the intake of water with high nitrate levels (11). Nitrate in food or water becomes a hazard to health when the nitrate is converted to nitrite; this ion when absorbed converts haemoglobin to methaemoglobin. The conversion of haemoglobin to methaemoglobin renders the haemoglobin molecules incapable of transporting oxygen to various organs in the body. Methaemoglobinaemia resulting from the consumption of water with high nitrate levels was first recognised clinically by Comly (1945). Since then about 2000 cases including many fatal poisonings in infants resulting from ingestion of water containing

nitrates have been recorded in many countries of the world. Recent studies in Europe have reported clinical and sub-clinical cases of the disease in infants consuming water having less than 10 ppm of nitrate nitrogen (12). The World Health Organisation (1971) recommends a limit of 45 ppm nitrate (NO_3^+) in water for domestic uses and waters with nitrite - nitrogen concentrations over 1 ppm should not be used for infant feeding.

(h) Sulphate:

Well waters containing appreciable quantities of sulphate salts are classified as "sulphated water" and are unsuitable for domestic and drinking purposes (13). In nearly all well waters, the magnesium sulphate predominates and its aperient action may affect children especially in hot weather. The World Health Organisation recommends 250 ppm as the highest desirable level of sulphate in water for drinking and domestic uses. This limitation is based on the fact that high concentration of sulphate in drinking water can cause diarrhoea and "scour" in cattle (14).

(i) Phosphate:

Phosphate occurs in natural waters and well waters to the extent of parts per ten million or less. In recent years, most heavy-duty synthetic detergent

formulations designed for domestic uses contain large amount of polyphosphates as builders. The use of these materials as a substitute for soap in many homes has greatly increased the phosphate content of domestic sewage and well waters as a result of contamination. Water containing excessive phosphate may be undesirable for use in food preparation because of the buffering action on the stomach acids (15). A limit of 0.2 ppm of phosphate in drinking water has been set by Canadian Public Health Organisation.

(j) Dissolved Oxygen.

All living things are dependent upon oxygen in one form and another to maintain the metabolic processes that produce energy for growth and reproduction. Aerobic processes are the subject of greatest concern because of their need for free oxygen.

In well water, dissolved oxygen is predominantly derived from the atmosphere and from photosynthetic reactions in algae and higher aquatic plants. The total amount of oxygen that can be dissolved in water body is dependent upon the water temperature, the partial pressure of the oxygen in the atmosphere in contact with the water, the salinity of the water and the relative rates of biochemical depletion and reaeration.

In well water also dissolved oxygen is a factor which determines whether biological changes are brought about by aerobic or anaerobic organisms. The former require free oxygen to produce innocuous end products while the later can utilize chemical bound oxygen to produce poisonous end products. Since both types of organisms are present everywhere in nature, it is highly important that conditions favourable to aerobic organisms be maintained. Thus high dissolved oxygen content of well water is very important for maintaining aerobic conditions.

(k) Hardness.

Well waters can be classified "hard" or "soft" according to their action on soap. The less the amount of soap required in the water to produce lather, the softer is the water. Hardness of water is caused mainly by two cations (calcium and magnesium) commonly found in well water. It may be caused by other polyvalent cations such as aluminium, iron, manganese and zinc but because the first two cations are usually present in significant amount, hardness is defined as a characteristics of water that represents the total concentration of just calcium and magnesium ions expressed as calcium carbonate. When hardness is numerically greater than total alkalinity, the amount of hardness that is equivalent to total

alkalinity is called "Carbonate hardness" while the amount in excess of this is termed "non carbonate hardness (16). When hardness is numerically equal to or less than total alkalinity, then there is no non carbonate hardness.

Any well water with less than 100 ppm of hardness may be said to be soft while those with 150 ppm to 250 ppm of hardness may be said to be moderately hard. Those with over 350 ppm of hardness are said to be very hard.

The WHO maximium permissible limit of hardness of water for domestic use is 500 ppm.

(1) Alkalinity.

The alkalinity of well waters is due to the presence of salts of weak acids. Bicarbonates represent the major form of alkalinity since they are formed in considerable amounts from the action of carbon dioxide upon basic materials in the soil. Other salts of weak acids such as borates, silicates and phosphates may be present in small amounts. Few organic acids that are resistant to biological oxidation for example humic acid, form salts that add to the alkalinity of well waters. Highly alkaline waters are usually unpalatable and consumers tend to reject such water. Total or

methylorange alkalinity of well waters suitable for demestic uses ranges from 100 to 200 ppm but there have been reported cases of well water having total alkalinity up to 400 ppm and no harm has been reported from the consumption of such waters (17).

1.6 Physiological Effects of Trace Metals in Well Water.

The term trace metals refers to those metal that are found in water in very small concentration. Some of these trace metals are very toxic to human beings when present in the range 0.1 - 0.5 ppm while others are toxic only when present above 5 ppm. The metals include:

(a) Lead:

Lead is very toxic and the maximum permissible limit in drinking water and water for domestic uses is 0.1 ppm. When taken in higher concentrations, it may result in abdominal cramp, constipation, loss of appetite and anaemia. In children, it may result in kidney disease and mental retardation which may be attributed to inhibition of growth of the central nervous system (18).

(b) Zinc:

Zinc is abundant in rocks and ores. However, it is generally found in natural surface and ground waters

only in trace amount. High concentration of zinc in well waters results from the use of metallic buckets in drawing water from the wells. It may occur in well water in areas where zinc salts are abundant in the soil. Zinc in domestic water affects taste and appearance of the water. Water containing more than 5 ppm of zinc will form a greasy scum upon boiling and at 30 ppm of zinc has a milky appearance (10). While it is generally considered that low concentrations of zinc have no adverse physiological effects, levels of less 15 ppm in rain water held in galvanished tanks have been implicated as causing severe stomach disorders. A limit of 5 ppm of zinc in drinking water was suggested in the WHO International Drinking Water Standards (1971).

(c) Copper.

In natural surface water, copper is found only in trace amounts, generally in less than 0.05 ppm. In underground waters such as water from wells, concentrations of copper up to 12 ppm have been found. But when significant concentrations of copper occur in surface waters, it is generally due to pollution. It is recommended that maximum concentration of copper in water for domestic and

drinking purposes be 1.5 ppm to avoid unpleasant taste and staining problems, higher concentrations are irritating to the stomach and may lead to vomiting and liver damage (20).

(d) Iron.

Iron occurs naturally in well waters and springs. Sand formations are the most frequently source of supplies. It is an element essential to all metabolic processes and an appreciable amount impart a bitter taste to the water (21). When the iron precipitates as ferric hydroxide it renders the water objectionable and unsuitable for domestic uses e.g. it stains laundry brown. The recommended limit of 0.3 ppm (total iron) is based on a consideration of the possible effects of high iron concentrations on household uses of the water.

(e) Manganese.

Manganese frequently occurs in association with iron but in lesser amount and its presence is subject to the same objections as iron. Concentrations of 0.2 to 0.4 ppm of manganese in drinking water is likely to cause complaints and necessiate treatment of the water for its removal. A few cases of poisoning have

been reported but water tastes extremely unpleasant before toxicologically significant levels are reached.

(f) Arsenic.

Arsenic, a metalloid that occurs widely in nature is acutely and chronically toxic to human beings and also to marine organisms. Environmental pollution by arsenic may arise from agricultural practices (weed-killers fungicides, sheepdips, rodenticides and insecticides) and from industry. Chronic poisoning of arsenic may lead to loss of appetite and weight, diarrhoea and sometimes skin cancer (22). In 1900 in Manchester and Liverpool, some 7,000 clinical cases of subacute poisoning and 70 deaths were attributed to consumption of beer containing more than 15 ppm arsenic.

A recent study has shown evidence of increased storage of arsenic in the body as reflected in the increased arsenic level in hairs for population using well water with arsenic above 0.05 ppm (22). A limit of 0.05 ppm of arsanic in drinking water is recommended in WHO International Drinking Water Standards (1971) and European (1970) while a limit of 0.1 ppm arsenic is recommended in US Drinking Water Standards (1972).

(g) Cadmium.

Cadmium has long been recognised as a very toxic substance and reported cases of death following cadmium poisoning in Japan have led to increased concern regarding cadmium in the environment (23). Cadmium is present in the soil, vegetation and in man's food. It enters the human environment as a contaminant from mining and metallurgy, chemical industries, superphosphate fertilizers and cadmium - containing pesticides. Superphosphate fertilizer has been found to contain 1 to 170 mg of cadmium/kg of the fertilizer. Chronic cadmium poisoning affects the proximal tubules of the kidney causing the formation of kidney stones.

As a result of accumulation of cadmium by hepatic and renal tissue at intake levels as low as 0.1 ppm in water and the association of a servere edemic disease sydrome with ingestion of cadmium over a long period of time, it has been recommended that cadmium be limited to 0.01 ppm in drinking water (24).

1.7 Aims and Objectives of the project.

Water scarcity has been imposing a very big problem to the people of Zaria, particularly in Samaru village. This water scarcity results from inadequate/irrigular supply of treated water to the people. The irrigular/inadequate supply of treated water in Samaru couldbe traced to three factors:-

(i) irrigular supply of electricity on which the Water Works depend for pumping water to the public.

(ii) absence of piping system in some parts of Samaru.

(iii) population explosion which results in increase demand for treated water.

In order to meet up the daily demand for water, people have resorted to the use of well water for domestic uses and for drinking pruposes. A survey of Samaru village reveals that there are more than thirty wells. Many of these wells are public wells while others are private ones. Some of these wells are likely to contain many of the naturally occuring substances above the tolerable limit as recommended by World Health Organisation and hence people using such well water for domestic and drinking purposes

are exposed to danger. In consideration of this danger, therefore this study has been undertaken to examine the quality of water from these wells and make suggestions and recommendations to the Local Government Authority as regards the safe use of water from these wells.

In order to study the quality of the well water, chemical analyses of the water from ten commonly used wells located at different places in Samaru has been carried out. This would include the study of following parameters: Total residue, hardness, electrical conductivity, alkalinity, sulphate, chloride, total nitrogen, total phosphate, dissolved oxygen, temperature, pH and metal ions. One of the properly maintained private well will be included in this study to compare the quality of water from it and that from the public wells.

The results of analyses will be compared with International Standards for Drinking Water and Water for Domestic uses as recommended by World Health Organisation to ascertain the quality of water.

As treatment of water with alum, a chemical coagulant helps to reduce the amount of total residue in water, it is intended to carry out a systematic study to evaluate the minimum amount of alum required to treat a bucket of well water.

CHAPTER 2

2.0 SAMPLING AND DETERMINATION OF VARIOUS PARAMETERS.

2.1 Sampling Technique.

The reliability of any results obtained from analysis of any substance - be it solid, liquid or gaseous substance - depends on the efficiency of the sampling technique. A satisfactory sampling system must fulfil two conditions, which though obvious, are worth emphasizing:

(i) the concentration of the determinands in the substance entering the sampling system must be the same as those in the substance being sampled.

(ii) the concentration of the determinands in the sample must not change during contact between sample and sampling system (25).

For water samples, four effects which may cause problems in satisfying condition (ii) include:

(a) deposition within the sampling system, example suspended solid may settle gravitationally onto the walls of the sampler.

(b) chemical and/or biological reactions can take place, during passage through sampling system, example dissolved oxygen can react with mild steel.

(c) release of determinands into the sample, example dissolved oxygen can be released from respirating biological materials on the surface of the sampler.

(d) release of determinands into the sample from the materials of the sampling system itself, e.g. copper may enter the sample when copper sampling lines are used.

All these effects can be minimised by avoiding long contact - time between sample and the sampling system.

For many applications in which natural waters (well water) are of interest, no specific sampling system is required. It often suffices to immerse a bottle in the water of interest to draw the water and this is the technique used in this work.

2.2 Time interval between sampling and analysis.

The time interval between sampling and analysis is very important in determining the reliability of analytical results (26). Generally, the shorter the time interval between sampling and analysis, the more reliable and meaningful the result will be. For those determinands such as temperature, pH, dissolved oxygen, and electrical conductivity which change very readily with time, attempt should be made to determine them on the spot as delay will result in a considerable change.

2.3 Sample containers.

Sample containers have very important effects on the sample stability and compilations of analytical methods often make specific recommendation on the type of containers suitable for each determinand. Polyethylene or glass bottles have been found suitable for use as sample containers but there seems to be a growing preference for polyethylene bottles particularly when analysing for metal ions (27). Thus iron, manganese, zinc and lead may be leached from glass, thereby increasing their concentration in the sample. It is for this reason most authors appear to favour polyethylene bottles for trace concentrations of metallic impurities and glass when small concentrations of organic compounds

are of interest. Another types of contamination that should be borne in mind particularly when polyethylene bottles are used are:

(a) gaseous diffusion through the walls of the bottle leading to either increase or decrease in dissolved gases in the sample. This can be reduced by use of high-density polyethylene bottle.

(b) adsorption of substances of the sample on the walls of the container and subsequent contamination of the next sample. This can be reduced to minimum by adequate cleaning of the sample containers.

2.4 Sample preservations.

The composition of a sample can adversely affect the natures and rate of chemical and biological reactions occuring between sampling and analysis. Such reactions are common sources of sample instability e.g. condensed inorganic phosphates and polymeric silicic acid can depolymerise and cause increase in the concentration of ortho-phosphate and monomeric silicic acid. Calcium carbonate can precipitate from its saturated solutions and causes changes in the related determinands e.g. pH, alkalinity and hardness. Iron may precipitate on contact

with atmosphere. All these reactions can be affected by temperature and other constituents of the sample. Thus the importance of such reactions varies from samples to samples hence a complete and unequivocal preservation of a sample is practically impossible. Notwithstanding these problems, the following methods have been recommended (28).

(a) storage of samples in a dark bottle and under $4^{o}C$ markedly reduces the rate of biological activities.

(b) immediate treatment of samples, in this case, algae and bacterial activity can be reduced sufficiently by simply filtering the sample during or immediately after collection. Membrane filters (pore-size approximately 0.5 μm) and glass-fibre filters (Whatman gF/C) can be used for this purpose.

(c) addition of a preserving reagent: This can be used to fix those determinands whose concentrations change very readily with time e.g. manganese(II) salt can be added to water sample to fix the dissolved oxygen content. Similarly acidification of water samples using nitric, sulphuric or hydrochloric acid) helps to keep metal ions in solution.

Some authors' experience is that acidification to pH 1 ensures stability of elements such as iron, copper, nickel, aluminium and zinc for at least seven weeks.

2.5 The Wells Studied and their locations.

General Consideration:-

Before the commencement of this study, identification of the wells was carried out by the help of Mr. J.O. Ogbonna, a Senior Laboratory Technologist in NAPRI, Ahmadu Bello University, Zaria who made his car available to me. He has lived in Samaru for more than eight years. He understands and speaks Hausa language fluently. With him beside me, I was able to communicate with the people - asking them such questions as "What do you use this well water for?, How often do you fetch water from this well?, Why do you prefer well water to tap water?, Why do many people prefer fetching water from this well?, What is the depth of this well during rainy season or dry season?, Which of these well retain water throughout the year?, At what time of the year is the water problem very acute?".

Answers to these questions guided me in my choice of these wells listed below. This opinion sampling was done three times before the wells were finally selected.

Well No.	Locations
1.	Danraka Street, Samaru
2.	47 Habibu Road, Samaru
3.	81 Habibu Road, Samaru.
4.	Near Texaco petrol station and the Market
5.	Funtua motor park
6.	Intermediate and Junior staff quarter (I & J) A.B.U. Zaria.
7.	Intermediate and Junior staff quarter (I & J) A.B.U. Zaria.
8.	35 Habibu Road, Samaru
9.	Beside Suleman Hall, A.B.U. Zaria
10.	Beside Suleman Hall, A.B.U. Zaria.

For the identification of these wells, the above serial numbers will be used throughout the text. Except well 8, the rest are public wells.

Well 1, 2 and 3 are deep wells relative to the rest and retain water all year round. Wells 4 and 5 are relatively shallow and retain little water during acute dry season. Well 4 is near Samaru market and Samaru central mosque. People coming to the mosque use water from this well for cleaning and drinking. Similarly many market women use well 4 water for drinking and

washing vegetables, fruits and other articles for sale. Well 5 is in a motor park and beside a mosque. It serves many people. It has a peculiar taste and foams when shaken. The mouths of wells 4 and 5 are not raised above the ground level with the result that part of the water from the washings of people goes back into the wells. Wells 6 and 7 are located in the Intermediate and Junior staff quarter of Ahmadu Bello University, Zaria. The walls of the wells are well cemented, the mouths are raised about 1 metre above the ground level but they are not covered. Well 8 is a private well located inside compound 35 Habibu road, Samaru. The inside walls are not cemented but the mouth is well cemented and covered. This particular well is included to compare the quality of water from a private maintained well and the public ones. Wells 9 and 10 are found in the University campus and are used by more than 1,500 students during acute water shortage in Samaru.

2.6 Colour, Odour and Taste of the Well water.

Water obtained from all the wells during the period of analyses was fairly clear free from turbidity, odour and taste except for well 5 which has a bitter taste. This bitter taste can be attributed to the presence of iron and manganese in the water.

2.7 Experimental.

This section of the study gives details of the experimental work done in the Laboratory and in the sample locations.

2.7.1 Sampling, frequency and preservation of samples studied.

Reagents:

All reagents were of analytical - reagent grade unless otherwise stated.

8M Nitric acid, 1M hydrochloric acid, distilled water and deionised water.

Apparatus:

20 polyethylene bottles of capacity 2.5 litres each, polyethylene bucket of capacity 4 litres and a refrigerator.

(a) Sampling procedure:

Polyethylene bottles for the sample collection were washed with 1M hydrochloric acid except those used for collecting samples for chloride determination which were washed with 10% V/V nitric acid, rinsed several times with distilled water followed by deionised water. Lastly, they were soaked overnight

in deionised water. The following morning the bottles were emptied, packed in a suitable carton for sample collection. The bucket for drawing water from the wells was similarly cleaned. At the sample locations, the water was collected by lowering the bucket by means of a polyethylene rope and filling it with the water. After this, the polyethylene bottles were filled to the brim and properly corked.

(b) Frequency of Sampling:

The samples for this study were collected weekly from ten wells in the months of August and September 1983. Thereafter, the samples were collected weekly in the last two weeks of October and the first two weeks of November 1983. This period ran across rainy season and dry season. The idea was to examine the variation in the quality of the well waterin rainy season and dry season. During this later period, there was scarcely any rainfall and signs of harmattan were observed everywhere in Samaru. Altogether, twelve samples were collected (between 8.00 a.m and 10.00a.m. every Mondays) for analysis.

(c) Sample preservation:

Procedure:

After collecting the samples, 2.5 ml of 8M nitric acid were added to 1 litre of water sample in

order to stabilize or keep the metal ions in solution and the determination was carried out within one week. While samples for nitrogen and phosphate determination were stored in a refrigerator under $4^{o}C$ and determination was carried out within 48 hours. In summary, the preservation technique used throughout the study is as shown below:

Parameters	Preservative reagent	Maximium Holding time
Temperature	Determined on site	No holding time
pH	Determined on site	No holding time
Electrical Conductivity	Determined on site	No holding time
Dissolved oxygen	Determined on site	No holding time
Residues	--	4 - 10 hours
Sulphate	Refrigerated at $4^{o}C$	24 hours
Phosphate	Refrigerated at $4^{o}C$	24 hours
Chloride	--	10 hours
Hardness	--	4 hours
Alkalinity	--	4 hours
Total nitrogen	Refrigerated at $4^{o}C$	24 hours
Metal ions - Na^{+}, K^{+}, Ca^{2+}, Zn^{2+}, Cu^{2+}, Pb^{2+}, Ni^{2+}, Fe^{3+}, Al^{3+}, Mn^{2+}, Cd^{2+}, Mg^{2+}.	2.5ml HNO_3/litre of sample, pH < 3	7 days

2.7.2 Measurement of Temperature, pH and Electrical conductivity.

Apparatus:

A griffin portable, battery operated pH meter type $B_{17}DA$ with a glass electrode - calomel electrode system, 500ml beaker, thermometer of range $0^{\circ}C$ - $100^{\circ}C$, a portable battery operated conductivity bridge, Type MC 3 ElL.

Reagents:

All reagents used were of analytical reagent grade.

(a) Standard buffer solution pH 7, prepared by dissolved a sachet pH 7 salt in 200ml of deionised water.

(b) Deionised water.

Procedure:

The temperature, pH and electrical conductivity of the well water were determined on the spot as described below.

(a) Temperature:

The temperature of the water was determined by putting the thermometer in the sample of water contained in a 500 ml beaker and reading the temperature after about 2 minutes.

(b) pH.

Before measuring the pH of the samples, the pH meter was first standardized with standard buffer solution. The electrode was cleared with deionised water, wiped dry with tissue paper, immersed in the standard buffer solution of pH 7, and stirred a little. Then the buffer setting knob was used to set the pH 7. Without further adjustment, the electrode was cleared again with deionised water, wiped dry with tissue paper and immersed in the buffer solution again in order to check the instrument before it was finally cleaned and used to measure the pH of the samples. Each time the electrode was immersed in the sample solutions, they were stirred a little and reading taken after few seconds.

(c) Electrical Conductivity.

After checking the instrument, the cell was rinsed with deionised water, followed by the sample whose electrical conductivity was to be measured before it was finally filled with the sample. In all cases the selector switch was set at x 100 range, the "on" button was pressed while the actuator knob was slowly rotated until the balance indicator moved to the centre of the scale. The results of temperature, pH and electrical conductivity measurement are shown in table 3.1. and appendixes (III)a - c.

2.7.3 Determination of Dissolved Oxygen (29, 30).

Dissolved oxygen measurement in drinking water and water for domestic uses is very important for maintaining aerobic conditions necessary for survival of organisms in it. There are many methods of determining dissolved oxygen in water samples of which the following methods are very reliable.

(a) Winkler method and its modifications

(b) Membrane electrode method.

In this work, the membrance electrode was used. This involved the use of a portable dissolved oxygen meter.

Experimental

Reagents:

No reagent was required except distilled water saturated with oxygen.

Apparatus:

YSl model 57, Oxygen Meter.

Procedure:

Calibration of the instrument (31)

(a) The instrument was switched off, and meter adjusted to zero, then switched to red line and adjusted.

(b) Salinity knob was adjusted to fresh.

(c) Then the oxygen probe was immersed in the oxygen saturated distilled water and meter switched to temperature.

(d) The probe temperature and the true local atmospheric pressure or feet above sea level were used to determine correct calibration values from tables (i) and (ii) as shown below e.g. probe temperature = 27°C, altitude = 1000 feet, from table (i) calibration value for 27°C is 8.1 ppm, from table (ii) altitude factor for 1000 feet is about 0.96. Then correct calibration value is 8.1 ppm x 0.96 factor or 7.78 ppm.

Lastly the meter was adjusted to 7.78 ppm and allowed to stabilize before measuring dissolved oxygen in samples.

Table (i)

Temperature ^{o}C	dissolved. oxygen (ppm)
25	8.4
26	8.2
27	8.1
28	7.9
29	7.8
30	7.7

Table (ii)

pressure (mm Hg)	Altitude feet	Factor
760	0	1.00
745	542	0.98
730	1092	0.96
714	1688	0.94
699	2274	0.92
684	2864	0.90

Measurement of dissolved oxygen in samples.

The dissolved oxygen (DO) meter can record in units of ppm dissolved oxygen in three ranges 0 - 5, 0 - 10, and 0 - 20 ppm. If instrument was calibrated to 0 - 10 ppm, switching to 0 - 5 or 0 - 20 ppm can introduce 1% error.

After calibrating the instrument, it was switched to the appropriate range 0 - 10 ppm and allowed to stabilize. After this, the probe was immersed in the water sample immediately after collecting from the well and stirrer control switched to "ON". Once the meter indicator stablized, the reading was taken. The results obtained are shown in table 3.1. and appendix (III)b.

2.7.4 Determination of Alkalinity (32, 33, 34)

The determination of alkalinity is very important in determining the palatability of water as highly alkaline waters are unpalatable and consumers tend to reject such water. By measuring the alkalinity indicated by phenolphthalein, indicator and the methyl orange or total alkalinity it is possible to calculate the concentration of hydroxyl, carbonate and bicarbonate ions in most water samples. These values are very important in controlling various processes in water treatment.

Experimental.

Reagents.

All reagents used were of analytical reagent grade

(i) 0.02 M sulphuric acid - prepared by diluting 1.20ml of 98% concentrated sulphuric acid of specific gravity 1.84 to 1 litre with deionised water. This solution was standardised with 0.02M sodium carbonate solution.

(ii) methyl orange indicator solution 1% (m/V) - prepared by dissolving 1g of the salt in distilled water and diluting to 100m.

(iii) Phenolphthalein indicator solution 1% (m/V) - prepared by dissolving 0.5g of the salt in 50 ml 95% ethanol and 50 ml of water (V/V).

Apparatus:

50ml-burette, 100ml-pipette (10) and 500ml-conical flasks (10).

Phenolphthalein alkalinity.

Procedure:

To 100ml of sample in 500ml conical flask, four drops of phenolphthalein indicator were added. In all cases, there was no colour change showing that all the water samples have zero phenolphthalein alkalinity or negligible amount of hydroxyl and carbonate ions.

Methyl orange or Total alkalinity.

Procedure:

To 100 ml of the water sample, three drops of methyl orange indicator were added and titrated with 0.02M sulphuric acid from a burette to a definite reddish finge. Duplicate determinations were done in each case.

Calculation.

Total alkalinity (ppm) $CaCO_3 = \frac{A}{B} \times 1000$

A = total volume of acid used for each titration.

B = Volume of water sample used for each titration.

The results of the analyses are shown in table 3.2. These values are equal to the carbonate hardness or temporary hardness of the well water samples. The difference between these values and total hardness gives non-carbonate or parmanent hardness. (see table 3.2 and appendix (III)e - i).

2.7.5 Determination of Hardness (35, 36, 37)

There are two basic methods of determining hardness of water.

Method A - called hardness by calculation. This involves a complete analysis of mineral constituents of water and it is known to yield highest accuracy. Here the concentration of each mineral found is multiplied by a proper factor to obtain the equivalent of calcium carbonate concentration and by suming up these calcium carbonate concentrations, we obtain the total hardness.

Method B - which is the method used in this study involves the estimation of hardness by titrating with a standard solution of disodium ethylenediaminetetra-acetate dihydrate (EDTA), $Na_2H_2C_{10}H_{12}O_8N_2.2H_2O$ which complexes with the two principal elements (calcium and magnesium) concerned with hardness of water. This can be applied to any type of water with appropriate modification.

Experimental.

Reagents.

All chemicals used were of analytical-reagent grade. Deionised water was used for preparing all reagents and as dilution water.

0.01M EDTA.

This was prepared by dissolving 3.723g of the salt (dried at 80°C for 3 hours and allowed to cool in a desicator before weighing) in about 300ml of deionised distilled water and made up to 1 litre with more deionised water. This solution was standardised with standard calcium solution prepared as described below.

Standard Calcium Solution:

This was prepared by dissolving 1.00g anhydrous calcium carbonate in about 10 ml of 1:1 hydrochloric acid, then evaporated to almost dryness and diluted to 1 litre with deionised water (1 ml = 1 mg $CaCO_3$).

Buffer solution pH 10 ± 0.1: - prepared by adding 142 ml concentrated ammonium hydroxide solution (S.g 0.88) to 17.5g of ammonium chloride and diluting to 250 ml with deionised water.

Eriochrome Black T indicator - prepared by dissolving 0.20g of the dye stuff in 15ml triethanolamine with addition of 5 ml absolute ethanol to reduce viscosity, the reagent was used throughout for the period.

Apparatus:

50ml-burette, 50ml pipettes and 500ml-conical flasks (10 each)

Procedure: (1) Total Hardness.

50ml of each sample in 500ml conical flask was diluted to 100ml with deionised water. Then about 2ml ammonia - ammonium chloride buffer solution and 2 to 3 drops of Eriochrome Black T were added and titrated with standard 0.01 M EDTA solution from a burette to a clear blue end point.

$$\text{Total Hardness (ppm } CaCO_3) = \frac{A \times B \times 1000}{\text{Volume of Sample used}}$$

where

A = Volume of EDTA used for sample

B = mg $CaCo_3$ equivalent to 1 mg EDTA titrant.

(ii) Calcium hardness:

50ml of each sample in 500 ml conical flask was diluted to 100ml with deionized water, then 2ml 2M sodium hydroxide and 2 to 3 drops of Erio- Blue-Black R indicator were added, mixed thoroughly and titrated with 0.01M EDTA solution from a burette to clear blue end point.

$$\text{Calcium hardness (ppm } CaCo_3) = \frac{A_1 \times B_1 \times 1000}{\text{Volume of Sample used.}}$$

where

A_1 = Volume of 0.01M EDTA used for sample

B_1 = mg of $CaCO_3$ equivalent to 1mg EDTA titrant.

(iii) Magnessium hardness - determined by difference between total hardness and calcium hardness since the same quantity of sample was used each time.

Magnessium hardness (ppm $CaCO_3$) = Total hardness - Calcium hardness

Non carbonat hardness = Total hardness - Total alkalinity (ppm $CaCO_3$)

The results obtained from the analysis are shown in table 3.2. and appendix (III)f.

2.7.6 Determination of sulphate (38, 39).

There are three basic methods of determining the concentration of sulphate in water samples and the choice of a method depends on the concentration range of sulphate and the degree of accuracy required.

(i) Gravimetric method:

This involves the precipitation of the sulphate in a hydrochloric acid medium as barium sulphate by the addition of barium chloride solution. The precipit is ignited and weighed as barium sulphate. From this amount of sulphate present in the sample can be calcula Although this method is very accurate, it is subject to many errors both positive and negative.

(ii) Volumetric method.

Here the sulphate present in a water sample is determined by titration with standard barium chloride solution using tetrahydroxyquinone (THQ) as an indicator. The disadvantage of this method is that the precipitation of barium sulphate is very slow and so vigorous swirling and slow addition of barium chlori solution is necessary.

(iii) Turbidimetric methed.

This method is based on the precipitation of sulphate as barium sulphate from an acidified water sample to which a stabilizing agent has been added to render the barium sulphate less soluble and produce a relatively stable turbid solution, the absorbance of which can be measured in a spectrophotometer at a wavelength of 420nm. The concentration of sulphate is then determined from a prepared calibration curve. Interferences due to suspended matter are removed by filtering the water samples. This method is more rapid and may be either more or less accurate than methods (i) and (ii) for sulphate concentrations less than 10 ppm, depending on the skill of the analyst.

Experimental

Apparatus:

(1) Spectrophotometer - spectronic 20, Analytical system Division, Bausch and Lomb.

(2) 50 ml-volumetric flasks (20)

(3) 2 ml-micro pipette

(4) 50 ml-pipettes (10)

(5) 30 mesh size seive

(6) Sintered glass filter G 3 (10)

(7) Vaccum pump.

Reagents:

All reagents used were of analytical-reagent grade.

(1) Stabilising Reagent:

This was prepared by dissolving 135.00g of calcium chloride dihydrate ($CaCl_2.2H_2O$) in about 200ml deionised water containing 50ml concentrated hydrochloric acid. Then 500 ml diethylene glycol was added and diluted to 1 litre with more water and mixed thoroughly. This solution was used throughout.

(2) Barium chloride crystals ($BaCl_2.2H_2O$).

20 - 30 mesh - prepared by grinding the salt and seiving with 30 mesh size seive.

(3) Standard Sulphate Solution.

This was prepared by dissolving 1.479g anhydrous sodium sulphate (Na_2SO_4) in deionised water and diluting to 1 litre with more deionised water. (1.00ml = 1.00mg sulphate).

Preparation of Calibration Curve.

(a) 0.50, 1.00, 1.50, 2.00, 2.50, and 3.00ml portions of standard sulphate solution were transfered into a series of 50ml volumetric flasks and diluted to about 30 ml.

(b) Blank - 30ml of deionised water was put in a 50ml volumetric flask for use as blank.

(c) To each flask including the blank, 10.00ml of the stabilising reagent was added and diluted to the mark.

(d) To each flask again, about 0.30g barium chloride crystals (20 - 30 mesh) was added and stoppered. Then these flasks were inverted several times until all the barium chloride crystals dissolved.

(e) About 10 minutes after adding the barium chloride, the blank solution was used to set the instrument (spectrophotometer) at zero absorbance. After this, the absorbances of the standard solutions were measured at 420 nm wavelength and the observed absorbances were plotted against the corresponding concentration of sulphate on a semi logarithic graph paper.

Procedure for analysis of samples.

(1) To 40ml of each of the filtered sample in a 50 ml volumetric flask, 10 ml of the stabilising reagent and about 0.3g barium chloride (20 - 30 mesh) were added, stoppered and mixed by inverting the flask several times until the barium chloride crystals dissolved.

(2) Blank - 40ml deionised water was treated in the same way as samples and used to set the instrument at zero absorbance; ten minutes after adding barium chloride.

(3) The absorbance of each sample was measured at 420 nm 10 minutes after adding barium chloride crystals (20 - 30 mesh).

(4) The amount of sulphate in each sample was determined from the calibration curve.

(5) Duplicate determinations were carried out for each sample and the average used.

Calibration curve is shown in figure (2.1) while results of the analyses are shown in table 3.3. and in appendix (III)j.

2.7.7 Determination of phosphate (40, 41).

There are numerous methods of determining phosphate content of water samples. These include ascorbic acid method and stannous chloride method. But in this study, the stennous chloride method described below was used.

Experimental

Reagents.

All reagents used were analytical reagent grade unless otherwise stated.

1. Ammonium molybdate solution:

This solution was prepared by dissolving 64g of the salt in a mixture of 300ml of deionised water and 500ml of 5M sulphuric acid. To this solution, 10g of sulfamic acid ($HSO_3.NH_2$) was added, stirred and diluted to 1 litre.

2. Stannous chloride solution.

This was prepared by dissolving 5g of the salt ($SnCl_2.2H_2O$) in 25ml concentrated hydrochloric acid. This solution was renewed every week and for daily use, 1ml of it was taken and diluted to 100ml with deionised water.

3. 5M Sulphuric acid:

This was prepared by adding slowly 280ml of the concentration acid to 500ml deionised water, mixed, cooled and diluted to 1 litre with more deionised water.

4. Standard phosphate solution:

This was prepared by dissolving 1.433g potassium dihydrogen phosphate (KH_2PO_4) in about 300ml of deionised water and diluting to 1 litre.

5. Intermediate standard phosphate solution:

This was prepared by diluting 10ml of the standard phosphate solution to 100ml with deionised water (1ml = 0.10mg PO_4).

Apparatus:

(1) Spectrophotometer, spectra, Evans Electroselenium Ltd Halstead, England.

(2) 2ml-micro-pipette.

(3) 100ml-volumetric flasks (20).

(4) 500ml-beakers (10).

(5) Switered glass filter g3

(6) Vacuum pump.

Preparation of calibration curve.

(1) 1.0, 1.5, 2.0, 2.5, 3.0ml and 4.0ml of the intermediate phosphate solution were pepitted into a series of 100ml volumetric flasks containing about 50ml of deionised water. While swirling the solutions, 10ml of 5M sulphuric acid, 10ml molybdate solution and 5ml dilute stannous chloride were added and diluted to the mark after mixing thoroughly.

(2) The absorbance of the characteristic blue colour of the solutions was measured at 650nm between 10 and 15 minutes after adding the stannous chloride solution.

(3) Blank determination - For this determination deionised water was used in place of phosphate solution and treated as described above. This was used to set the instrument at zero absorbance. The observed absorbance was plotted against the corresponding ppm of phosphate on a semilogarithmic graph paper.

Procedure for phosphate in Samples.

(1) 200ml of each filtered sample was transfered into 500ml, beaker, 10ml of 5M sulphuric acid added and evaporated until volume reduced to about 50ml.

(2) After evaporating/concentrating the sample, this was cooled, transfered quantitatively into 100ml volumetric flask and beaker resined three times with 5ml of deionised water in each case.

(3) Then the sample was treated as the standard phosphate solution and absorbance measured at 650nm between 10 and 15 minutes after adding stannous chloride solution.

From the previously prepared calibration curve, the amount of phosphate in the samples was determined. Results of analyses are shown in table 3.3 while the calibration curve is shown in figure 2.2.

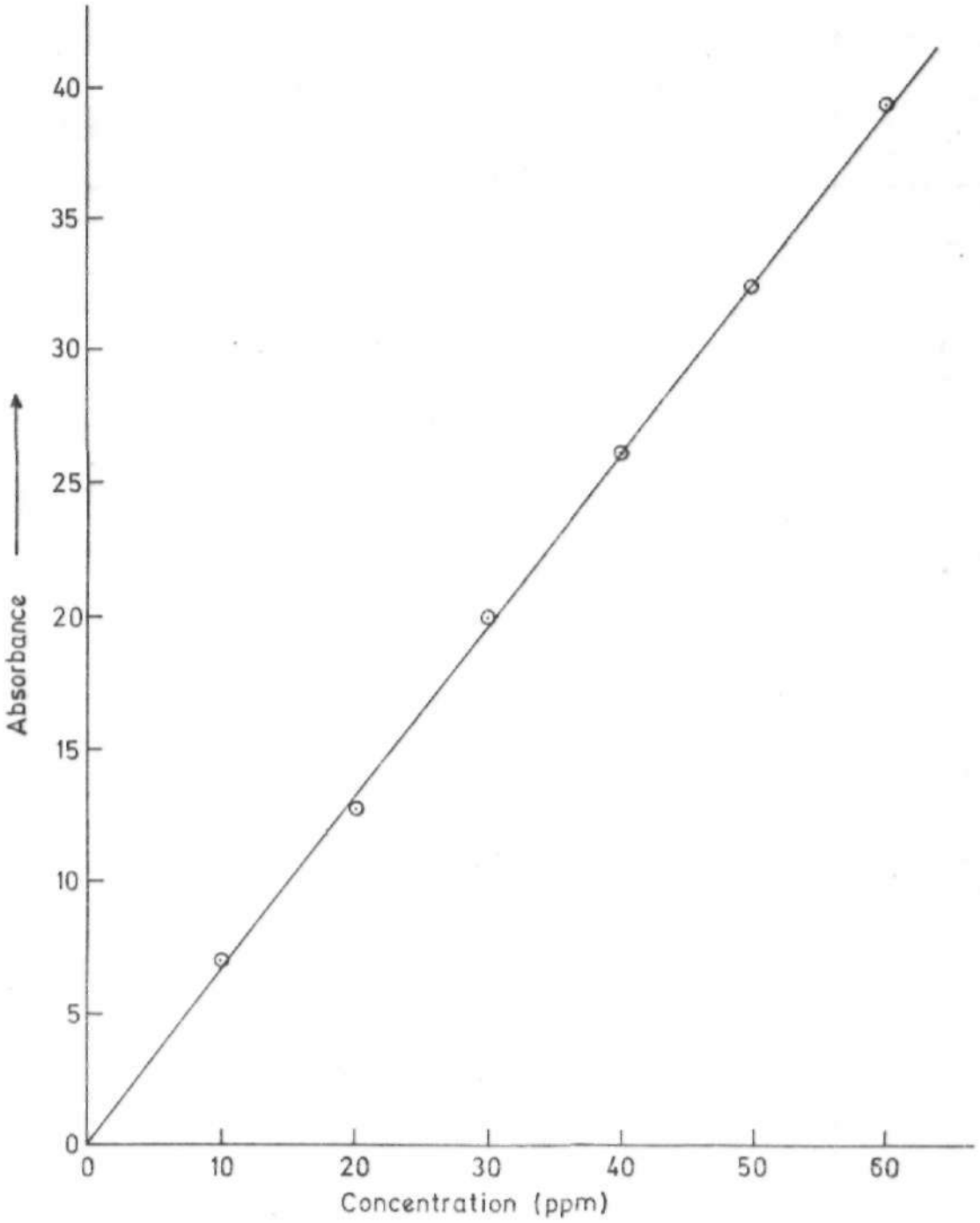


Fig. 2.1 Calibration curve for the determination of Sulphate.

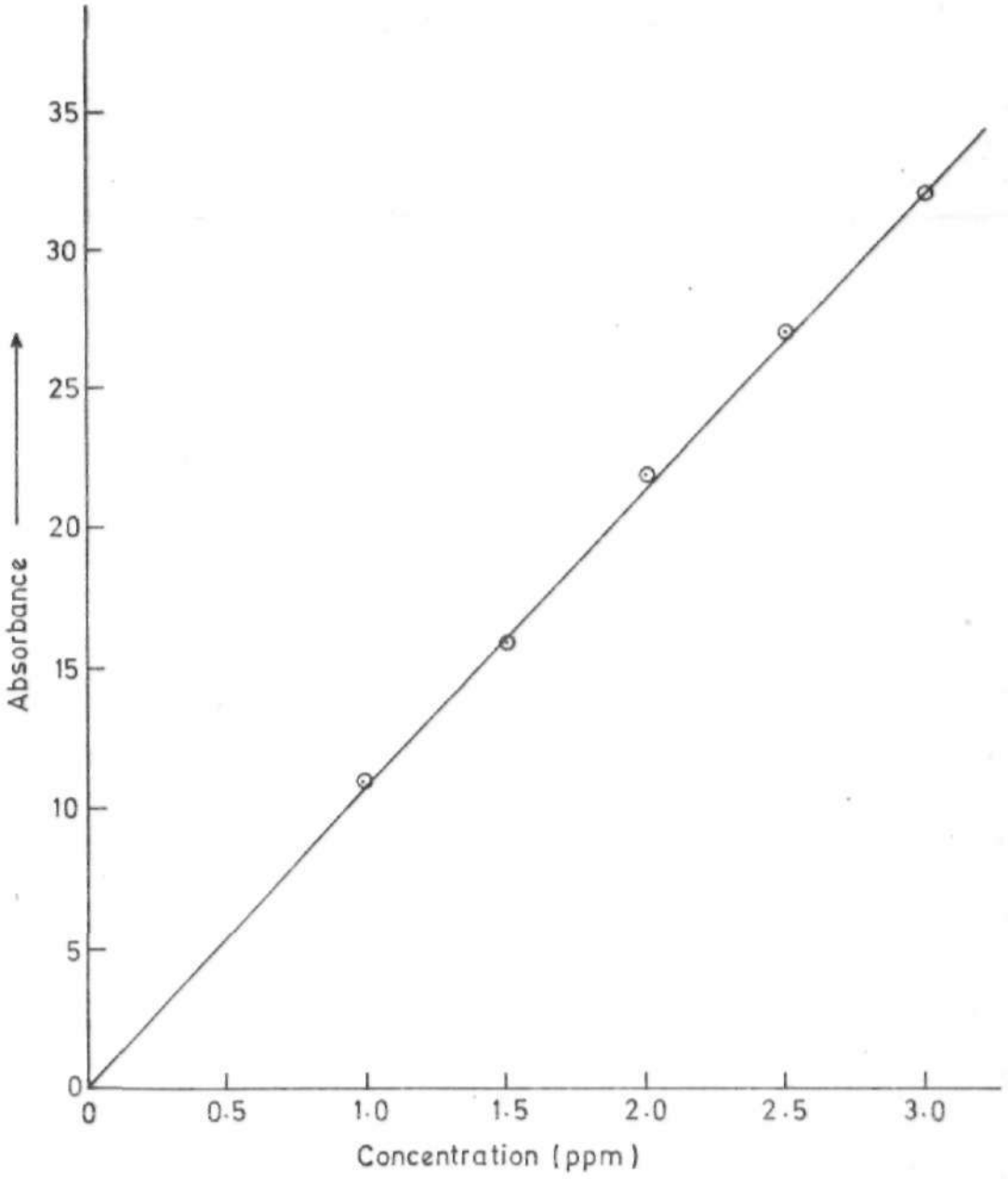


Fig. 2.2 Calibration curve for the determination of Phosphate.

2.7.8 Determination of chloride (42, 43, 44, 45).

There are three different methods for the determination of chloride in natural waters and waste waters.

(i) The mercuric nitrate method based on the fact that when chloride is titrated with mercuric nitrate solution, a soluble and slightly dissociated mercuric chloride is formed. In the pH range 2.3 to 2.8, diphenylcarbazone indicates end point of this titration by formation of a purple complex with excess mercuric ions.

(ii) Potentiometric method in which case the chloride is determined by potentiometric titration with silver nitrate solution with a glass and silver - silver chloride electrode system. This method is suitable for coloured or turbid samples in which colour-indicated end point might be difficult.

(iii) The Argentometric method commonly known as Mohr's method. This involves titration of the chloride with standard silver nitrate solution using potassium chromate solution as an indicator. This is the method used in this work.

General principle of Mohr's method:

When silver nitrate solution is added to a solution containing chloride and chromate ions, both silver chloride and silver chromate are precipitated at first. But the silver chromate is rapidly decomposed by chloride ions remaining in solution but at the amount of unprecipitated chloride decreases, the decomposition of the silver chromate becomes slower and slower indicating the approach of the end point of the reaction. As excess of silver nitrate solution is added, red or pink colour of silver chromate is produced indicating complete precipitation of chloride ions.

As the sensitivity of the indicator is markedly decreased in acidic solution, the pH of the samples should be greater than 7 but less than 10.5. This is achieved by adding about 0.20 g of pure solid sodium hydrogen carbonate which brings the pH of the sample to about 8.4.

A study by Sheen and Kahlar has shown that the Mohr method of estimating the amount of chloride ions in a sample of water is unaffected by the normal amount of sulphate, alkalinity, hardness, phosphate, silicate and iron found in natural and portable waters.

Interferences due to sulphide, thiosulphate and sulphite ions can be removed by treatment of the samples with small amount of hydrogen peroxide.

Experimental

Apparatus.

(1) 50ml-burette

(2) 100ml-pipettes (10)

(3) 500ml-conical flasks

(4) Sintered glass filter g3

(5) Vaccum pump.

Reagents:

All reagents were of analytical reagent grade.

(1) Standard silver nitrate solution (0.0171M)

This was prepared by dissolving 3.0g silver nitrate in about 500ml distilled water and diluted to 1 litre with more water. This solution was stored in a dark bottle and kept in a dark place.

(2) Potassium chromate indicator (5% m/m)

This was prepared by dissolving 5g of the salt in distilled water and diluting to 100ml with more distilled water.

(3) Standard sodium chloride solution:

1.00g accurately weighed sodium chloride (dried at 110°C for 3 hours) was dissolved in 300ml distilled water and diluted to 1 litre. (1ml = 1mg NaCl).

(4) 3% hydrogen peroxide (H_2O_2)

This was prepared by diluting 10ml of 30% hydrogen peroxide to 100ml with distilled water.

(5) Standardization of Silver nitrate solution.

This was standardized with sodium chloride solution. Later the silver nitrate solution was adjusted so that 1 ml = 1 mg sodium chloride giving 0.0171M.

Procedure:

100ml of the filtered sample plus 1ml of 3% hydrogen peroxide was put in 500ml - conical flask, 0.2g solid sodium hydrogen carbonate was added to adjust the pH of the sample to about 8.4. Then 1 ml of 5% potassium chromate indicator was added and sample titrated with 0.0171M silver nitrate from a burette to a faint orange or pink colour end point. Duplicate determinations were carried out on each sample and the average volume of silver nitrate solution used taken for calculation.

Blank determination:

100ml distilled water was similarly treated as the samples and titrated with 0.0171M silver nitrate to a pink colour end point.

Calculation:

$$\text{ppm NaCl} = \frac{(A - B) \times 1000}{\text{Volume of sample used}}.$$

where

A = Average volume of silver nitrate used for sample.

B = Average volume of silver nitrate used for blank determination.

The results of the analyses are shown in table 3.3

2.7.9 Determination of solids (46, 47)

(a) Total solids - refers to the solid substances suspended and dissolved in a sample of water. This is normally obtained after evaporating the sample of water, followed by subsequent drying in an oven at a definite temperature to a constant weight.

(b) Total dissolved solid - refers to all the solid materials dissolved in the water sample. There are various methods of determining this:

(i) By evaporating a certain quantity of filtered sample and drying the residue in an oven at a definite temperature and to a constant weight. Usually the residue is dried to a constant weight at 103 - 105°C. But drying at 180°C

for 1 hour is better in order to remove maximium amount of water of crystallization which may be associated with the mineral residue and the value so obtained approximates that obtained by adding together all the components determined individually by instrumental methods or any other methods.

(ii) Conductometric method - The total dissolved solid in a water sample can be determined by measuring the specific conductance of the water. This is based on the fact that the more the concentration of the ions in a solution, the greater is the conductivity and this is roughly proportional to the residue dried at 180°C.

(c) Total suspended solid, when the value of total solid, and total dissolved solid are obtained by evaporating and drying to a constant weight at 103 - 105°C, then the total suspended solid is obtained by difference between the two values provided the same quantity of sample is used for each determination.

Determination of total solids.

Apparatus:

(1) Porcelain evaporating dishes capable of holding 100ml of water sample.

(2) Water bath

(3) Desiccators containing silica gel

(4) Drying oven equipped with a thermostatic control capable of maintaining the temperature within a 2°C range.

(5) Analytical balance capable of weighing up to 0.1mg.

Procedure:

Well clean porcelain evaporating dishes were put in an oven set at 105°C for 3 hours. These were cooled in a desiccator and weighed. 100ml of the well mixed sample was measured into the weighed evaporating dish and evaporated to dryness on a steam bath. The residue was then dried in the oven set at 105°C for 1 hour. This was cooled in a desiccator and weighed. Drying, cooling and weighing was repeated until constant weight was obtained. Duplicate determinations were carried out simultaneously for each sample and the average result taken for calculation.

Calculation:

$$(\text{ppm})\ \text{total solid} = \frac{(A - B) \times 1000}{C}$$

where

A = weight of sample + evaporating dish

B = weight of empty evaporating dish

C = volume of sample used for each determination.

The results obtained from the analyses are shown on table 3.4. and appendix (III)n.

Determination of total dissolved solids.

Apparatus:

In addition to those mentioned under total solid, the following were included:

(1) 500ml-suction flask equipped with rubber bung.

(2) Sintered glass filter, size G4 pyrex.

(3) Suction pump.

Procedure:

The water samples were filtered through a well washed sintered glass filter, (size G4 pyrex) with the help of suction pump. After this, 100ml of the filterate was pipetted into a weighed evaporating dish (dried in

an oven at 105°C and cooled in a desiccator). The sample was evaporated to dryness in a steam bath. Then the residue was dried in an oven at 105°C for 1 hour, cooled in a desiccator and weighed. Subsequent drying, cooling, and weighing were made until a constant weight was obtained. Duplicate determination were carried out simultaneously for each sample and average result taken for calculation.

Calculation:

$$\text{(ppm) dissolved solid} = \frac{(A - B) \times 1000}{C}$$

where

A = Weight evaporating dish + dried residue.

B = Weight of empty dry evaporating dish.

C = Volume of filtered sample used for each determination.

The results of determination are shown on table 3.4. and on appendix (III)o.

Determination of suspended solids.

Procedure:

This was determined for each sample from the relationship.

Total suspended solid = Total solid - Total dissolved solid.

This relationship holds since equal volumes of samples were used for total solid and total dissolved solid (100 ml).

The results of the analyses are shown on table 3.4. and appendix (III)p.

2.7.10 Determination of total nitrogen (organic nitrogen) (48, 49).

The estimation of total nitrogen content of samples of well water, gives an indication of the amount of organic matter present in them. The method most often used is the Kjeldahl's method. The principle of the method is based on the conversion of the nitrogen of the nitrogenous substance into ammonium sulphate by boiling with concentrated sulphuric acid. This reaction is usually very slow and so to facilitate the reaction, mixed catalyst such as potassium sulphate and anhydrous copper sulphate is added. After digestion, the sample is treated with caustic alkali and the liberated ammonia absorbed in boric acid from where it is estimated by titration with any standard mineral acid e.g. hydrochloric acid.

The Kjeldahl's method works well for nitrogen determination in proteins and also in amines and amides but not applicable to nitro, azo, hydrazo and cyano compounds without modification. For instance to avoid loss of nitrate as nitric acid during diggestion,

salicyclic acid is added to the sulphuric acid (1g to 30.00ml sulphuric acid) which fixes the nitric acid as nitrosalicyclic acid. Upon addition of zinc dust or anhydrous sodium thiosulphate, the nitro-salicyclic acid is reduced to the amino-compound which can be estimated by Kjeldahl's process.

Experimental

Apparatus:

(1) A standard Kjeldahl's digestion and distillation set up consisting of six 500ml digestion flasks, six distillation apparatus each with 500ml Kjeldahl's flask fitted with a special funnel with a tap for controlling the in flow of caustic soda into the digest.

(2) Six 500ml conical flasks each containing 100ml of 4% boric acid.

(3) A 2-ml microburette for titration.

Reagents:

All reagents used were of analytical-reagent grade unless otherwise stated.

(i) 4% boric acid:

This was prepared by dissolving 4.0g of the acid in about 50ml of distilled water and later diluted to 100ml with more distilled water.

(ii) Sodium hydroxide sodium thiosulphate solution:

This was prepared by dissolving 500g of sodium hydroxide and 25g of sodium thiosulphate in water and diluting to 1 litre.

(iii) 0.1M hydrochloric:

This was prepared by diluting 9.00ml of 35%, specific gravity 1.18, hydrochloric acid to 1 litre with distilled water. This solution was standardized with 0.1M sodium carbonate solution.

(iv) Phenolphthalein indicator solution 1% (m/V).

This was prepared by dissolving 0.5g of the salt in 50ml of 95% ethanol and 50ml of distilled water.

(v) Mixed Catalyst:

This was prepared by grinding together 50g of potassium sulphate and 10g of anhydrous copper sulphate.

(vi) Mixed indicator solution 1% (m/V).

This was prepared by dissolving 0.5g each of methyl red and bromocresol green in 100ml of 95% ethanol.

Procedure:

To 250ml of ice cold sample in the Kjeldahl's flask, 10g of mixed catalyst, 20ml of concentrated sulphuric acid and about 1g of salicyclic acid were added and the sample diggested until fumes of suphuric acid started coming out. The set up was allowed to cool and diluted with 100ml of distilled water. After this, the solution was quantitatively transfered into the distillation flask, 1ml of the phenolphthalein indicator was added, then the sodium hydroxide - sodium thiosulphate solution added until the solution turned red indicating complete neutralization of the sulphuric acid left. Some porous procelain pieces were added and the ammonia distilled off into the 100ml boric acid in a conical flask containing two drops of the bromocresol green - methyl red mixed indicator. At the end of the distillation, the amount of ammonia absorbed in boric acid was estimated by titration with 0.1M hydrochloric acid back to the pink colour of the mixed indicator in boric acid.

Duplicate determinations were carried out on each sample and average volume of 0.1M hydrochloric acid consumed was used for calculation.

Blank determination.

250ml of distilled water in Kjeldahl's flask was treated in the same way as the samples.

Calculation:

Amount of nitrogen present in each sample in

$$\text{ppm} = \frac{(V_2 - V_1) \times M_A \times 0.01401 \times 10^3}{\text{ml of sample used.}}$$

where

V_2 = Volume in ml of standard acid used in titration of samples.

V_1 = Volume in ml of standard acid used in blank titration.

M_A = Molarity of the acid used.

Detailed results of the determination are shown in appendix (iii)m, while summary of results are on table 3.3.

2.7.11 Determination of Sodium, Potassium and Calcium by Flame photometry (50, 51, 52, 53).

Principle of Flame photometry.

Some elements such as sodium, potassium and calcium impart characteristic colours to non luminous bunsen flame and the brightness of the flame is proportional to the amount of salt introduced to the flame. So the principle of flame photometry is based upon the emission of electromagnetic radiation in the visible and ultraviolet regions of the spectrum by atoms after excitation in flames and the correlation of the emission intensity with concentration of these elements.

Experimental

Apparatus:

(1) A Flame photometer corning EEL Scientific instrument, Evans Electroselenium Ltd, England.

(2) Sodium, potassium and calcium filters.

(3) Butane gas.

(4) Air compressor.

(5) 100ml - volumetric flasks (20).

(6) 1 litre-volumetric flask(3).

Reagents:

All reagents used were of analytical - reagent grade. Deionised water was used for preparing all reagents and as dilution water.

(i) Sodium Standard Solution:

1000ppm of the stock solution of sodium was prepared by dissolving 2.542g accurately weighed sodium chloride (dried at 140°C for 2 hours and cooled in a desicator) in a small quantity of deionised water and later diluted to 1 litre with more deionised water. From this stock solution, an intermediate solution of 100 ppm sodium was prepared by diluting 10ml of the stock solution to 100ml. From the intermediate solution, concentrations in the range 1 to 5 ppm sodium were prepared by appropriate dilution with deionised water.

(ii) Potassium Standard Solution:

1000ppm stock solution of potassium was prepared by dissolving 1.907g accurately weighed potassium chloride (dried at 110°C for 2 hours and cooled in a desicator) in a small quantity of deionised water and diluting to 1 litre with more water. From the stock, an intermediate solution of 100ppm potassium was prepared by diluting 10ml of it to 100ml. From this, working standards of 1 to 10ppm potassium were prepared by appropriate dilution with more water.

(iii) Calcium Standard Solution:

1000 ppm of calcium was prepared by dissolving 2.497g calcium carbonate in 10ml of 20% hydrochloric acid solution and diluting to 1 litre with deionised water. This solution was standardised with 0.1M EDTA solution using Eriochrome Black T as indicator (57). From the stock solution, concentrations of 10 ppm to 100 ppm were prepared by appropriate dilution.

(iv) Lanthanium nitrate solution (1% m/V):

This was prepared by dissolving 3.1175g Lanthanium nitrate in deionised water and diluting to 1 litre with more deionised water.

Preparation of calibration curves for sodium, potassium and calcium and analysis of samples.

Distilled water was used to set the instrument at 0% intensity while highest concentration of each standard solution (5ppm for sodium, 10ppm for potassium, 100 ppm for calcium) was used to set the instrument at 100% intensity. To 10ml of each calcium standard, 2.5ml of lanthanium solution was added before aspirating into the flame, samples were similarly treated before aspirating into the flame. The samples for sodium and potassium were analysed by direct aspiration into the

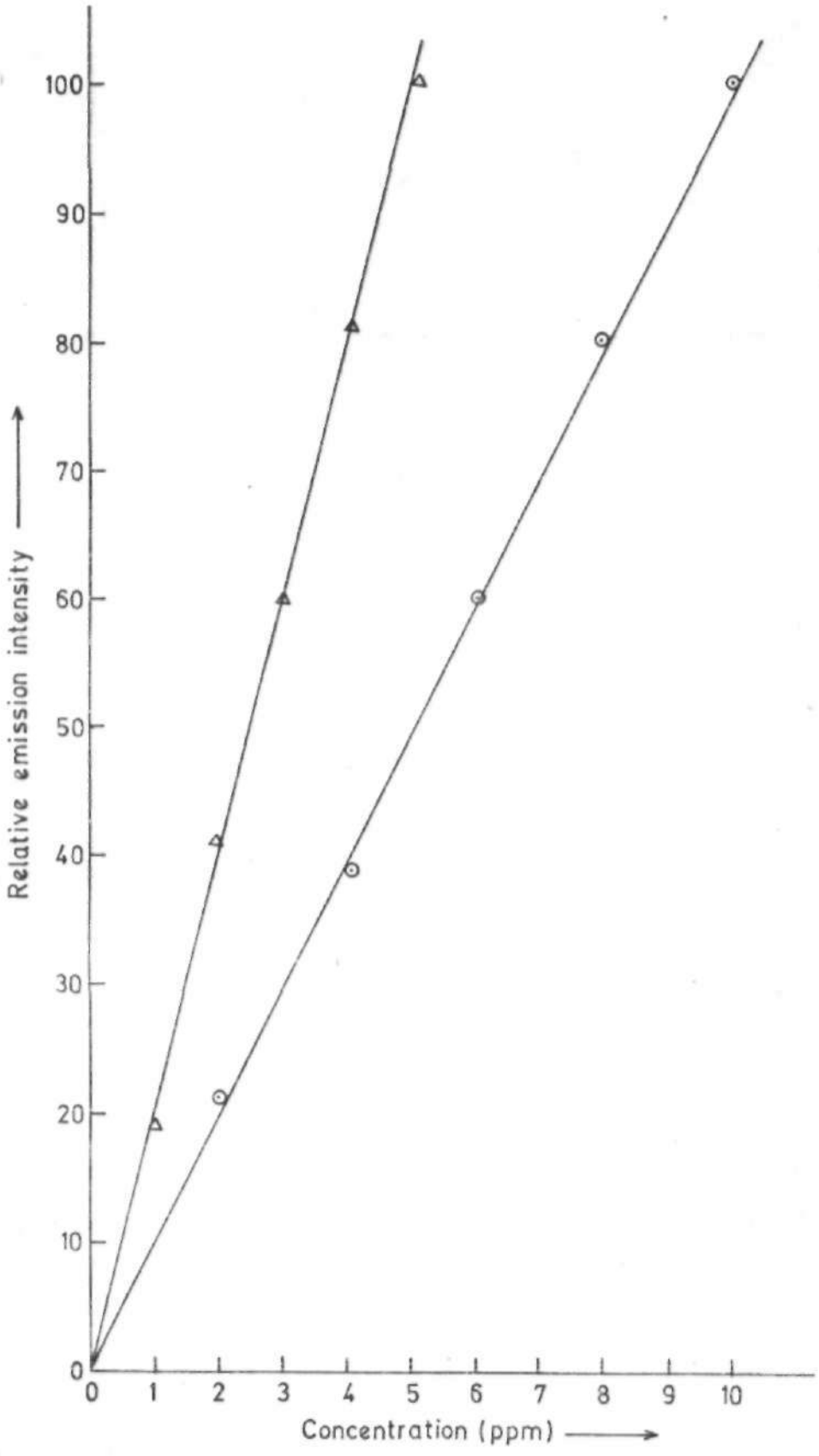


Fig. 2.3 Calibration curves for the determination of Sodium and Potassium.

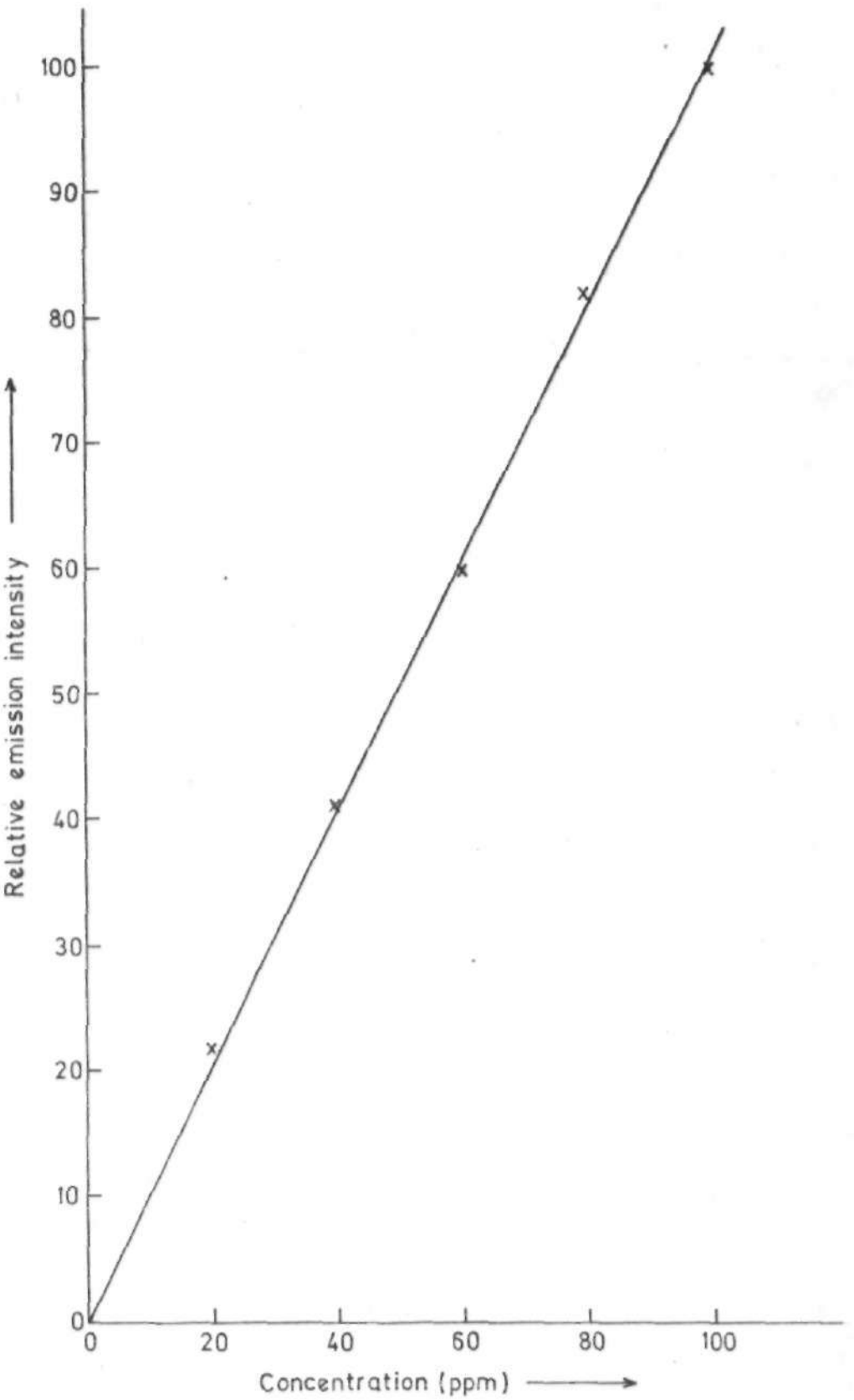


Fig. 2.4 Calibration curve for the determination of Calcium.

flame. Reading obtained from aspiration of the standard solutions were used to obtain the calibration curves shown on figures 2.3 and 2.4 while the readings obtained from aspiration of the samples into the flame were interpolated to the curves to get the corresponding concentration of the metal ions in the samples. Summary of results obtained are shown on table 3.5, while detailed results are on appendix (III) q, r, s.

2.7.12 Determination of magnesium, iron, lead, manganese, arsenic, zinc, cadmium, copper and nickel by atomic absorption spectrophotometry (AAS) (54, 55, 56).

Principle of Atomic Absorption Spectrophotometry.

The procedure is based upon absorption of electromagnetic radiation in the visible and ultraviolet regions of the spectrum by atoms rather than flame emission. The absorption of radiation results in changes in electronic structure of the atoms, observed by passing the radiation characteristic of the particular element through an atomic vapour of the sample. When electromagnetic radiation characteristic of electronic transitions in the outer orbitals of atoms of a particular element is passed through an atomic vapour of that element, the radiation at a certain frequency is attanuated. The absorbed radiation excites electrons

from the ground state to various higher energy levels and the degree of absorption is a quantitative measure of the concentration of the ground-state atoms in the vapour.

Preparation of Calibration curves and analyses of the samples.

The calibration curves for magnesium, iron, lead, manganese, arsenic, zinc, cadmium, copper and nickel were prepared by aspirating the working standards of these elements (prepared as described below) into the flame of A.A.S. and plotting the absorbance of each working standard against the concentration. The samples were analysed by aspirating each sample after treatment into the flame of A.A.S. The absorbance of each element in each sample was interpolated to the calibration curve to get the concentration of metal ion in the sample. Summaried results obtained are shown in tables 3.5 and 3.6 while the detailed results are shown on appendix (III) u and v. and calibration curves for the metal ions are shown in figures 2.5 and 2.6. The calibration curves for those metals which are absent or not within the detection limit of the instrument are not shown.

Experimental

Apparatus:

(1) A Unicam SP 1900 atomic absorption spectrophotometer equipped with a standard air-acetylene burner head and individual hollow cathode lamps for the metal ions under investigation.

(2) 1 litre volumetric flasks (10).

(3) 100ml-volumetric flasks (30).

Reagents.

All reagents used were of analytical-reagent grade.

(1) Deionised distilled water was used for preparing the metal ions standard solutions.

(2) Lanthanum nitrate solution, 1% m/V:

This was prepared by dissolving 3.1175g lanthanium nitrate in about 200ml deionised water and diluting it to 1 litre with more deionised water.

(3) 0.1M E.D.T.A. Standard Solution:

This was prepared by dissolving 37.23g of the salt (dried at 80^{o}C for 3 hours and allowed to cool in a desicator) in deionised water and volume made up to

1 litre with more deionised water. This solution was standardised as described under determination of hardness of water samples. From this solution, other solutions of lower concentrations were obtained by dilution.

(4) Xylenol Orange indicator solution:

This was prepared by dissolving 0.5g of the dye in 100ml of deionised water. This solution is stable almost indefinitely.

(5) Calcium Solution:

This was prepared by dissolving 0.630g calcium carbonate in 10ml concentrated hydrochloric acid, evaporated to almost dryness and diluted to 1 litre with deionised water. A stock of 2 litres was prepared for use throughout the period.

(6) 0.025M Potassium iodate:

This was prepared by dissolving 5.350g of the finely powdered salt (dried at 120°C for 1 hour and allowed to cool in a covered vessel in a desicator), in deionised water and diluting to 1 litre.

(7) 0.1M Potassium dichromate solution:

This was prepared by dissolving 4.904g of the salt (dried at 150°C for 1 hour and allowed to cool in a desicator) in about 200ml of deionised water and diluting to 1 litre with more water.

(8) N-phenylanthranilic acid indicator solution:

This was prepared by dissolving 0.25g of the salt in 12ml 0.1N - NaOH and diluting to 250ml with water.

Procedure for preparation of working standards of the metal ions.

(1) Magnesium:

A stock solution - 1000 ppm magnesium was prepared by dissolving 10.0135g magnesium sulphate heptahydrate, $MgSO_4.7H_2O$ in about 300ml deionised water containing 1.5ml concentrated nitric acid and diluting to 1 litre with more water. This solution was standardised with 0.1M EDTA solution using Eriochrome Black T as indicator (57). An intermediate solution of 10 ppm magnesium was prepared by diluting 1 ml of the stock solution to 100ml. Working standards in the range 0.1 to 2.5ppm magnesium were obtained from the intermediate solution by appropriate dilution with deionised water. To 10ml of each standard solution, 2.5ml of lanthanium nitrate solution was added before aspirating into the flame. The samples were diluted and similarly treated before aspirating into the flame.

(2) Iron:

A stock solution of 1000 ppm of iron was prepared by dissolving 4.9778g ferrous sulphate heptahydrate, $FeSO_4.7H_2O$ in about 200ml deionised water containing 50ml

concentrated sulphuric acid and the volume made up to 1 litre with more deionised water. This solution was standardised with 0.1M potassium dichromate solution using N-phenylanthranilic acid as an indicator (57). From this solution, an intermediate solution of 10 ppm iron was obtained by diluting 1 ml of it to 100ml with deionised water. And from the intermediate solution, working standards in the range 1 to 5 ppm were obtained by similar dilution. To 10ml of each of these solutions 2.5ml calcium solution was added before aspirating into the flame. Samples were similarly treated before aspirating.

(3) Lead:

A 1000 ppm stock solution of lead was prepared by dissolving 1.5984g lead nitrate in about 200ml of deionized water and diluted to 1 litre. This solution was standardised with 0.05M EDTA using Xylenol orange as an indicator (57). An intermediate solution of 10 ppm was prepared by diluting 1 ml of the stock solution to 100ml with deionised water. From this, working standards in the range 0.1 to 0.5 ppm were obtained by appropriate dilution.

(4) Manganese:

1000 ppm stock solution of manganese was prepared by dissolving 4.060g manganous sulphate heptahydrate in about 200ml of deionised water containing 1.5ml of concentrated nitric acid and diluting to 1 litre with more deionised water. This solution was standardised with 0.1M EDTA solution using Eriochrome Black T as an indicator (57). An intermediate solution of 10 ppm was prepared by diluting 1 ml of the stock solution to 100ml with deionised water. Working standards in the range 1 to 5 ppm manganese were obtained by appropriate dilution. Standard addition method was used for the analyses.

(5) Arsenic:

A 1000 ppm stock solution of arsenic was prepared by dissolving 1.320g arsenic trioxide As_2O_3 in 50ml of concentrated hydrochloric acid and diluting to 1 litre with deionised water. This solution was standardised with 0.025M potassium iodate (57). From this stock solution, an intermediate solution of 10 ppm was obtained by diluting 1 ml of it to 100ml. Similarly working standards in the range 0.1 to 0.5 ppm were obtained by appropriate dilution.

(6) Zinc:

A 1000 ppm of zinc solution was prepared by dissolving 4.3980g of zinc sulphate heptahydrate ($ZnSO_4.7H_2O$) in about 200ml of deionised water and diluting to 1 litre with more water. This solution was standardized with 0.1M EDTA solution using Eriochrome Black T as indicator (57). From the stock solution, an intermediate solution of 10 ppm was obtained by diluting 1 ml of it to 100ml. Working standards in the range 1 to 5 ppm were obtained by similar dilution. Samples were asperated directly into the flame.

(7) Cadmium:

A stock solution of 1000 ppm was prepared by dissolving 2.1032g cadmium nitrate $Cd(NO_3)_2$ in 250ml deionised water and diluting to 1 litre with more water. This solution was standardized with 0.05M EDTA solution using xylenol orange indicator (57). From this, an intermediate solution of 10 ppm cadmium was obtained by diluting 1 ml of the stock solution to 100ml with deionised water. Working standards in the range 0.1 to 0.5ppm were obtained by similar dilution.

(8) Copper:

A stock solution of 1000 ppm was prepared by dissolving 3.798g copper nitrate trihydrate, $Cu(NO_3)_2.3H_2O$ in about 200ml deionized water and the volume made up to 1 litre with more water. The solution was standardised with 0.1M sodium thiosulphate solution using starch solution as an end point indicator (57). From this an intermediate solution of 10 ppm copper was obtained by diluting 1ml of the stock solution to 100ml with deionised water. Then from the intermediate solution, working standards in the range 1 to 5 ppm copper solution were prepared by similar dilution. Standard addition method was used for sample analyses.

(9) Nickel:

A stock solution of 1000 ppm of nickel was prepared by dissolving 4.953g nickelous nitrate hexahydrate $Ni(NO_3)_2.6H_2O$ in about 200ml of deionised water containing 1.5ml concentrated nitric acid and later made up to 1 litre. This solution was standardised with 0.1M EDTA solution using murexide as indicator (57). From the stock solution, an intermediate solution of 10 ppm was prepared by diluting 1 ml of it to 100ml with deionised water. And from the intermediate concentrations of 1 to 5 ppm were obtained by similar dilution.

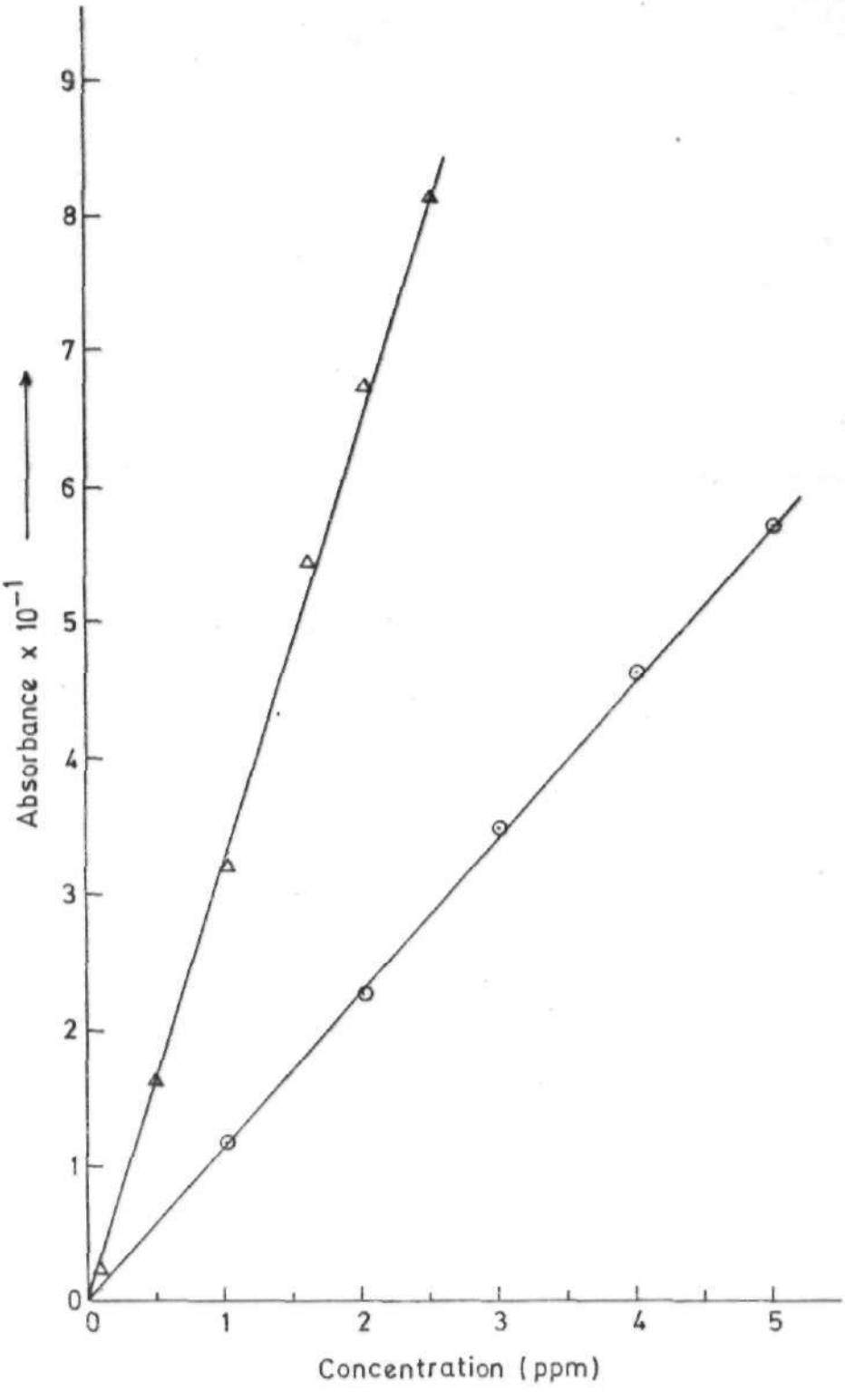


Fig. 2.5 Calibration curves for the determination of magnesium and zinc.
△ Magnesium ⊙ Zinc

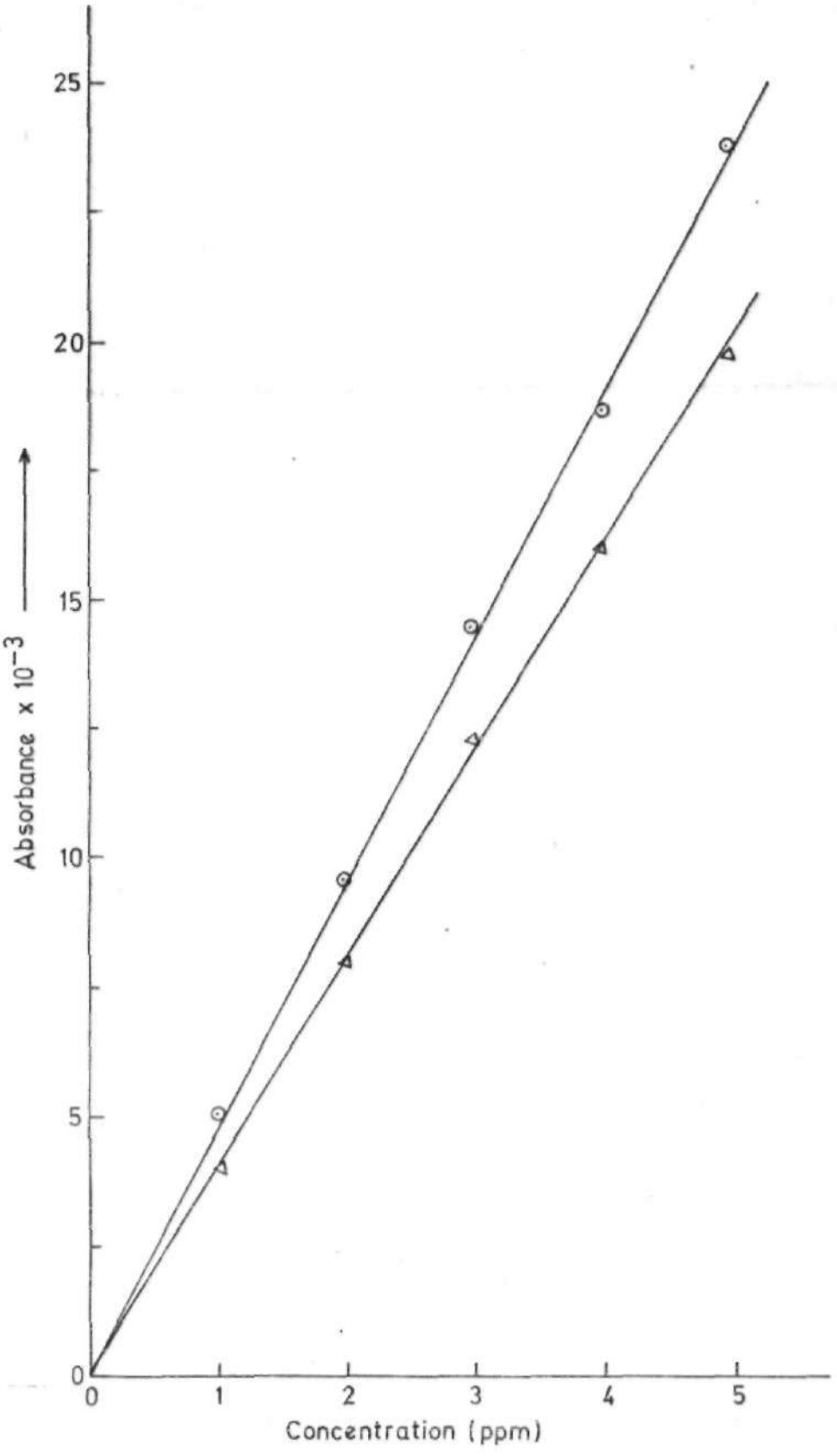


Fig. 2.6 Calibration curves for the determination of Iron and Manganese.
⊙ Iron, △ Manganese

2.7.13 A study on the use of alum as a chemical coagulant on well water.

General consideration:

Chemical coagulation is an important process applied extensively in water treatment practice particularly where well waters are concerned. Chemical coagulation of water is performed for many reasons, the major ones of which are the removal of

(i) inorganic and organic substances causing turbidity, colour and taste.

(ii) harmful bacteria and other pathogens.

(iii) algae and other plankton organisms.

(iv) odour producing substances.

Removal of these materials produce water that is aesthetically acceptable and can be disinfected properly (58).

As many of the suspended matter in well water are colloidal in nature and negatively charged, salts of trivalent metals such as iron and aluminium sulphates are used to coagulate them. Of these two salts, a double salt of aluminium usually refered to as filter alum [$K_2SO_4.Al_2(SO_4)_3.24H_2O$] is most commonly used.

Reactions involved in Chemical coagulation.

When alum is added to water, the moleales dissociates tc yield Al^{3+} and SO_4^{2-} ions. The aluminium ions may combine with the negatively charged colloids to neutralize part of the charge on the colloidal particules.



Aluminium ions may combine with the hydroxyl ions in water to form aluminium hydroxide.

$$Al^{3+} + 3OH^- \longrightarrow Al(OH)_3 \text{ and}$$

the aluminium hydroxide being colloidal in character adscrbs positive ions from solution to form positively charged solution.

$$Al(OH)_3 + \text{positive ions} \longrightarrow [Al(OH)_3]^+$$

The eventual precipitation of $[Al(OH)_3]^+$ is brought about by sulphate ions and other negative ions in water. As the trivalent aluminium ion is much more effective than the $Al(OH)_3^+$ in reducing the zeta potential on negative colloids, it is important that the aluminium sulphate alum be distributed very rapidly throughout the mass of the water in order that contact can be made with all the colloidal particules before other less desirable changes occur

Experimental

Apparatus:

(i) 100ml-volumetric flask.

(ii) 500ml-conical flasks (30).

(iii) Magnetic stirrer.

(iv) 100ml-pipette

Reagents:

(i) Distilled water

(ii) 1% m/V, alum $K_2SO_4.Al_2(SO_4)_3.24H_2O$ solution.

This was prepared by dissolving 1g of the alum in distilled water and later made up to 100ml.

Procedure:

5ml, 10ml and 15ml of the 1% m/V alum solution were used.

To 200ml of each well water sample in 500ml-conical flask, 5ml of 1% m/V alum solution was added, stirred by means of magnetic stirrer for about two minutes, then allowed to stand overnight. The following day, the clear supernatant solution was decanted into a beaker, from which 100ml of it was pipetted into a dried, preweighed evaporating dish. This was evaporated to dryness to obtain total solid content. Furthermore 100ml of the filtered supernatant liquid was evaporated

to obtain dissolved solid content. And by difference the suspended solid content was obtained since the same volume of sample was used in each case. The above procedure was repeated using 10ml, 15ml of the alum solution.

Calculation:

(a) Total solid (ppm) = $\frac{(A - B)}{C} \times 1000$

where

A = Weight of empty dish + dried solid.

B = Weight of empty dish alone.

C = Volume of water sample used.

(b) Dissolved solid (ppm) = $\frac{(A_1 - B_1)}{C} \times 1000$

where

A_1 = Weight of empty dish + dried solid.

B_1 = Weight of empty dish alone.

C = Volume of water sample used.

(c) Suspended solids (ppm) = Total solids - Dissolved solids.

The results of the study are shown in table 3.7.

CHAPTER 3

3.0 RESULTS AND DISCUSSION

3.1 Summary of Results of Analyses.

Below are the tables showing the results of the chemical analyses of the well water sampled.

Table 4.1

Results of Determination of some Physical Properties and measurement of Temp., pH, Conductivity and Dissolved Oxygen.

Wells	Colour	Odour	Taste	Temp °C			pH Values			Conductivity (μmhos x 10^3)			Dissolved oxygen ppm		
				Mean	Range	% SD	Mean	Range	% SD	Mean	Range	% SD	Mean	Range	% SD
1	Clear	no Odour	no taste	27.08	26.50-28.00	2.90	6.95	6.60-7.40	3.46	4.23	3.50-5.10	10.87	5.13	3.80-5.60	9.22
2	Clear	no odour	no taste	27.58	26.50-28.50	3.70	6.53	6.40-6.80	3.22	8.43	7.50-9.50	7.95	4.79	4.20-5.40	7.10
3	Clear	no odour	no taste	27.71	26.50-28.00	2.60	6.53	6.20-7.10	3.36	9.31	6.80-12.00	17.90	4.85	4.40-5.30	9.48
4	Clear	no odour	no taste	27.33	26.00-28.00	2.60	6.44	6.20-6.80	3.12	5.18	4.10- 6.20	11.77	5.71	4.10-6.50	16.28
5	Clear	no odour	bitter taste	27.67	26.50-29.00	.75	6.58	6.20-7.10	3.49	11.78	9.90-13.00	10.28	4.49	3.90-6.20	18.20
6	Clear	no odour	no taste	27.88	26.00-29.00	2.83	6.70	6.40-7.20	3.43	6.35	5.20- 7.80	14.02	5.10	4.70-5.80	8.43
7	Clear	no odour	no taste	28.29	26.50-29.00	2.55	6.43	5.80-6.80	4.19	5.03	4.60-5.40	4.75	4.66	3.80-6.20	15.45
8	Clear	no odour	no taste	27.54	26.50-29.00	3.27	6.66	5.90-7.20	4.80	6.80	6.40-7.30	4.69	5.61	4.80-6.80	12.29
9	Clear	no odour	no taste	28.38	27.00-29.50	3.07	6.59	6.20-7.20	5.92	2.83	2.70-2.90	2.34	4.74	4.30-5.60	12.65
10	Clear	no odour	no taste	28.79	27.00-30.00	3.30	6.87	6.40-7.10	4.66	1.61	1.40-1.80	8.69	4.62	4.20-5.10	4.76

%SD = Percentage Standard Deviation.

TABLE 3.2

Results of Determination of Alkalinity and Hardness

Wells	Alkalinity (ppm $CaCO_3$)			Total hardness (ppm $CaCO_3$)			non carbonate hardness (ppm $CaCO_3$)			Calcium hardness (ppm $CaCO_3$)			Magnesium hardness (ppm $CaCO_3$)		
	Mean	Range	% SD	Mean	Range	% SD	Mean	Range	% SD	Mean	Range	% SD	Mean	Range	% SD
1	52.68	43.50- 77.50	20.77	112.66	90.00-150.00	10.65	59.74	47.50- 81.00	18.28	86.64	74.00-102.00	10.97	25.90	22.00- 30.00	12.10
2	46.88	39.00- 60.00	11.86	140.00	128.00-204.00	11.67	130.13	89.00-147.50	13.75	126.52	70.80-148.00	20.21	54.80	46.00- 61.00	11.68
3	45.79	39.50- 51.00	7.38	185.75	148.00-216.00	14.31	149.96	106.00-202.50	19.70	133.18	85.50-148.00	17.83	54.25	48.00-64.00	8.21
4	26.83	22.00- 30.00	8.13	115.00	102.00-132.00	8.17	88.17	72.00-104.00	11.89	82.73	60.40- 96.00	14.78	31.08	26.00-39.60	9.23
5	110.46	98.00-129.00	8.63	288.83	254.00-356.00	9.11	178.71	138.50-264.00	18.47	180.28	146.00-198.00	9.10	99.42	84.00-120.00	9.37
6	44.63	34.00- 55.50	13.77	135.00	124.00-178.00	15.85	90.33	70.50-146.00	27.56	85.96	76.00- 96.00	12.46	46.42	42.00- 53.00	8.68
7	40.33	36.00- 51.00	16.82	133.33	116.00-156.00	6.83	93.00	82.50-124.00	14.22	90.58	70.50-106.00	11.61	36.00	32.00- 47.00	8.73
8	39.17	26.00-49.50	17.07	122.67	106.00-144.00	9.69	94.33	74.00-126.00	11.66	82.16	56.50- 96.00	17.66	30.08	32.00-42.50	17.74
9	22.29	18.00-26.00	16.00	49.33	42.00- 54.00	7.28	26.54	20.00-34.00	17.45	33.91	26.40-38.00	11.50	14.50	14.00-16.50	6.50
10	42.17	35.00-47.00	7.57	59.84	50.00- 68.00	8.57	18.50	16.00-22.50	11.41	45.28	26.80-56.00	18.83	12.66	12.00-15.50	10.36

% SD: Percentage Standard Deviation

TABLE 3.3

Results of Determination of Sulphate, Chloride, Phosphate and Nitrogen.

Wells	Sulphate (ppm)			Chloride (ppm NaCl)			Phosphate (ppm)			Total Nitrogen (ppm)		
	Mean	Range	% SD	Mean	Range	% SD	Mean	Range	% SD	Mean	Range	% SD
1	1.43	1.25- 1.75	13.64	75.47	68.00-82.00	6.00	0.069	0.055-0.078	10.14	4.39	3.87-5.49	10.56
2	27.68	21.25-32.00	13.29	157.92	145.00-180.00	6.86	0.023	0.015-0.030	21.74	6.07	5.50-6.50	5.00
3	17.33	15.50-19.00	12.58	91.50	118.00-210.00	6.85	0.034	0.023-0.040	17.65	3.69	3.20-4.25	8.02
4	20.32	17.00-24.60	11.13	104.91	102.00-106.00	1.80	0.173	0.150-0.200	12.14	5.69	5.20-6.10	5.28
5	31.92	29.50-34.00	5.73	244.90	235.00-264.00	3.68	0.166	0.113-0.225	18.67	3.99	3.54-4.82	8.35
6	38.40	35.00-43.75	17.10	122.92	110.00-136.00	9.14	0.042	0.035-0.048	11.14	4.37	3.87-4.98	9.10
7	35.10	30.00-44.50	14.70	182.42	52.00-102.00	13.86	0.030	0.024-0.040	16.67	4.99	4.56-5.49	7.43
8	16.50	14.45-17.50	5.98	156.92	136.00-170.00	7.58	0.025	0.021-0.033	16.00	7.26	6.70-7.96	6.45
9	BD	—	—	91.25	85.00- 96.00	4.54	0.029	0.021-0.038	17.24	3.80	3.36-4.47	8.37
10	BD	—	—	BD	—	-	0.164	0.138-0.200	9.76	2.97	2.42-3.64	11.57

% SD = Percentage Standard Deviation

TABLE 3.4

Results of Determination of Solids

Wells	Total Solids (ppm)			Dissolved Solids (ppm)			Suspended Solids (ppm)		
	Mean	Range	% SD	Mean	Range	% SD	Mean	Range	% SD
1	310	231 - 416	17	259	210 - 367	18	57	34 - 78	19
2	404	335 - 531	13	340	290 - 379	10	67	48 - 80	15
3	488	416 - 623	12	336	258 - 502	16	98	76 - 122	16
4	455	386 - 586	16	386	310 - 503	17	73	38 - 112	32
5	623	499 - 742	11	486	426 - 627	11	127	88 - 197	27
6	413	375 - 512	11	340	287 - 442	15	70	33 - 85	25
7	408	335 - 471	10	320	280 - 362	14	85	38 - 122	32
8	282	215 - 391	21	211	156 - 285	19	69	34 - 117	40
9	247	208 - 367	19	200	147 - 310	23	46	34 - 61	19
10	217	178 - 294	15	189	147 - 277	19	30	16 - 48	29

% SD: Percentage Standard Deviation.

TABLE 2.2

Results of Determinati[illegible] of Sodium, Potassium, Calcium, Magnesium, and Iron.

Wells	Sodium (Na) (ppm)			Potassium (K) (ppm)			Calcium (Ca) (ppm)			Magnesium (Mg) (ppm)			Iron (Fe) (ppm)		
	Mean	Range	% SD	Mean	Range	% SD	Mean	Range	% SD	Mean	Range	% SD	Mean	Range	% SD
1	30.93	26.00-34.00	10.46	7.10	6.20-8.70	11.9	25.50	24.00-27.00	3.5	9.83	7.50-11.20	12.04	0.03	0.02-0.04	28
2	72.01	65.00-84.00	7.11	18.18	15.0-21.50	9.45	36.67	35.50-45.00	6.82	22.58	19.00-24.30	9.45	0.02	0.01-0.03	00
3	70.29	61.50-78.50	8.90	15.69	14.0-17.50	10.09	38.28	34.00-44.50	8.60	20.78	17.20-24.50	12.05	0.03	0.01-0.04	00
4	43.45	38.00-48.75	7.33	6.53	5.50-7.20	8.34	24.92	21.00-28.00	7.59	11.47	9.50-13.10	11.94	0.05	0.03-0.06	1'
5	93.08	89.50-97.25	3.04	20.31	18.60-24.0	7.74	62.65	61.50-65.00	13.96	22.68	17.35-28.10	13.0	0.01	0.01-0.01	0
6	60.99	52.00-70.00	9.04	11.05	9.10-13.40	13.05	22.62	18.00-24.50	8.31	13.43	10.50-15.00	12.26	0.06	0.05-0.08	15
7	45.39	36.00-52.50	9.87	7.01	5.70-7.80	9.68	25.72	21.50-28.00	6.76	16.05	15.10-17.00	5.95	0.02	0.01-0.03	0
8	60.59	55.00-68.60	8.32	19.63	16.50-22.50	10.57	27.20	26.00-35.00	7.22	14.76	12.00-16.60	9.56	0.01	0.01-0.02	0
9	33.44	28.00-38.75	10.03	3.71	3.10-4.50	10.00	15.79	14.00-16.50	4.83	6.25	5.20-7.20	9.13	0.02	0.00-0.03	0
10	18.69	15.00-24.00	17.33	8.15	7.00-8.80	6.26	16.30	13.00-17.00	6.60	3.05	2.60-3.80	11.24	0.26	0.18-0.35	2

% SD = Percentage Standard Deviation.

TABLE 3.6

Results of Determination of Lead, Manganese, Arsenic, Zinc, Cadmium, Copper and Nickel

Wells	Lead (Pb) ppm	Manganese (Mn)			Arsenic (Ar) ppm	Zinc (Zn)			Cadmium (Cd) (ppm)	Copper (Cu) (ppm)	Nickel (Ni) (ppm)
		Mean	ppm Range	% SD		Mean	(ppm) Range	% SD			
1	BD	BD	-	-	BD	0.04	0.03-0.05	18	BD	BD	BD
2	BD	BD	-	-	BD	0.04	0.02-0.05	22	BD	BD	BD
3	BD	BD	-	-	BD	0.04	0.03-0.06	25	BD	BD	BD
4	BD	BD	-	-	BD	0.04	0.03-0.05	25	BD	BD	BD
5	BD	0.03	0.02-0.05	8.75	BD	0.03	0.02-0.04	25	BD	BD	BD
6	BD	BD	-	-	BD	0.05	0.04-0.06	17	BD	BD	BD
7	BD	BD	-	-	BD	0.04	0.03-0.05	16	BD	BD	BD
8	BD	BD	-	-	BD	0.06	0.05-0.07	12	BD	BD	BD
9	BD	BD	-	-	BD	0.10	0.07-0.11	13	BD	BD	BD
10	BD	BD	-	-	BD	0.57	0.44-0.65	15	BD	BD	BD

BD: Absent or below detection limite

%SD: Percentage Standard Deviation.

TABLE 3.7

Result of a Study on the useof alum as a chemical coagulant on well water.

(a) Well Water before treatment with 1% m/v alum solution.

Wells	Total Solids	Dissolved Solids	Suspended Solids
1	410	345	65
2	620	541	79
3	694	482	212
4	586	492	94
5	715	627	98
6	612	442	170
7	389	278	111

(b) Well Water after treatment with 5ml of 1% alum solution.

Wells	Total solids	Dissolved solids	Suspended solids
1	216	206	10
2	240	231	9
3	230	228	12
4	300	293	7
5	260	245	15
6	210	197	13
7	187	182	5

Table 3.7 (cont'd)

(c) Well Water after treatment with 10ml of 1% m/V alum solution.

Wells	Total solids	Dissolved solids	Suspended solids
1	287	286	1
2	311	311	0
3	307	306	1
4	368	364	4
5	236	235	1
6	291	290	1
7	275	275	0

(d) Well Water after treatment with 15ml of 1% m/V alum solution.

Wells	Total solids	Dissolved solids	Suspended solids
1	319	319	0
2	440	440	0
3	443	443	0
4	489	488	1
5	364	364	0
6	410	410	0
7	401	400	1

3.2 Discussion.

The results of this study are best discussed in terms of:

(a) range of variation of the various parameters from each well and their standard deviation expressed as percentage standard deviation (SD).

(b) how the various parameters of the wells sampled compare with one another and how these parameters measure up to the International Standards for Drinking Water as recommended by World Health Organisation (WHO).

3.2.1 Colour, Odour and Taste.

Colour and odour are the first physical properties that determine the acceptability of water for domestic uses. Once any water supply has colour and/or odour, people would not venture to taste the water. But water from all the wells sampled is clear and odourless. The water also has no taste except water from well 5 which has a little bitter taste. This bitter taste may be associated with small amount of iron and manganese detected in the well water.

3.2.2 Temperature.

The temperature of all the well water analysed ranges from 26°C to 29.5°C with a mean value of about 28°C and percentage standard deviation of 3.0 ± 0.4 (see table 3.1). The World Health Organisation gives no standard for temperature of drinking water but recommended that water for drinking purposes should have a reasonable temperature. Since people drink water stored in refrigerators at 10°C to 20°C and fresh water at 30°C from public water supplies, then by this criterion, all the well waters are fit for human consumption.

3.2.3 pH Values.

The pH values of all the well waters sampled range from 6.20 to 7.40 except for wells 1, 2 and 8 whose pH ranges from 6.40 to 7.20, 7.10 and 7.20 respectively and well 10 has pH ranging from 6.50 to 7.40 (see table 3.1). But the average pH values of all the well water are within the range 6.70 ± 0.20 which compares very well with the International Standards (6.50 - 9.20) for Drinking Water recommended by World Health Organisation (1971) (See Appendix I). By this criterion, water from the wells sampled are acceptable for human consumption.

3.2.4 Electrical Conductivity.

There is a very wide variation in the electrical conductivity of water from the wells sampled. Whereas water from wells 1, 4, 7, 9 and 10 have an average of about 423, 518, 503, 282 and 161 μmhos respectively, water from wells 2, 3, 5, 6 and 8 have an average of about 842, 930, 1177, 635 and 688 μmhos respectively. In most cases the electrical conductivity is high on rainy days which is in accordance with the theoritical concept of conductivity of solutions (conductivity of a solution increases with dilution). Electrical conductivity of water from wells 2, 3 and 5 are relatively high compared with water from other wells. This is also reflected in the dissolved solid contents of the water from these wells which are also higher than that in water from other wells. There is no standards for comparism.

3.2.5 Dissolved Oxygen.

The dissolved oxygen of water from all the wells ranges from 3.40 ppm to 6.6 ppm (see table 3.1). Except water from wells 1, 4, 6 and 8 whose average dissolved oxygen values are above 5.0ppm, the rest have values below 5.0ppm. The solubility of oxygen in fresh water under one atmosphere pressure ranges from 14.6 ppm at $0^{o}C$ to about 7.0 ppm at $35^{o}C$. With this

in mind, any fresh water with dissolved oxygen content far below this range may be declared unfit for human consumption as the low value may be due to the presence of harmful substances which are continously consuming the dissolved oxygen. The World Health Organisation recommends 5.0 ppm as the minimum for dissolved oxygen in water for drinking purposes (see appendix I). On the basis of this therefore, water from wells 2, 3, 5, 7, 9 and 10 is not safe for domestic uses.

3.2.6 Alkalinity.

The average values of total alkalinity of water from all the wells sampled are below 50 ppm $CaCO_3$ except water from wells 1 and 5 whose average values are 52.88 and 110.46 ppm $CaCO_3$ respectively. The percentage relative standard deviations of total alkalinity values of water from all the wells are well below 10% (see table 3.2) except for well water 5 whose percentage relative standard deviation is 9.53. The recommended limit of total alkalinity in drinking water is 100 to 200 ppm $CaCO_3$ (see appendix I). There have been cases of people consuming water with total alkalinity below 100 ppm $CaCO_3$ or above 400 ppm and no harm has been reported from the consumption of such water (17).

The low alkalinity of the water could be due to small amount of calcium content of the water. Following the recommended limit the water from the wells except well 5 is not good for human consumption otherwise, water is good for domestic uses.

3.2.7 Hardness.

The total hardness of all the well water ranges from 100 ppm to 300 ppm (as $CaCO_3$) except for wells 9 and 10 where total hardness ranges from 40 ppm to 70 ppm. The percentage standard deviation of all the values of total hardness of all the well water is less than 10% except for wells 2, 3 and 6 where it is more than 10% (see table 3.2). In respect of non-carbonate hardness, the non-carbonate hardness is higher than the carbonate hardness in all the wells except in well 10 where carbonate hardness is higher than the non-carbonate hardness (see table 3.2). This means that the concentrations of other salts of calcium and magnesium such as sulphate, nitrate, chloride etc, taken together are higher than the carbonate salts of magnesium and calcium present in the well water.

Similarly the calcium hardness is higher than magnesium hardness in all the wells. In most cases the calcium hardness is about three times as high as magnesium hardness. The principal problems caused by

hardness in domestic water are economic in nature (16) e.g. hardness reduces the life-time of cooking utensils, hard water requires more soap and detergent for efficient washing. It is also reported that vegetable cooked in hard water may be tougher and may lose more vitamins than those cooked in soft water (17). To minimise these effect, the World Health Organisation (1971) recommends 100 ppm total hardness as the highest desirable limit in drinking water and waterfor domestic uses (see appendix I). Based on the values obtained in this study, wells 1 to 8 need treatment in order to reduced total hardness.

3.2.8 Sulphate.

The sulphate content of water from well 1 ranges from 1.25 - 1.75 ppm with a mean value of 1.43 ppm while that of water from wells 2, 3, 4 and 8 ranges from 15.00 to 20.00 ppm. The mean sulphate content of water from wells 5, 6 and 7 ranges from 30.00 to 40.00ppm. No sulphate has been detected water from wells 9 and 10. This means that sulphate is absent in the water or below detection limit (see table 3.3). The World Health Organisation (1971) recommends 400 ppm as the maximum permissible level of sulphate in water for domestic uses (see appendix I). From the results

of this study, no health hazard could result from the use of water from all these wells as the sulphate content of the water is far below this level.

3.2.9 Phosphate.

Phosphate occurs in all the well water in the range 0.015 ppm to 0.040 ppm except in water from wells 4, 5 and 10 where phosphate occurs in the range 0.113 to 0.138 ppm. This high phosphate content in the water from these wells could be attributed to the use of detergent in washing near these wells. The mouths of these wells are not raised above the ground level. The consequence of this is that any time people wash near these wells, their waste water carry part of the dirty and detergent back into the wells. No standard has been recommended by World Health Organisatio but the Canadian Public Health Organisation recommends a limit of 0.2ppm phosphate in drinking water and water for domestic uses (15). On the basis of this therefore, water from all these wells are safe for domestic uses and for drinking purposes.

3.2.10 Chloride.

The mean chloride content of water from well 1 is 75.47 ppm NaCl with percentage standard deviation of of 6% while water from wells 2, 3, 4, 6 and 8 have mean

chloride content ranging from 104 to 200 ppm NaCl and percentage standard deviation less than 10%. The chloride content of water from well 5 is 244.92 ppm NaCl with percentage standard deviation of 3.68 (see table 3.3). This is the highest value obtained from the analyses. Water from wells 7 and 9 have a mean chloride content of 82.42 and 91.25 ppm NaCl respectively. No chloride ions have been detected in water from well 10. This means that chloride ions are absent in this well water or below detection limit.

According to WHO (1971) the highest desirable level of chloride in drinking water is 200 ppm Cl while the maximum permissible level is 600 ppm Cl. (see appendices I and II). On the basis of this therefore water from all the wells sampled are safe for domestic uses.

3.2.11 Solids.

The total solids in water from all the wells range from 200 to 600 ppm except for well 5 whose total solids range from 499 to 742 ppm (see table 3.4). The World Health Organisation (1971) recommends 500 ppm as the highest desirable level and 1500 ppm as the maximium permissible level of total solids in water for domestic uses (see appendices I and II). By this

limitation, water from wells 1 to 7 need treatment with alum, a chemical coagulant in order to bring down the level of the total solids in the well water.

3.2.12 Total Nitrogen.

The average total nitrogen content of water from all the wells sampled ranges from 2.97 to 7.26 ppm with percentage standard deviation less than 10% (see table 3.3). The nitrogen content of water from well 8 is higher than that in water from all the other wells. The World Health Organisation recommends total nitrogen (exclusive of nitrate) in drinking water to be 1.0 ppm and nitrate (as NO_3^-) to be 45.0 ppm as the maximium permissible level (see appendix I). But total nitrogen obtained from this study (nitrate inclusive) is far less than 45.0 ppm. On the basis of this result, no health hazard could result from the use of the well waters for drinking and domestic purposes.

3.2.13 Sodium and Potassium.

With respect to sodium, the result of this study shows that sodium content of water from wells 2 to 8 falls within the range 40 - 100 ppm with percentage standard deviation less than 10%. Sodium content of

water from wells 1, 9 and 10 falls in the range 15 - 40ppm with percentage standard deviation less than 10% (see table 3.5). With respect to potassium, the result of this study shows that potassium content of water from all the wells range from 3 to 20 ppm except for wells 5 and 8 whose potassium content ranges from 16 - 24 ppm. There are no standards for sodium and potassium from WHO for comparism. The values of sodium obtained in this study do not even compare with those got from the public water supplies of the 100 largest cities in the United States of America where a maximium of 198 ppm and a minimium of 1.1 ppm have been detected (59). In general the levels of potassium in the water are lower than those of sodium in water from all the wells analysed.

3.2.14 Calcium and Magnesium.

With respect to calcium, the values obtained from analyses of water from all the wells range from 20 - 45ppm except for well 5 whose value ranges from 60 - 65 ppm. The values of magnesium obtained from this study are lower than those of calcium. The values range from 2.5 ppm to 28 ppm. (see table 3.5). Although WHO (1971) recommended 200ppm calcium and 150ppm magnesium as the maximum tolerable level in our water for domestic and drinking purposes no harm has been reported from people drinking water containing higher concentration of these metals.

Furthermore, the calcium requirement of human body is so high that it cannot compare with the WHO's recommended limit of 200 ppm and values obtained from this study are very low. It could also be argued that the limit of 200 ppm calcium and 150 ppm magnesium in water for domestic used is based on economic ground, since these two elements are concerned with hardness of water (see page 99).

3.2.15 Iron, Lead and Manganese.

Iron occurs in trace amount in water from all the wells sampled. The concentration ranges from 0.01 ppm to 0.07 ppm except for well 10 where the concentration ranges from 0.15 ppm to 0.37 ppm with a mean value of 0.26 ppm (see table 3.5). The sources of this trace amount of iron found in these well waters could be from the rust iron buckets used in drawing water from the wells. In respect of lead, it has been found to be absent in water from all the wells sampled. This may not mean that lead is totally absent in the well waters. It could be it is present but its concentration is below the detection limit of the instrument used.

Manganese has been found only in water from well 5 and in the range 0.02 ppm to 0.05 ppm. In all the other wells, manganese is either absent or occurs below the

detection limit of atomic absorption spectrophotometer used for the analyses. The World Health Organisation (1971) recommends 0.1 ppm as the highest desirable limit for both iron and lead, 0.05 ppm for manganese in drinking water (see appendix I). On the basis of the result of this study, water from all the wells are fit for human consumption.

3.2.16 Arsenic, Zinc, Cadmium, Copper and Nickel.

All these metals except zinc have been found to be absent in water from all the wells sampled. Zinc has been found to be present in trace amount in water from all the wells sampled. The average concentration of zinc in the well waters ranges from 0.04 ppm to 0.11 ppm (see table 3.6). The presence of zinc in the well water could be traced to the use of metallic buckets in drawing water from the wells. A limit of 5 ppm zinc in drinking water has been set by World Health Organisation on the basis that water containing higher concentration of zinc causes servere stomach disorders. Based on this, the well waters analysed are safe for drinking. The other metals (arsenic cadmium, copper and nickel) although found to be absent, may be present below the detection limit of the instrument used for the study.

3.2.17 A study on the use of alum as a chemical coagulant on well water.

Treatment of water from wells 1 to 7 has been carried out using 5ml, 10ml and 15ml of 1% m/V alum solution in succession to determine the minimium amount of alum required to bring to minimium level the concentration of total solids in the water from these wells. The total solid content of these wells has been found to be higher than the highest desirable limit recommended by WHO (see table 3.4 and appendix I). From the results shown in table 3.7, it is noted that treatment of the water from these wells with alum solution considerably reduces the amount of suspended solids in the water. By comparing the results in tables 3.7 b, c and d,) it is noted that 5 ml of 1% m/V alum solution or 50 mg alum is as effective in reducing the amount of suspended solids in 200ml of water sample as 10ml of 1% m/V or 100mg alum. And so it will be an economic waste to use more than 50mg alum for treatment of 200ml of each well water. Furthermore 2.5g alum is effective for treatment of 10 litres of each well water contained in a bucket.

3.2.18 Summary and Conclusions.

The study has been carried out to ascertain the quality of well water consumed by people in Samaru, Zaria. The samples for the study have been collected from ten commonly used wells located at different places in Samaru and Ahmadu Bello University, main campus, Zaria. The water samples from these wells have been collected weekly in the months of August and September and thereafter collected weekly in the last two weeks of October and the first two weeks of November 1983 (the period which ran across rainy season and dry season).

The quality of the well water has been ascertained by carrying out chemical analyses of the water which include: the determination of colour, odour, taste temperature, pH, electrical conductivity, dissolved oxygen, alkalinity, hardness, sulphate, phosphate, chloride, solids, total nitrogen, and some metal ions (sodium, potassium, calcium, magnesium, iron, lead, manganese, arsenic, zinc, cadmium, copper and nickel).

The water from all the wells has no colour, odour and taste except well 5 which has a bitter taste. The temperature, pH, electrical conductivity and dissolved oxygen have been measured by thermometer, pH meter

a potable conductivity bridge and dissolved oxygen meter respectively. The temperature and pH of the water have been found to be in line with International Standards for drinking water in all the wells while dissolved oxygen content has been found to fall short of the International Standards in wells 2, 3, 5, 7, 9 and 10.

The hardness, alkalinity and chloride have been determined by titration with standard E.D.T.A. solution, sulphuric acid and silver nitrate solution respectively. Alkalinity and chloride are within the tolerable limit while hardness has been found to be high in wells 1 to 8.

Sulphate and phosphate have been determined by colorimetric methods and have been found to be within tolerable limit while solids have been determined by gravimetric method. This has been found to be higher than the recommended limit in wells 1 to 7. Total nitrogen has been determined by kjeldhal's method and found to be within tolerable limit.

In the case of the metal ions, sodium, potassium and calcium have been determined by flame photometry while magnesium, iron, lead, manganese, arsenic, zinc, cadmium, copper and nickel have been determined by

atomic absorption spectrophotometry. The results of all these have been compared with International Standards for drinking water and water for domestic uses as recommended by World Health Organisation. Sodium, potassium, calcium, magnesium, iron, zinc and manganese have been found to occur within the tolerable limit while lead, cadmium, arsenic, copper and nickel have been found to be absent or below detection limit of the instrument used.

The results of the study show that there is no serious health hazard in consuming water from these wells since most of the parameters studied compare very well with the International Standards for Drinking Water as recommended by World Health Organisation.

A study on the use of alum as a chemical coagulant on the well water has been carried out. 2.5g alum has been found to be effective in treating a bucket full of the well water in order to reduce the solid contents in the water.

As bacteriological examination of the well water has not been included in this study, the use of milton, a chemical disinfectant has been suggested for the treatment of the water against germs likely to be present in the water.

3.2.19 Suggestions.

As these wells form major sources of water supply for domestic uses in Samaru, they should be properly maintained. The local Government Authority should help the community put covers in wells 1, 2, 3, 4, 5, 6, 7 and 9. The mouths of wells 4 and 5 should be raised at least 1 metre above the ground level. This will prevent waste water from going back into the wells. Meanwhile people should be discouraged from washing their clothes very close to the wells.

In order to treat the well water, it is suggested that a tea-spoon full of well grinded alum be added to a bucket full of water. When stirred and allowed to stay overnight would help remove virtually all the suspended solids.

As bacterialogical examination of the water from these wells has not been included in this work, a study on this parameter is recommended to be undertaken in future to further ascertain the quality of the well water.

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APPENEIX I

World Health Organisation (Geneva 1971) Drinking Water Standards (60).

Concentration in ppm except where noted.

Characteristics	Highest desirable level	Maximum permissible level
Total solids	500	1500
Colour (^{o}H)	5	50
Taste	Unobjectionable	-
Odour	Unobjectionable	-
Turbidity (Formazin unit)	5	25
Chloride	200	600
Iron	0.1	1
Manganese	0.05	0.5
Copper	0.05	1.5
Zinc	5	15
Calcium	75	200
Magnesium	30	150
Total hardness (as $CaCO_3$)	100	500
Nitrate (as NO_3^-)	45	-
Phenol	0.00	0.002
pH (units)	7 - 8	6.5 - 9.2
Arsenic	-	0.05
Cadmium	-	0.01
Chromium (6+)	-	0.05
Cyamide	-	0.05
Lead	-	0.10
Mercury	-	0.001
Fluoride	0.9 - 1.7 at 12^{o}C	-
	0.6 - 0.8 at 32^{o}C	-

APPENDIX II

World Health Organisation (WHO) International Standards for Water 1971 (61).

Substance	Maximium permissible level(ppm)	
	For Domestic use	For Drinking water
Arsenic (as As)*	-	0.05
Calcium (as Ca)	200	-
Cadmium (as Cd)*		0.01
Chromium (as Cr)*	0.05	
Copper (as Cu)	1.5	
Iron (total Fe)	1.0	
Lead (as Pb)*		0.01
Magnesium (as Mg)	150.0	-
Manganese (as Mn)	0.5	-
Mercury (total Hg)*		0.0001
Selenium (as Se)*		0.01
Zinc (as Zn)	15	
Ammonia		0.5
Chloride (as Cl)	600.0	
Cyamide (as Cn)*		0.05
Fluoride (at 10-12°C)*		1.7
Nitrate (as NO_3^-)		45
Total nitrogen (exclusive of NO_3^-)		1.0
Phenol	0.002	
Sulphate (as SO_4^{2-})	400.0	
Total Hardness (as $CaCO_3$)	500	
pH	6.5 - 9.2	
Total dissolved solids	1500	

* Highly toxic
\+ Hazardous to health

APPENDIX III

Detailed Results of Analyses.

Appendix (III)a.

Temperature values (^{o}C)

WEEK	WELLS									
	1	2	3	4	5	6	7	8	9	10
1	27.00	27.00	28.00	28.50	28.50	28.50	28.50	27.00	27.00	29.50
2	27.50	27.50	27.00	27.50	27.00	28.00	28.50	27.50	27.50	27.50
3	26.00	26.00	26.50	27.00	26.50	27.00	27.50	26.50	27.50	27.50
4	27.00	27.00	27.50	27.50	27.00	28.00	28.00	27.00	28.00	29.50
5	28.00	27.50	28.00	28.00	28.50	29.00	29.00	28.00	29.00	30.00
6	27.00	28.00	28.00	27.50	29.00	28.50	29.00	27.50	29.00	29.50
7	29.00	28.00	28.00	28.00	28.00	28.50	28.50	29.00	28.50	29.00
8	27.00	28.50	28.50	27.00	28.00	28.00	29.00	29.50	29.50	29.00
9	27.00	29.50	28.00	28.00	28.50	28.00	29.00	28.00	29.50	30.00
10	27.00	29.00	27.50	26.50	27.50	27.50	27.50	27.00	29.50	28.50
11	26.50	26.50	27.00	26.50	28.00	27.50	28.50	27.00	28.00	28.00
12.	26.00	26.50	26.50	26.00	26.50	26.00	26.00	26.50	27.50	27.00
Mean	27.08	27.58	27.71	27.33	27.67	27.88	28.29	27.54	28.38	28.79
% SD	2.90	3.70	2.60	2.60	2.75	2.83	2.55	3.27	3.07	3.30

APPENDIX (III)b

pH values (°C)

WEEK	W E L L S									
	1	2	3	4	5	6	7	8	9	10
1	6.80	6.40	6.80	6.90	6.40	6.60	6.60	6.80	7.20	7.10
2	7.40	6.60	6.80	6.80	6.60	6.50	6.20	6.60	6.40	6.80
3	6.60	6.50	6.60	6.20	6.30	6.40	5.80	6.70	7.40	6.60
4	7.40	6.40	6.20	6.70	6.60	6.70	6.20	6.50	6.40	6.50
5	7.20	6.50	6.60	6.20	6.60	6.90	6.40	6.80	6.20	7.40
6	7.20	6.40	6.30	6.20	6.80	6.60	6.40	6.60	6.20	6.30
7	6.40	6.40	6.20	6.20	6.40	6.60	6.70	6.60	6.90	6.60
8	6.60	6.40	6.20	6.40	6.20	6.60	6.40	6.80	6.20	7.20
9	6.80	6.60	6.40	6.20	6.60	6.80	6.40	6.60	6.20	7.20
10	6.40	6.70	6.20	6.60	6.70	6.70	6.60	6.40	6.60	6.80
11	7.40	6.60	6.90	6.90	7.10	6.90	6.80	7.10	6.60	6.80
12	7.20	6.80	7.10	6.80	6.60	7.20	6.70	7.20	6.80	7.10
Mean	6.95	6.53	6.53	6.44	6.58	6.70	6.43	6.66	6.59	6.87
% SD	5.46	3.22	3.36	5.12	3.49	3.43	4.19	4.80	5.92	4.66

APPENDIX (III)c

Conductivity values (μmhos)

WEEK	WELLS									
	1	2	3	4	5	6	7	8	9	10
1	410	780	690	410	1020	580	460	650	280	160
2	420	730	680	460	990	610	470	640	280	180
3	390	750	720	460	1050	550	480	680	300	170
4	350	870	840	480	1200	570	500	700	280	180
5	400	900	900	500	1200	580	520	720	290	175
6	380	900	920	500	1400	520	500	700	270	140
7	400	900	1000	580	1220	640	500	650	280	150
8	420	950	1100	560	1300	660	540	650	290	170
9	420	900	920	500	1200	580	540	730	280	170
10	480	800	1100	550	1200	750	520	710	280	140
11	500	820	1100	600	1050	720	500	700	270	150
12	510	810	1200	620	1300	780	510	730	290	150
Mean	423.33	842.50	930.83	518.33	1177.50	635.00	503.33	688.33	282.50	161.25
% SD	10.87	7.95	17.90	11.77	10.28	14.02	4.75	4.65	2.84	8.69

Dissolved Oxygen Values (ppm)

WEEK	WELLS									
	1	2	3	4	5	6	7	8	9	10
1	5.30	4.80	4.80	6.50	4.20	5.80	6.20	5.90	5.10	4.60
2	5.40	5.40	5.30	6.30	6.30	5.20	5.80	6.20	4.30	4.50
3	5.80	5.20	5.30	6.50	5.10	5.70	5.20	6.60	5.20	5.10
4	4.60	4.40	3.80	4.20	4.70	4.80	4.50	5.20	5.60	4.20
5	4.80	4.70	5.30	4.10	3.90	4.90	3.90	6.10	4.60	4.70
6	5.80	4.40	4.70	6.40	3.90	5.30	4.60	6.10	4.50	4.50
7	4.60	4.80	4.50	6.60	4.30	4.90	4.60	5.80	4.90	4.50
8	4.70	4.20	5.20	5.50	4.20	4.90	3.80	5.70	4.40	4.90
9	4.40	4.80	4.40	4.20	3.90	4.70	3.80	4.10	4.60	4.80
10	5.40	5.20	4.70	6.20	4.30	5.20	4.80	5.90	4.50	4.50
11	5.60	4.90	5.10	5.90	4.70	4.70	4.40	4.60	4.90	4.70
12	5.20	4.70	4.80	6.10	4.80	5.20	4.30	5.10	4.30	4.50
Mean	5.13	4.79	4.83	5.71	4.53	5.10	4.66	5.61	4.74	4.62
%SD	9.22	7.10	9.00	16.38	14.39	8,43	15.45	12.29	12.65	4.76

APPENDIX (III) e

Total Alkalinity Values (ppm $CaCO_3$)

WEEK	WELLS									
	1	2	3	4	5	6	7	8	9	10
1	75.50	39.00	42.00	30.00	115.50	43.00	47.50	32.00	27.00	46.00
2	77.50	49.50	48.50	29.00	114.50	38.00	46.50	26.00	24.00	45.50
3	52.00	43.00	46.50	28.00	104.00	55.50	47.50	49.50	21.00	45.00
4	56.00	60.00	50.50	27.50	122.00	42.50	50.00	44.50	23.50	46.50
5	50.00	50.50	50.50	28.00	119.00	47.50	51.00	35.00	27.00	47.50
6	46.50	57.00	46.50	26.00	92.00	52.00	40.00	27.00	23.50	40.00
7	43.50	46.50	43.00	23.00	101.00	43.00	32.00	17.50	18.00	37.00
8	44.00	43.50	45.50	24.00	105.00	39.00	30.00	19.50	15.50	35.00
9	48.50	50.50	48.50	29.00	111.50	45.50	48.50	26.00	26.00	43.00
10	47.50	56.50	46.50	28.00	98.00	53.00	36.00	24.00	24.00	39.50
11	46.50	52.00	39.50	24.00	129.00	34.00	28.00	18.00	20.00	39.50
12	47.00	50.50	42.00	25.50	118.00	42.50	27.00	21.00	18.00	41.00
Mean	52.83	49.88	45.79	26.83	110.46	44.63	40.33	39.17	22.29	42.17
% SD	20.77	11.87	7.37	8.12	8.66	13.79	16.98	17,76	16.20	7.52

APPENDIX (III)f

Total Hardness Values (ppm $CaCO_3$)

WEEK	WELLS									
	1	2	3	4	5	6	7	8	9	10
1	130.00	128.00	148.00	102.00	254.00	144.00	130.00	106.00	50.00	58.00
2	128.00	148.00	161.00	102.00	262.00	142.00	130.00	108.00	54.00	68.00
3	108.00	166.00	170.00	106.00	270.00	126.00	132.00	134.00	54.00	64.00
4	108.00	190.00	186.00	114.00	282.00	124.00	134.00	130.00	48.00	62.00
5	98.00	194.00	194.00	116.00	304.00	124.00	140.00	124.00	52.00	66.00
6	106.00	204.00	206.00	120.00	356.00	124.00	130.00	130.00	50.00	56.00
7	102.00	194.00	196.00	112.00	312.00	118.00	124.00	116.00	46.00	54.00
8	104.00	190.00	192.00	110.00	306.00	112.00	116.00	112.00	42.00	50.00
9	96.00	190.00	192.00	112.00	284.00	124.00	136.00	116.00	50.00	64.00
10	118.00	190.00	216.00	132.00	276.00	124.00	130.00	114.00	44.00	56.00
11	126.00	184.00	212.00	128.00	278.00	178.00	132.00	144.00	50.00	58.00
12	128.00	182.00	216.00	126.00	282.00	178.00	146.00	138.00	52.00	62.00
Mean	112.66	180.00	195.75	115.00	288.83	135.00	133.33	122.66	49.33	59.83
% SD	10.70	11.69	14.32	8.20	11.35	15.85	6.84	9.67	7.28	8.57

APPENDIX (III)g

Calcium Hardness Values (ppm $CaCO_3$)

WEEK	WELLS									
	1	2	3	4	5	6	7	8	9	10
1	93.60	80.80	99.50	62.40	182.70	80.40	93.30	55.55	26.50	31.80
2	93.60	70.80	85.50	60.40	170.80	82.50	72.80	65.40	28.40	26.80
3	76.50	102.60	111.00	67.95	197.60	61.40	70.80	95.50	38.60	50.70
4	74.00	126.00	124.00	80.00	198.00	92.00	98.00	60.00	36.00	54.00
5	78.00	144.00	146.00	88.00	168.00	88.00	106.00	96.00	38.00	46.00
6	84.00	148.00	156.00	94.00	198.00	106.00	96.00	92.00	38.00	48.00
7	84.00	142.00	150.00	86.00	174.00	84.00	90.00	82.00	38.00	46.00
8	82.00	144.00	142.00	82.00	164.00	76.00	82.00	78.00	32.00	35.00
9	76.00	142.00	142.00	86.00	172.00	88.00	104.00	96.00	34.00	46,00
10	96.00	138.00	152.00	76.00	146.00	86.00	88.00	82.00	36.00	46.00
11	100.00	144.00	148.00	94.00	198.00	96.00	96.00	94.00	32.00	54.00
12	102.00	136.00	132.00	96.00	194.00	92.00	90.00	90.00	30.00	56.00
Mean	86.64	126.52	133.18	82.73	180.26	85.96	90.58	82.16	33.91	45.28
% SD	10.97	20.21	17.83	14.78	9.10	12.46	11.61	17.66	11.5	18.93

APPENDIX (III)h

Non-Carbonate hardness Values (ppm $CaCO_3$)

WEEK	W E L L S									
	1	2	3	4	5	6	7	8	9	10
1	54.50	89.00	106.00	72.00	138.50	101.00	82.50	74.00	23.00	16.00
2	50.50	98.50	112.50	73.00	147.50	104.00	83.50	82.00	30.00	22.50
3	56.00	123.00	123.50	78.00	166.00	70.50	84.50	84.50	33.00	18.50
4	52.00	130.00	135.50	86.50	100.00	81.50	84.00	85.50	24.50	15.50
5	48.00	143.50	143.50	88.00	185.00	76.50	89.00	89.00	25.00	18.50
6	59.50	147.00	159.50	94.00	264.00	72.00	90.00	103.00	26.50	16.00
7	58.50	147.50	153.00	89.00	211.00	75.00	92.00	98.50	28.00	17.00
8	60.00	146.50	146.50	86.00	201.00	73.00	86.00	92.50	26.50	16.00
9	47.50	139.50	143.50	83.00	172.50	78.50	87.50	70.00	18.00	21.00
10	70.50	133.50	169.50	104.00	186.00	71.00	94.00	90.00	20.00	16.50
11	79.50	132.00	202.50	104.00	149.00	146.00	124.00	126.00	30.00	22.50
12	81.00	131.50	202.00	100.50	164.00	135.50	119.00	117.00	34.00	21.00
Mean	59.79	130.13	149.96	88.17	178.71	90.33	93.00	94.33	26.54	18.50
% SD	18.28	13.82	19.73	11.89	18.47	27.5	14.21	15.05	17.47	11.41

APPENDIX (III)i

Magnesium Hardness Values (ppm $CaCO_3$)

WEEK	WELLS									
	1	2	3	4	5	6	7	8	9	10
1	30.40	64.20	61.40	39.60	79.30	51.50	36.70	32.40	14.50	12.28
2	38.40	57.20	56.40	38.60	83.20	52.43	47.20	42.50	16.60	11.20
3	31.50	63.40	59.00	38.00	92.00	48.00	41.20	32.50	15.40	13.20
4	30.00	64.00	52.00	34.00	84.00	42.00	36.00	34.00	15.00	12.00
5	24.50	50.00	48.00	28.50	116.00	46.00	34.00	32.00	14.00	
6	22.00	56.00	48.00	26.00	108.00	48.00	34.00	38.00	14.00	12.00
7	26.00	55.00	54.00	26.00	118.00	44.00	34.00	34.00	15.00	12.00
8	22.00	46.00	50.00	28.00	120.00	42.00	34.00	34.00	14.00	12.00
9	24.00	48.00	50.00	26.00	112.00	46.00	32.00	32.00	16.50	15.50
10	22.00	52.00	64.00	36.00	110.00	48.00	42.00	32.00	14.00	14.00
11	26.00	50.00	54.00	24.00	82.00	44.00	36.00	40.00	16.00	14.00
12	24.00	52.00	52.00	26.00	88.00	46.00	36.00	42.00	16.00	10.00
Mean	25.90	54.80	54.25	31.08	99.42	46.42	36.00	35.08	14.50	12.66
% SD	12.10	11.68	8.21	9.27	9.37	6.35	8.73	17.74	6.50	10.36

APPENDIX (III)j

Total Sulphate Values (ppm)

WEEK	WELLS									
	1	2	3	4	5	6	7	8	9	10
1	1.75	21.25	16.75	21.75	29.50	40.50	42.50	17.50	0.00	0.00
2	1.25	25.00	16.55	24.65	29.75	40.85	44.25	17.35	0.00	0.00
3	1.75	29.50	18.00	21.25	33.75	43.75	31.25	16.25	0.00	0.00
4	1.45	30.00	18.75	23.00	33.75	37.65	33.75	16.75	0.00	0.00
5	1.25	28.00	15.50	20.00	34.00	35.00	30.00	14.45	0.00	0.00
6	1.35	28.00	18.50	18.50	34.00	38.00	30.00	17.50	0.00	0.00
7	1.45	27.00	19.00	18.00	31.00	38.00	33.00	18.50	0.00	0.00
8.	1.25	32.00	17.50	21.00	33.00	35.00	32.50	16.65	0.00	0.00
9	1.25	22.50	17.50	17.00	30.00	37.50	44.50	14.50	0.00	0.00
10	1.35	35.00	20.00	17.00	30.00	37.00	33.00	16.00	0.00	0.00
11	1.75	28.75	18.75	21.25	33.75	36.25	33.75	7.25	0.00	0.00
12	1.35	25.25	17.50	21.25	30.00	38.15	32.50	16.75	0.00	0.00
Mean	1.43	27.68	17.33	20.59	31.92	39.40	35.10	16.50	-	-
% SD	13.64	12.29	12.58	11.13	5.73	17.10	14.70	5.98	-	-

APPENDIX (III)k

Total Phosphate Values (ppm)

WEEK	WELLS									
	1	2	3	4	5	6	7	8	9	10
1	0.068	0.015	0.030	0.150	0.175	0.043	0.038	0.025	0.038	0.163
2	0.063	0.020	0.028	0.160	0.150	0.040	0.034	0.030	0.033	0.168
3	0.073	0.015	0.035	0.175	0.200	0.045	0.028	0.024	0.028	0.138
4	0.055	0.025	0.043	0.175	0.163	0.035	0.040	0.028	0.021	0.145
5	0.068	0.028	0.030	0.175	0.188	0.038	0.030	0.033	0.030	0.160
6	0.078	0.025	0.043	0.200	0.125	0.048	0.028	0,021	0.025	0.158
7	0.063	0.030	0.041	0.160	0.150	0.048	0.024	0.024	0.021	0.200
8	0.068	0.023	0.028	0.165	0.200	0.039	0.030	0.030	0.023	0.175
9	0.063	0.020	0.023	0.158	0.225	0.046	0.028	0.019	0.028	0.175
10	0.075	0.023	0.035	0.200	0.175	0.045	0.028	0.021	0.035	0.150
11	0.078	0.028	0.040	0.180	0.125	0.034	0.024	0.021	0.033	0,180
12	0.075	0.025	0.033	0.175	0.113	0.038	0.033	0.028	0.028	0.158
Mean	0.069	0.023	0.034	0.173	0.166	0.042	0.030	0.025	0.029	0.164
% SD	10.14	21.74	17.65	12.14	18.67	11.44	16.67	16.00	17.24	9.76

APPENDIX (III)L

Chloride Values (ppm NaCl)

WEEK	W E L L S									
	1	2	3	4	5	6	7	8	9	10
1	80.00	146.00	178.00	104.00	246.00	136.00	86.00	164.00	86.00	0.00
2	80.00	180.00	188.00	104.00	236.00	134.00	102.00	170.00	94.00	0.00
3	76.00	148.00	172.00	108.00	242.00	138.00	86.00	170.00	88.00	0.00
4	70.00	168.00	204.00	104.00	240.00	108.00	32.00	144.00	92.00	0.00
5	72.00	156.00	196.00	106.00	250.00	129.00	88.00	136.00	98.00	0.00
6	71.60	154.00	168.00	102.00	238.00	140.00	83.00	169.00	85.00	0.00
7	68.00	145.00	198.00	105.00	235.00	115.00	80.00	150.00	92.00	0.00
8	74.00	150.00	210.00	106.00	240.00	119.00	82.00	156.00	96.00	0.00
9	72.00	172.00	202.00	102.00	242.00	110.00	52.00	142.00	90.00	0.00
10	82.00	156.00	204.00	108.00	244.00	112.00	76.00	148.00	96.00	0.00
11	78.00	158.00	196.00	104.00	262.00	115.00	94.00	168.00	92.00	0.00
12	81.00	162.00	182.00	106.00	264.00	119.00	78.00	166.00	86.00	0.00
Mean	75.47	157.92	191.50	104.91	244.92	122.92	82.42	156.92	91.25	--
% SD	6.90	6.86	6.85	1.80	3.68	9.14	13.86	7.58	4.5/4	--

APPENDIX (III)m

Total Nitrogen (Kjeldahl's nitrogen) Values
(ppm)

WEEK	WELLS									
	1	2	3	4	5	6	7	8	9	10
1	4.43	5.70	3.80	5.30	3.80	3.98	4.70	7.83	3.36	3.08
2	4.80	6.40	3.40	5.40	4.20	4.20	5.00	7.70	3.40	3.80
3	4.40	5.75	3.80	5.20	3.81	4.11	5.51	6.80	3.91	2.80
4	4.20	5.80	3.20	6.10	3.62	4.12	5.72	7.22	3.44	2.42
5	3.98	6.11	3.81	5.88	3.75	4.03	4.98	7.96	3.64	2.52
6	4.15	6.17	3.70	5.72	3.92	3.87	4.70	6.72	3.75	3.19
7	3.87	6.25	3.59	6.03	4.82	4.03	4.59	6.83	3.75	3.14
8	4.68	5.50	4.25	5.50	3.98	4.68	4.56	5.70	4.47	3.19
9	4.49	6.12	4.20	5.44	4.15	4.82	4.89	7.46	3.89	3.64
10	4.71	6.16	3.60	6.01	4.31	4.93	5.49	7.35	4.77	2.98
11	5.38	6.41	3.54	5.67	3.54	4.72	4.98	7.79	4.27	3.37
12	4.60	6.50	3.42	5.98	4.01	4.98	4.72	6.73	3.89	2.65
Mean	4.56	6.07	3.69	5.69	3.99	4.37	4.99	7.26	3.80	2.97
% SD	10.56	5.00	8.02	5.28	8.35	9.10	7.4	6.45	8.37	11.57

APPENDIX (III)n

Total Solid Values (ppm)

WEEK	WELLS									
	1	2	3	4	5	6	7	8	9	10
1	305	413	560	427	635	413	335	265	230	233
2	416	531	623	579	742	501	418	391	367	294
3	296	425	522	412	597	386	398	235	248	229
4	403	430	416	398	640	410	421	287	297	178
5	410	420	494	586	715	512	389	382	289	263
6	312	360	425	405	720	415	344	224	265	191
7	305	382	464	532	612	378	456	332	219	231
8	314	364	439	516	596	381	466	345	208	211
9	281	413	511	402	615	396	471	252	210	197
10	296	432	517	421	587	375	388	215	220	201
11	231	340	437	398	499	392	411	226	212	182
12	244	335	442	386	521	401	398	234	208	190
Mean	310	404	488	455	623	413	408	282	247	217
% SD	17	13	12	16	11	11	10	21	19	15

APPENDIX (III)o

Total dissolved solid values (ppm)

WEEK	W E L L S									
	1	2	3	4	5	6	7	8	9	10
1	248	293	475	289	455	380	297	231	185	205
2	367	379	502	503	426	433	296	285	310	277
3	262	376	423	359	489	338	340	193	214	213
4	255	369	340	331	544	358	346	249	238	147
5	345	341	382	492	627	442	278	265	245	237
6	234	290	335	366	525	352	280	173	228	166
7	251	319	385	430	499	297	341	234	163	192
8	252	306	258	404	488	285	340	232	147	163
9	210	346	404	340	442	317	362	198	168	166
10	242	358	385	322	456	288	322	156	182	174
11	221	319	341	312	441	298	342	176	159	165
12	218	332	356	310	439	287	338	168	162	162
Mean	259	340	383	380	486	340	320	213	200	189
% SD	18	9	16	17	11	15	14	19	23	19

APPENDIX (III)p

Total Suspended Solid - Values (ppm)

WEEK	W E L L S									
	1	2	3	4	5	6	7	8	9	10
1	57	80	85	38	180	33	38	34	45	28
2	49	82	121	76	116	68	122	106	57	17
3	34	48	98	53	108	48	58	42	34	16
4	49	61	76	67	96	52	75	38	59	31
5	65	79	112	94	88	70	111	117	44	26
6	78	60	90	39	195	63	65	51	37	25
7	54	63	79	102	113	81	115	98	56	39
8	62	58	81	112	108	96	122	103	61	48
9	71	67	107	62	173	79	109	54	42	31
10	54	74	122	99	131	87	66	59	38	27
11	58	64	98	67	108	82	69	59	41	32
12	56	67	103	71	102	79	65	61	43	39
Mean	57	67	98	73	127	70	85	69	46	30
% SD	19	15	16	31	27	25	32	40	19	29

APPENDIX (III)g

Sodium Values obtained (ppm)

WEEK	WELLS									
	1	2	3	4	5	6	7	8	9	10
1	29.00	72.50	70.00	41.00	95.00	60.00	36.00	55.00	28.00	18.50
2	33.75	73.75	72.50	48.75	97.25	70.00	42.50	60.00	38.75	23.75
3	31.20	78.75	73.00	46.00	96.00	65.75	47.50	67.50	31.25	24.50
4	34.00	73.00	69.00	38.00	97.00	65.00	46.00	59.00	32.00	16.00
5	32.75	70.75	70.50	46.65	94.40	69.50	52.50	61.20	36.50	24.00
6	36.00	84.20	79.00	40.12	92.35	62.50	48.20	68.60	35.40	17.40
7	28.00	67.00	65.00	41.00	92.00	62.00	45.00	62.00	28.50	18.20
8	27.00	65.00	62.00	43.00	94.00	60.00	42.00	57.00	30.00	16.50
9	34.00	76.00	78.00	47.20	89.50	57.20	47.00	61.40	33.00	17.50
10	32.50	74.00	79.50	45.00	91.00	54.50	43.50	59.00	36.50	15.00
11	26.00	66.00	63.00	43.20	89.00	53.20	43.00	58.40	36.40	16.00
12	27.00	71.00	61.50	41.50	89.50	52.00	41.50	58.00	35.00	16.30
Mean	30.93	72.91	70.29	43.45	93.09	60.99	45.39	60.59	33.44	18.69
% SD	10.47	7.11	8.90	7.22	3.04	9.40	9.87	6.32	10.02	17.38

APPENDIX (III)r

Potassium Values (ppm)

WEEK	W E L L S									
	1	2	3	4	5	6	7	8	9	10
1	6.50	15.00	14.00	5.70	20.65	9.10	6.00	22.50	3.50	8.20
2	6.00	17.50	12.50	5.50	21.20	9.50	6.50	16.50	4.00	8.50
3	6.75	16.00	14.50	6.50	19.00	11.10	7.00	17.50	3.75	8.90
4	4.90	18.00	14.00	5.80	20.00	12.00	5.70	17.00	3.30	8.80
5	5.80	20.00	15.00	6.50	24.00	12.00	6.50	20.00	4.00	8.20
6	8.00	20.20	16.50	6.75	22.40	9.50	7.00	18.00	3.10	7.80
7	6.20	18.00	17.30	7.20	18.60	12.50	7.70	22.00	4.00	8.50
8	6.80	17.50	17.00	7.00	20.00	12.80	9.20	20.40	3.90	8.20
9	6.50	21.50	16.00	6.70	19.10	13.40	7.80	18.50	3.60	7.50
10	7.50	19.00	16.50	6.75	21.00	11.20	7.20	17.00	3.50	7.00
11	8.70	17.50	17.50	8.70	18.80	10.00	7.70	18.00	4.50	8.00
12	8.50	18.00	16.50	7.20	19.00	9.50	7.80	16.50	3.40	8.20
Mean	7.10	18,18	15.69	6.58	20.31	11.05	7.01	18.63	3.71	8,15
% SD	11.90	9.45	10.09	8.34	7.74	13.05	9.68	10.57	10.00	6.26

APPENDIX (III)s

Calcium Values (ppm)

WEEK	W E L L S									
	1	2	3	4	5	6	7	8	9	10
1	25.00	35.5	34.50	22.50	61150	20:50	24.00	27.00	16.00	16.00
2	24.50	35.50	36.50	23.00	62.00	18.00	25.00	26.00	15.50	17.00
3	24.00	36.50	35.00	21.00	62.50	22.00	26.50	26.50	14.00	13.00
4	26.00	37.00	34.00	25.00	65.00	22.50	21.50	26.00	15.50	16.50
5	25.50	36.00	37.50	25.50	62.50	24.00	24.00	33.50	16.50	17.00
6	25.50	35.50	39.00	25.00	62.00	24.50	27.50	26.00	16.50	17.00
7	24.50	36.00	38.00	24.50	63.50	22.00	26.50	27.00	15.00	16.00
8	27.00	36.00	38.50	27.00	63.00	23.50	27.00	26.00	16.50	17.00
9	25.50	37.00	36.50	26.00	62.00	24.50	28.00	27.00	16.00	16.50
10	26.00	35.00	42.50	28.00	62.50	23.00	25.00	27.50	16.50	17.00
11	25.00	45.00	43.00	25.00	64.00	24.50	27.00	27.00	16.00	17.00
12	27.00	36.00	44.50	26.50	62.50	22.50	26.50	27.00	15.50	16.50
Mean	25.50	36.87	38.28	24.92	62.65	22.62	25.20	27.20	15.79	16.39
% SD	3.5(	6.82	8.60	7.59	13.95	8.31	6.76	7.22	4.83	6.60

APPENDIX (III) t

Magnesium Values (ppm)

WEEK	WELLS									
	1	2	3	4	5	6	7	8	9	10
1	11.20	21.20	18.40	10.20	22.10	11.30	14.50	14.60	5.20	2.80
2	8.40	19.40	17.00	11.30	22.80	11.70	15.10	15.20	5.80	2.60
3	8.20	24.10	22.50	13.10	28.10	14.20	17.02	14.20	6.10	2.70
4	10.40	25.70	23.00	13.02	27.60	15.70	17.00	16.50	6.50	2.70
5	7.50	19.00	18.50	9.50	21.00	10.50	14.50	16.60	6.00	2.80
6	10.50	26.20	17.20	10.40	17.35	11.35	17.20	14.50	6.20	4.10
7	10.50	24.30	24.50	13.02	20.20	14.10	16.50	16.00	6.20	3.20
8	10.50	22.50	24.00	12.50	22.50	14.50	16.50	17.20	5.50	3.70
9	11.20	21.60	23.00	13.00	25.00	15.00	15.50	14.60	6.50	3.00
10	9.40	21.80	20.80	11.80	19.80	13.90	15.40	12.20	7.20	3.10
11	10.20	22.40	18.70	9.70	23.10	14.25	16.50	14.00	6.70	3.80
12	9.70	22.70	21.10	10.15	22.60	14.60	16.90	12.50	7.10	3.10
Mean	9.83	22.58	20.78	11.47	22.68	13.43	16.05	14.76	6.25	3.05
% SD	12.04	9.45	12.05	11.94	13.06	12.26	5.95	9.36	9.13	11.93

APPENDIX (III)u

Iron Values (ppm)

WEEK	WELLS									
	1	2	3	4	5	6	7	8	9	10
1	0.04	0.02	0.02	0.05	0.01	0.05	0.01	0.00	0.01	0.22
2	0.02	0.01	0.02	0.04	0.01	0.06	0.03	0.01	0.00	0.24
3	0.02	0.01	0.01	0.04	0.02	0.05	0.03	0.01	0.01	0.15
4	0.03	0.00	0.03	0.04	0.00	0.05	0.02	0.00	0.01	0.17
5	0.02	0.02	0.01	0.03	0.00	0.06	0.04	0.00	0.04	0.16
6	0.03	0.02	0.01	0.04	0.01	0.05	0.01	0.00	0.02	0.25
7	0.04	0.01	0.02	0.06	0.01	0.06	0.01	0.01	0.00	0.23
8	0.04	0.01	0.03	0.05	0.00	0.06	0.01	0.02	0.00	0.29
9	0.04	0.02	0.03	0.05	0.02	0.06	0.01	0.02	0.01	0.34
10	0.04	0.02	0.04	0.06	0.02	0.05	0.02	0.00	0.03	0.32
11	0.03	0.01	0.03	0.04	0.01	0.07	0.00	0.04	0.02	0.37
12	0.03	0.02	0.05	0.04	0.00	0.08	0.03	0.02	0.02	0.36
Mean	0.03	0.01	0.03	0.05	0.01	0.06	0.02	0.01	0.03	0.26
% SD	0.27	0.00	00	0.17	15	05	00	00	00	29