ANALYTICAL STUDIES OF DOMESTIC WATER AND INDUSTRIAL WASTEWATER EFFLUENTS

A THESIS PRESENTED TO THE
AHMADU BELLO UNIVERSITY, ZARIA
IN PARTIAL FULFILLMENT FOR THE AWARD
OF THE DEGREE OF

MASTER OF SCIENCE
IN ANALYTICAL CHEMISTRY

BY

HAJARA ZUBAIRU OMENESA (MRS).
B. Sc (Hons). CHEMISTRY.

DEPARTMENT OF CHEMISTRY,
AHMADU BELLO UNIVERSITY
ZARIA.

DECLARATION

Chemical Analysis of Domestic and Industrial Wastewater effluents is wholely my work. It is not being and has not been submitted for any other degree.

Mrs. Hajara Omenesa
M.Sc. Candidate

Dr. K. Singh
Supervisor

Dr. M. S. Kazmi
Co-Supervisor

Dr. H. T. Bozimo
Ag. Head of Department

C O N T E N T S

		Page
Declaration	.. ..	i
Dedication	.. ..	ii
Acknowledgement	.. ..	iii
Abstract	.. ..	iv
CHAPTER I		
I.	INTRODUCTION	1
II.	SAMPLING AND METHODS OF ANALYSIS	11
III.	RESULTS OF ANALYSIS	48
IV.	DISCUSSION AND CONCLUSION	71
REFERENCES	.. ..	84

D E D I C A T I O N

This work is dedicated to my husband and children, and most especially to my mother for her untiring support and care.

A C K N O W L E D G E M E N T

I wish to express my profound gratitude to my supervisor, Dr. K. Singh, for his constructive criticisms, suggestions and patience which have led to the success of this work.

I thank my co-supervisor, Dr. S. Kazmi; and Dr. Basak for their contribution.

I am grateful to the Acting Head of Department, Dr. H. T. Bozimo for making available all the chemicals, equipments and materials vital to this work.

I appreciate the contribution made by the entire laboratory staff, most especially Yakubu Mohammed, Christopher Uwadiale, O. K. Abubakar and Peter Apeji to the success of this work.

Finally, I am grateful to M. J. Salami for his useful advice, encouragement and untiring efforts to see that I achieve my goal.

A B S T R A C T

This analytical study was carried out on eight well-water samples from various locations in Samaru and Zaria town; two dam water samples from Zaria water works and Jos, one stream water sample from Gubuchi-Makarfi-Kaduna; the laboratory tap water in A.B.U., treated water sample from Zaria water works; and industrial effluent samples from nine different industries in Kaduna, Kano and Jos. These include the Superphosphate Fertilizer Company, Arewa and United Nigeria Textiles, Asbestos Company and Nigerian Breweries, all at Kakuri, Kaduna; Others are North Breweries in Kano, Brytex Soap and Detergent Company and Makeri Tin Smelting Company at Jos,

The samples were analyzed for chemical factors such as total solids, alkalinity, total hardness, dissolved oxygen (D.O.), Biochemical oxygen demand (B.O.D.), total nitrogen, residual chlorine, sulphide and sulphate contents, metal ion contents which included sodium, potassium, calcium, magnesium, copper, lead, iron and zinc. The effect of coagulating agents on the suspended solid contents of the water samples was also determined.

Prom the data collected an attempt has been made to

(a) enumerate how the various water samples analyzed compare with each other, and how they measure up to stipulated quality standards of potable water for domestic and

industrial uses.

(b) compare the quality of treated and untreated water samples.

(c) investigate quality or chemical contents of some effluent waste waters and their effects on some sources of urban water supplies.

C H A P T E R I

INTRODUCTION

1.1 WATER: THE FUNDAMENTAL SUBSTANCE OF LIFE

Water is a basic necessity of all known forms of life. Although at higher levels, air might be thought of as an additional necessity, the existence of anaerobic life forms shows that water occupies a position more fundamental to life than even air. Its simple chemical composition and its relatively small mass would scarcely be expected to qualify it for the one substance which is common to all known forms of life. But it possesses properties which uniquely fit it for its role not only as a universal solvent but as a basic constituent of life.

Consistent with the wide distribution of life forms over the earth, water can be found in varying amounts all over the earth. Man depends on water for his personal well-being as well as his various domestic and industrial activities. The food which he eats consists, overall of about 70% water. His personal cleanliness requires large amounts of water. Much of his transportation and many of his recreational activities are based on water. Many of his industries require water as a basic ingredient or as an agent for mixing, washing or finishing. His personal waste

products and those of his industries are often disposed of in, or with, water. In short, even if water were not a basic constituent of his make-up, Man could not, without water, live a life comparable with what we now know.

1.2 VARIOUS WATERS - THEIR QUALITY AND HAZARDS

So intimate is Man's relationship with water that the quantity and quality of available water not only influences his life style but also sets an upper limit on the formal possibilities open to him. Although water is widely distributed over the earth, and covers fully four-fifths of the earth's surface, it is not always found where it is most needed, or, for that matter, in the required degree of purity. As a universal solvent, water is almost never found pure in nature. The composition of dissolved substances determines the quality of water, and dictates the uses to which it can be put.

The nature of dissolved matter in natural waters[1] often depends on the composition of atmospheric gases through which rain falls, the nature of rock through which ground water flows, the life processes of the world's flora and fauna, and the effects of Man's domestic and industrial activities. Chemical contents can render a given body of water a healing spring.[2] (There is evidence to suggest

that the healing properties of certain natural springs may be due to chemicals dissolved in them), or make another one a source of illness or death.[3]

In past centuries, water-borne diseases such as typhoid and cholera devastated large populations. Although these diseases are under control in technologically developed countries, they still constitute a threat in less developed countries like Nigeria.

1.3 INDUSTRIAL WASTE WATER

Of even greater danger, for not being always recognized, are the dissolved substances which result from industrial wastes. Little by little, evidence has been collected to show that major damage could result from industrial waste products. From drastic physical and mental retardation which results from ingestion of mercury - poisoned[4] fish, to the ill-effects of acid rain[5] which result in major physical damage to buildings and other structures as well as decreased soil fertility, the world is being gradually brought to face up to the dangers of industrial wastes.

But this awareness is limited largely to the industrialized world. Partly due to ignorance, and often to lack of concern, under-developed countries like Nigeria have still not made the necessary arrangements to carry out routine measurements of the

quality of water that is available for domestic and industrial use. There is the general feeling that since environmental pollution results mainly from industrial activities, there is no need for a non-industrialized country like Nigeria, with vast amounts of land for refuse dumping purposes, to worry about environmental pollution. Nevertheless, such cases as acid rain in which ill-effects of pollutants show up at considerable geographic distances from their actual sources, and the world-wide migratory patterns of the world's fauna would suggest that the non-industrialized world has little justification for smugness.

1.4 DOMESTIC WATER

Various industries require certain minimal quality of water. If a country like Nigeria is to embark on a meaningful industrialization programme, it must have the necessary data on the quality of available water to make a proper choice for the sites of different industries. Apparently, the various water supply schemes all over the country make little attempt to determine the actual chemical contents of our water. Their various treatment schemes are directed towards the elimination of biological rather than chemical hazards.

To illustrate this point, the Zaria water supply situation might be used as an example. Within the Nigerian context, Zaria is an Urban Area, being an educational as well as an increasingly important centre of commerce and industry within Kaduna State. Industries include the Zaria Oil Mills, the Nigerian Tobacco Company and the Zaria Industries Limited. The first waterworks[6] was officially commissioned in December, 1974. The supply of water was dramatically increased in March, 1975 following the completion of the Zaria Dam and the installation of the necessary treatment and distribution facilities. The dam has an estimated capacity of 14,000 million litres per day, but the present operating capacity of the waterworks is 22 million litres per day.

Water purification at the waterworks is done by Sedimentation, or coagulation, where alum, $(Al_2(SO_4)_3)$ is added to the untreated dam water to remove suspended solids and silt. This is followed by filteration which removes the remaining fine particles and colour. Sterilization to ensure the absence of biological contaminants is done by adding chlorine and ammonium sulphate solution (both producing chloramine). The amount of chlorine gas present in the treated water as compared to the added quantity is tested for on hourly basis as it indicates the extent of sterilization, although this decreases greatly by the time the water gets to the consumers.

The supply serves Zaria town, city, Tudun-Wada, Samaru and Wusasa. It was recently extended through an 8" (20cm) water main to Shika and Giwa.

Inspite of the current relative abundance of potable water from the Zaria waterworks, there are still substantial areas within Zaria and the outlying region where the inhabitants depend on well water for drinking and other domestic purposes. For example, some parts of Samaru village and Muchia area of Zaria where samples from eight different wells at different locations were analysed. For these inhabitants, the quality of the available water would have an important bearing on their state of health and well-being. Rational planning for the health of these inhabitants requires a knowledge of the state of the water which is available for their use.

1.5 POSSIBLE EFFECTS OF INDUSTRIAL EFFLUENTS

As has already been stated, Zaria is an increasingly important industrial centre within Kaduna State. The activities of the various industries result in the production of chemical waste products, some of which end up in their water effluents. Other towns such as Kaduna, Kano and Jos, from where thirteen effluent samples were collected and analyzed, have industries which also produce effluents that are of chemical interest.

There is currently no general awareness within Nigeria of the possible ill-effects of such effluents. Most of the problem results from lack of basic information.

Domestic plumbing regulations[7] and practice recognize the separateness of water supply and sewage disposal systems. However, the necessity for separateness is usually not taken seriously or acted upon by industrialists. The problem is partly economic but also partly due to lack of information. Many of the industries in this country are not even aware of the composition of their effluents.

Any effort, like the present project, which is directed to a determination of the composition of effluents, represents for them, an unwarranted and often unacceptable expenditure. Even in the developed countries, industries do only those determinations that are legally enforced on them; and do their best to eliminate or circumvent legal requirements.

In the circumstances, the Universities could prove to be the best agents for obtaining the basic data which could be used at the official level for policy decisions.

Aims and Objectives

This project is undertaken to

1) study the chemical constituents of some of the available domestic water supplies which include four well water samples from various locations in Samaru, four others from various areas of Muchia, Zaria Dam water, Jos Dam water, treated water from Zaria water-works, and water from the Laboratory tap;

2) determine the composition of industrial waste water effluents of some industries which include samples from Arewa, United Nigeria and Kaduna Textiles, Turners Asbestors, Nigeria Brewery and Superphosphate Fertilizer Company all in Kaduna, others are North Brewery in Kano, Brytex Detergent Company and Makeri tin Smelting Company of Jos;

3) study the effect of coagulating agent on the solid contents of the water samples.

This study would hopefully provide basic data on the quality of available water supplies as well as some industrial effluents: and it aims.

i) to satisfy a basic scientific curiosity;

ii) to suggest a programme for the systematic monitoring of the chemical effects of man's domestic and indust-

rial activities on the quality of available water supplies;

iii) to stress the need, to the Government, for controlling environmental pollution due to chemical effluents, by enacting laws or giving guidelines by which industries must operate;

iv) to stimulate awareness of, and interest in, the existing situation with a view to encouraging the development of national water policies and plans.

In an attempt to achieve these, the following studies were carried out on the samples:-

a) Measurement of temperature, electrical conductivity, solid content and pH,

b) Determination of alkalinity, residual chlorine, dissolved oxygen (DO),

c) Determination of nitrogen, Sulphate, Sulphide, and hardness,

d) Treatment of water samples with coagulating and flocculating agents followed by the measurement of solid content,

e) Determination of metal ions by flame photometry (for calcium, sodium and potassium), and atomic absorption spectrophotometry (for calcium, sodium, potassium, magnesium, copper, zinc, lead and iron).

CHAPTER II

SAMPLING AND METHODS OF ANALYSIS

2.1 SAMPLING

It is generally believed that the result of any analysis depends to a large extent on the sampling method. The instability of water and effluent samples necessitates sampling precautions to correct or prevent changes in sample composition between time of collection and analysis.

More meaningful results can be obtained if the purpose and types of analyses are clearly defined before sampling.

Every sample was labelled at the time of collection with

i) nature of sample,

ii) time and date of collection,

iii) location of sample,

iv) temperature and pH.

Representative Samples

It is of utmost importance to obtain a sample that is truelly representative of existing conditions and to prevent its deterioration or contamination before analysis. Sometimes, representative

samples can be obtained only by making composites of samples that have been collected over a period of time or at many different sampling points. However, it is of importance that numerous separate samples be analyzed to give consistent results instead of just one composite sample. In the present work, three separate samples were analyzed for each source or location.

2.2 SAMPLES STUDIED

These included eight well water samples, labelled well 1 to well 8, four of which were from various locations of Samaru Village and the other four from various locations of Muchia and Zaria town.

There were two dam water samples, from Jos Dam and Zaria Dam labelled Jos (D) and Zww (R) respectively; and a stream sample from Gubuchi stream along Makarfi road in Kaduna labelled KDJ. There were also treated water samples from Zaria water-works labelled Zww (T) and the laboratory tap water labelled TW.

The Industrial Effluent samples included those from Makeri Tin Smelting Company in Jos Labelled MAK 1 to 5, Brytex Soap and Detergent Company in Jos, Arewa Textiles, Kaduna Textiles (KTL I & II), United Nigerian Textiles (UNTL), Turners Asbestos Company, Superphosphate Fertilizer Company (SP I & II), Nigeria Breweries - all in Kakuri Kaduna; and North Brewery, Kano.

2.3 TIME INTERVAL BETWEEN SAMPLING AND ANALYSIS

It is an accepted fact that the shorter the time interval between sample collection and analysis the more reliable and meaningful the result. However, this depends on the type of analysis as is mentioned in Table 2.1.

2.4 SAMPLE PRESERVATION

Complete and unequivocal preservation of samples, either domestic sewage, or industrial wastes, or natural waters[8] is a practical impossibility. Regardless of the nature of the sample, complete stability for every constituent can never be guaranteed. At best, preservation techniques can only retard the chemical and biological changes that inevitably continue after the sample is removed from its source. Certain chemical changes alter the chemical structure of the constituents that are a function of physical conditions. Metal cations may precipitate as hydroxides or form complexes with other constituents, cations or anions may change valence states under certain reducing or oxidizing conditions; other constituents may dissolve or volatilize with the passage of time. Metal cations, such as iron and lead, may also adsorb onto container (glass, plastic, quartz, etc.) surfaces. Biological changes in the sample may change the valency state of an element or a radical.

Soluble constituents may be converted to organically bound materials in cell structures. The well known nitrogen and phosphorus cycles are examples of biological influence on sample composition.

Preservation methods are generally limited to pH control, chemical addition, refrigeration and freezing; and are intended to

i) retard biological action

ii) retard hydrolysis of chemical components and complexes, and

iii) reduce volatility of constituents.

TABLE 1.1: SHOWS THE VARIOUS PRESERVATION METHODS THAT WERE USED TO RETARD CHANGES IN SAMPLES.

Measurement	Preservation Method	Holding Time
Temperature	Determined on site	No holding
pH	Determined on site or cool at 4°C	6 hours
Conductivity	Cool at 4°C	24 hours
Alkalinity	Cool at 4°C	24 hours
Settleable Matter	None required	24 hours
Kjeldahl Nitrogen	Cool at 4°C H_2SO_4 to pH< 2	7 days
Metals	HNO_3 to pH< 2	6 months
Hardness	Cool at 4°C HNO_3 to pH< 2	7 days
Dissolved Oxygen	Fixed on site	4-8 hours
BOD	Cool at 4°C	6 hours
Chlorine	Determined on site	No holding
Sulphate	Cool at 4°C	7 days
Sulphide	4ml/l Zinc acetate	24 hours

2.5 ANALYSIS OF THE SAMPLES

Because of the reasons listed above some analyses were carried out on the spot of sample collection using portable but sensitive instruments. These analyses included:-

i) Temperature

ii) pH

iii) Electrical conductivity and

iv) Residual chlorine;

whereas other studies were carried out in the laboratories.

EXPERIMENTAL

Apparatus

Thermometer: A thermometer of 0 to 100°C temperature range

Conductivity Bridge: Type MC 3 EIL portable conductivity Bridge.

pH Meter: Griffin portable pH Meter type B 17 DA.

Oven: A thermostatically controlled electric Gallenkamp oven BS Model, OV - 160 size 2 range 20-260°C

Furnace: A Gallenkamp electric furnace with a temperature range of 0-1000°C.

Heating Mantle: 1 litre capacity with range 10 to 100°C.

Atomic Absorption Spectrophotometer: A Pye Unicam SP 1900 Atomic Absorption Spectrophotometer.

Flame Photometer: A Gallenkamp Flame Analyzer type 27-FGA-300-A.

Glasswares: Incubation bottles of 250ml capacity for Biochemical Oxygen Demand Pyrex-Kjeldahl flasks of 300ml capacity and Pyrex-glass distillation set-up for nitrogen determination.

Reagents and Chemicals

All reagents and chemicals used were of Analytical grade, unless-otherwise stated.

Sulphuric acid, 0.02M was prepared by diluting 1.08ml of sulphuric acid, 98%, sp. gr. 1.84 to 1 litre with distilled water.

Hydrochloric acid, 0.01M was prepared by diluting 0.86ml of hydrochloric acid, 36%, sp. gr. 1.18 to 1 litre with distilled water.

This was standardized[9] by titrating against 0.2g anhydrous sodium carbonate (dried at 260°C for one hour and cooled) which was dissolved in 50ml distilled water with methyl orange as indicator.

Methyl orange indicator solution, 0.1% (m/v) was prepared by dissolving 1g methyl orange in water and made up to 100ml with distilled water.

Phenolphthalein indicator solution 1% (m/v) was prepared by dissolving 1g phenolphthalein in 100ml of ethanol, 95% (v/v), and 100ml of water added with stirring.

Acetic acid, glacial

Ammonia solution, sp. gr. 0.88

Starch indicator[10] solution, 5% (m/v), was prepared by triturating 5g soluble starch into a smooth paste with a small amount of cold water and the slurry poured, with constant stirring, into

1 litre of boiling. This was boiled for 1 minute, allowed to cool before use and was preserved by the addition of 1.25g salicylic acid.

Sodium thiosulphate, 0.125M - non-standardized volumetric solution, was prepared by dissolving 31.2g of hydrated sodium thiosulphate, $Na_2S_2O_3.5H_2O$, in water and diluted to 1 litre.

Sodium thiosulphate, 0.0025M - standardized volumetric solution was prepared by diluting 20ml of sodium thiosulphate, 0.125M to 1 litre. This was standardized[11] by titrating with a solution containing 10ml of potassium iodate, 0.0025M, 0.5g of potassium iodide, and 5ml glacial acetic acid all dissolved in 500ml distilled water and allowed to stand for 1 minute, until the colour of the liberated iodine was nearly discharged after which 2ml of starch indicator solution was added and titrated to blue end point.

Potassium iodate, 0.0025M - was prepared by diluting 20ml of potassium iodate, 0.125M, (4.459g/l , dried at 110°C for 1 hour) to 1 litre with distilled water.

Potassium iodide solution, 50g/l (m/v) was prepared by dissolving 50g of potassium iodide in water and made up to 1 litre with water.

Iodine solution, 0.125M - was prepared by dissolving 25g potassium iodide in 50ml water, 15.9g of iodine was allowed to dissolve in this and the solution made up to 1 litre.

Cadmium acetate solution was prepared by dissolving 250g cadmium acetate in water and made up to 1 litre.

Silver nitrate-nitric acid reagent was prepared by dissolving 8.5g silver nitrate and 0.5ml concentrated nitric acid in 500ml distilled water.

Sodium hydroxide, 40% (m/V) was prepared by dissolving 40g sodium hydroxide pellets in 100ml distilled water.

Boric acid, 4% (m/V) was prepared by dissolving 4g boric acid. in 100ml of distilled water.

Mixed indicator solution 0.1% (m/V) was prepared by dissolving 5g each of methyl red and Bromocresol Green in 95% ethanol.

A phosphate buffer to give a pH of about 7.2 was prepared by dissolving 8.5g potassium dihydrogen phosphate,

21.75g dipotassium hydrogen phosphate, 33.4g disodium hydrogen phosphate, heptahydrate, and 1.7g ammonium chloride in 500ml distilled water and made up to 1 litre.

A buffer solution of about pH 10 $\pm$ 0.1 was prepared by adding a solution of 1.179g disodium salt of ethylenediamine tetraacetic acid dihydrate (EDTA) and 0.78g magnesium sulphate heptahydrate,

in 50ml distilled water to a solution of 16.9g ammonium chloride in 143ml concentrated ammonium hydroxide with mixing and the resulting solution was diluted to 250ml with distilled water.

Standard EDTA titrant, 0.01M was prepared by dissolving 3.723g of disodium ethylenediamine tetraacetate dihydrate, (EDTA), $Na_2H_2C_{10}H_{12}O_8N_2.2H_2O$, in distilled water and made up to 1 litre.

This was standardized with a standard calcium[12] solution of 1g anhydrous calcium carbonate dissolved in a little 1+1 hydrochloric acid and then 200ml water, the solution boiled to expel carbon dioxide and then made up to 1 litre with water.

Eriochrome black T dye indicator was prepared by dissolving a mixture of 0.5g dye and 4.5g hydroxylamine hydrochloride in 100ml of 95% ethylalcohol.

Magnesium sulphate solution was prepared by dissolving 22.5g of magnesium sulphate heptahydrate, $MgSO_4.7H_2O$ in distilled water and made up to 1 litre.

Calcium chloride solution was prepared by dissolving 27.5g anhydrous calcium chloride in water and made up to 1 litre.

Ferric chloride solution was prepared by dissolving 0.25g ferric chloride hexahydrate, $FeCl_3.6H_2O$ in water and made up to 1 litre.

Alkaline iodide-Azide solution was prepared by adding a solution of 10g sodium azide in 40ml distilled water to a solution of 500g

sodium hydroxide and 135g sodium iodide in distilled water which had been diluted to 1 litre.

1. Measurement of Electrical Conductivity

Principle

Conductivity is a measure of the ability of a conductor to convey an electric current. In the case of water, it is related to the concentration of ions present and to the temperature at which the measurement is made. Being the reverse of resistivity (with ohm/cm as unit), it is generally reported as mho/cm. The conductivity of most waters are so low that it is often reported as µmho/cm (micro mho/cm). Conductivity gives no indication of the nature of the substances in solution, but merely reflects an increase or decrease in overall ion concentration.

Measurement: After rinsing the clean cell with the sample, it was filled with the sample and the temperature measured. The selector switch was set to X100 range, the "ON" key depressed and the conductivity recorded[13] as in Table 3.1.

2. Measurement of pH

This was carried out in the field with a portable battery-operated field pH meter. The accuracy of the meter was improved by checking against buffers of known pH values close to those of the samples.

Measurement: The correctness[14] of the scale factor of the meter was checked by standardizing with various buffer solutions - pH 2, 4, 7, 10 and 13; by checking each time to see that the correct reading was obtained (without further adjustment of the controls) on a succeeding buffer solution different from the preceeding one. The pH values obtained are given in table 3.2.

3. Determination of Solid Contents

(a) Total Solids

Principle

A well mixed sample is evaporated in a weighed dish and dried to constant weight in an oven maintained at 103 to 105°C. The increase in weight over that of the empty dish represents the total residue, which is an arbitrary quantity defined by the procedure followed.

Procedure: A clean percelain evaporating dish was dried in an oven at 103 to 105°C, cooled in a desiccator and weighed to constant weight at an hourly interval. 100ml of the sample was then allowed to evaporate to dryness in the dish over a steam bath, after which the residue was dried in an oven at 103-105°C for one hour, cooled and weighed. Subsequent drying, cooling and weighings were made until successive weights did not differ by more than 0.2mg.

(b) Determination of Dissolved Solids

The recommended methods, in order of preference are

(i) Filtration through glass fibre filter discs and

(ii) Centrifugal method which is not applicable if any part of the suspended solid floats.

In this work, the filtration method was used.

Procedure: The glass fibre filter disc was placed at the bottom of a Cooch crucible and with vacuum suction, it was washed with three successive 20 ml volumes of distilled water, while suction continued for 2 minutes to remove all traces of water and the washings discarded. Under vacuum, 100ml of a well mixed sample was then filtered through the fiber disc. a known volume of the filtrate was then transfered into a preignited, cooled and weighed evaporating dish and evaporated over steam - bath; the residue was dried at 103-105°C, cooled and weighed to a successive weight difference of about 0.2mg. The results are shown in table 3.3.

Calculation:

(a) mg/l total solids

$$= \frac{(A - B) \times 1000}{C}$$

where A = weight of dried residue + dish

B = weight of empty dish

C = volume of sample used

(b) mg/l Dissolved solids

$$= \frac{(A_1 - B_1) \times 1000}{C_1}$$

A_1 = weight of dish and dried residue

B_1 = weight of empty dish

C_1 = volume of filtrate used.

(c) Suspended solids (mg/l)

= Total solids - Dissolved solids.

Alkalinity

Principle: Hydroxyl ions present in a sample as a result of dissociation or hydrolysis of solutes are neutralized by titration with standard acid.[15,16] The amount of carbonate and hydroxyl ions is determined by titration with acid to pH≃8.3, the end point being detected with phenolphthalein.

The amount of bicarbonate ions present is determined by further titration with acid to an end point pH between 4.2 and 5.4, with methyl orange, as end point indicator.

The four quantities commonly reported are:

	Quantity	Symbol	Compounds	End point pH
1.	Phenolphthalein alkalinity	PA	$OH^- + CO_3^{2-}$	$\simeq$ 8.3
2.	Total alkalinity	TA	$OH^- + CO_3^{2-} + HCO_3^-$	4.2 to 5.4
3.	Carbonate alkalinity	CA	$CO_3^{2-} + HCO_3^-$	
4.	Total Carbon dioxide	TC	$CO_3^{2-} + HCO_3^- + CO_2$	

CA and TC may be obtained by calculation from TA, the pH and conductivity of the original water sample.

Determination

There are two standard methods:

(1) Potentiometric method, and

(2) Indicator method.

Although the first method is for water samples of low alkalinity, the indicator method was used due to its rapidity, convenience as well as accuracy for this work.

Procedure: To 100ml filtered sample was added 2 drops (0.1ml) phenolphthalein and titrated to carbonate and hydroxide end point with 0.02N H_2SO_4 and titre noted.

To the above solution was added 2 drops (0.1ml) methyl orange and further titrated to carbonate and bicarbonate end point with 0.02N sulphuric while noting the titre value as the total volume of acid used for both titrations. The experiement was repeated twice more to obtain the mean reading. The results are given in table 3.4.

The reactions taking place are as follows:-

i) Hydroxide:

$$H_2SO_4 + 2[OH^-] \rightarrow SO_4^{2-} + 2H_2O$$

ii) Carbonate:

$$H_2SO_4 + 2[CO_3^{2-}] \rightarrow 2[HCO_3^-] + SO_4^{2-}$$

iii) Bicarbonate:

$$H_2SO_4 + 2[HCO_3^-] \rightarrow SO_4^{2-} + 2H_2CO_3$$

Calculation:

a) Phenolphthalein Alkalinity:

$$\text{as mg/l } CaCO_3 = \frac{A \times M \times 1000}{V}$$

b) Methyl Orange (or Total) Alkalinity:

$$\text{as mg/l } CaCO_3 = \frac{A_1 \times M \times 1000}{V}$$

where A = volume of sulphuric acid used for (a)

A_1 = total volume of sulphuric acid used for (a) & (b)

M = Molarity of sulphuric acid

V = Volume of sample used.

5. Determination of Residual Chlorine

Of the several methods available for this determination, the Iodometric Method[17] was found suitable and used for this work.

Principle: Chlorine liberates free iodine from potassium iodide solution at pH 8 or less. The liberated iodine is titrated with a standard solution of sodium thiosulphate, with starch as the indicator. The reaction is preferably carried out at pH 3 to 4.

Procedure: To 500ml sample was added 10ml of potassium iodide solution (or 0.5g of the solid) and 5ml of glacial acetic acid.

This was mixed and at once titrated, away from sunlight, with standardized sodium thiosulphate, 0.0025M until the colour of the liberated iodine was nearly discharged. 1ml starch indicator solution was added and the mixture titrated until the blue colour was discharged.

The result of the sample titration was corrected with a blank titration to annule contribution by interferring free iodine or iodates or traces of reducing agents that might reduce some of the iodine liberated. The experiment was repeated twice more .

6. Determination of Dissolved Oxygen (DO)

The two available methods used for determination of dissolved oxygen are:-

1) The Winkler or Iodometric method

2) The Electrometric method using membrane electrodes.

The iodometric method is a titrimetric procedure based on the oxidizing property of Dissolved Oxygen, while the membrane electrode procedure is based on the rate of diffusion of molecular oxygen across a membrane.

The iodometric method, known to be the most precise and reliable titrimetric method was used in this work.

Principle: The determination is based on the addition of divalent manganese solution, followed by strong alkali, to the sample in a glass-stoppered bottle. The dissolved oxygen present rapidly oxidizes an equivalent amount of the dispersed divalent manganous hydroxide precipitate to hydroxides of higher valency

states. In the presence of iodide ions and in acid medium, the oxidized manganese reverts to the divalent (or lower) state, with the liberation of iodine equivalent to the original Dissolved oxygen content in the sample. The iodine is then titrated with a standard thiosulphate solution.

The reactions involved[18] are:-

$$Mn^{II} + 2[OH^-] \longrightarrow Mn(OH)_2$$

$$2Mn(OH)_2 + O_2 \longrightarrow 2MnO(OH)_2$$
Brown

$$MnO(OH)_2 + 2H_2SO_4 \longrightarrow Mn(SO_4)_2 + 3H_2O$$

$$Mn(SO_4)_2 + 2KI \longrightarrow MnSO_4 + K_2SO_4 + I_2$$

Procedure: A bottle of 250ml capacity was filled to the brim with the sample solution. 2ml manganous sulphate solution was added, with a pipette, to the sample well below the liquid surface, and 2ml alkaline iodide solution added at the surface. The stopper was carefully replaced to avoid inclusion of air bubbles and the contents thoroughly mixed by vigorously inverting. and rotating the bottle several times.

The mixing was repeated, when the precipitate had settled to the lower third of the bottle, and the precipitate was then allowed to settle completely, leaving a clean supernatant liquid. 4ml of diluted sulphuric acid was then added with a pipette. The stopper

was replaced and the content thoroughly mixed till it dissolved.

The bottle was again mixed immediately before measuring 100ml of the content into a conical flask and the liberated iodine immediately titrated with standard 0.0125M sodium thiosulphate solution, using starch as indicator. The results are shown in table 3.5.

Calculation:

Dissolved oxygen content (mg/l)

$$= \frac{\text{vol. } 0.0125M\ Na_2S_2O_3 \times 101.6}{\text{vol. of sample titrated}}$$

$$= (100ml)$$

7. Determination of Biochemical Oxygen Demand (BOD)

The dilution method,[19] which is generally used, was found suitable for this work.

Principle: The dissolved oxygen content of the sample, after dilution with dilution water was determined before and after incubation for 5 days at a standard temperature, the difference giving the oxygen demand of the sample, allowance being made for the dilution received by the sample.

Preparation of Dilution water: The distilled water to be used was stored for some days in a cotton-plugged bottle, aided by frequent shaking, in order to saturate it with dissolved oxygen.

To this were added 1ml each of phosphate buffer solution, manganous sulphate, calcium chloride and ferric chloride solution per litre of water.

Procedure: A 250ml capacity incubator bottle was half-filled with the sample solution without any entrainment of air and the sample pH adjusted to between 6.5 and 8.5 by the addition, where necessary, of acid or alkali, (1M H_2SO_4 and 1M NaOH respectively). To this were added 2ml each of alkaline iodide-azide solution and sulphuric acid. The bottle was then filled to the brim with dilution water, vigorously shaken, and 200ml of the mixture titrated against 0.0125M sodium thiosulphate using starch as indicator, to obtain the dissolved oxygen content of the sample before incubation.

The process was repeated and the BOD bottle incubated in the dark at 20°C for five days before titrating another 200ml of the sample against 0.0125M sodium thiosulphate solution with starch as indicator. The blank dilution was similarly incubated and the DO also determined. The results are shown in table 3.6.

Calculation

$$\text{BOD as mg/l} = \frac{D_1 - D_2}{P}$$

where

D_1 = Dissolved oxygen (DO) of original diluted sample before incubation

D_2 = DO of diluted sample after incubation

P = Volume of sample used.

8. Determination of Nitrogen

Kjeldahl Digestion (Volumetric) Method: The conversion of organic nitrogen to ammonia is the basis of the well-known Kjeldahl's digestion method,[20] the common method for the determination of total nitrogen.

Principle: In the presence of sulphuric acid, potassium sulphate and copper sulphate catalyst (mixed catalyst), the amino nitrogen of many organic materials is converted to ammonium sulphate[21]. After the decomposition of the copper ammonium complex in the digestate the ammonia is distilled from an alkaline medium and absorbed in boric acid after which the ammonia is determined by titration with a standard mineral acid.

Procedure: 10ml of the water sample and 6ml of concentrated sulphuric acid were placed in a 300ml Kjeldahl digestion flask. 1g of catalyst mixture was added and the solution digested until it became clear (2 to 4 hours).

After cooling, the digest was diluted to 50ml with distilled water. 5ml of 40% sodium hydroxide was added to 5ml of the digest in a distillation set up and the ammonia was steam - distilled into 10ml boric acid containing a drop of mixed indicator in a receiver.

The distillate was titrated against 0.0142M (M/70) hydrochloric acid to end point. The experiment was repeated twice more and a blank titration using all the above reagents was also carried out with distilled water as sample. The results are shown in Table 3.7.

Calculation

$$\text{Total Nitrogen as } NH_3 \underset{(mg/l)}{} = \frac{M \times \text{Titre} \times V_1 \times A \times MW}{V}$$

where

M = Molarity of Hydrochloric acid

V_1 = total volume of digest

V = original volume of sample digested

A = volume of digest distilled

MW = molecular weight of nitrogen.

9. Determination of Sulphate

The sulphate content of the samples was determined by gravimetric method.

Principle: Sulphate is precipitated in a hydrochloric acid medium as barium sulphate by the addition of barium chloride. The precipitation is carried out near the boiling temperature, and after a digestion period the precipitate is filtered, washed with water until free of chlorides, ignited and weighed as barium sulphate.

$$BaCl_2 + SO_4^{2-} \longrightarrow BaSO_4 + 2Cl^-$$

Procedure: To 100ml of the sample was added a few drops of 1+1 hydrochloric acid, or ammonia solution as necessary, until the pH had been adjusted to 4.5-5 using a pH meter. The volume was adjusted to 250ml with distilled water, 2ml of 1+1 hydrochloric acid was added and the mixture boiled for one minute.

15ml of hot barium chloride solution was gradually added with stirring when precipitation appeared to be complete.

The precipitate was digested overnight at 80-90°C in an oven after which it was filtered through an ashless filter paper and washed with small portions of warm distilled water until the washings were free of chloride, as indicated by testing with silver nitrate-nitric acid reagent.

The precipitate and filter paper were dried in the oven at 80°-90°C and then ignited at 800°C in a furnace for one hour, cooled in a dessicator and weighed. The ignition, cooling and weighing

were repeated until a constant weight was obtained.

The results are shown in table 3.8.

Calculation

$$\text{Sulphate (mg/l) as } SO_4^{2-} = \frac{\text{weight of } BaSO_4 \times 411.5}{\text{Vol. sample used}}$$

10. Determination of Sulphide

By Precipitation Method: Of the two methods available for the determination of sulphide, the precipitation or titrimetric (iodine) method was found satisfactory and used for this work.

Principle: Cadmium sulphide is precipitated [2] by the addition of the sample to a solution of cadmium acetate. The precipitate is separated and acidified in the presence of excess standard iodine solution. Hydrogen sulphide is liberated and is oxidized by the iodine, the amount of iodine consumed being determined by titration.

$$Cd^{2+} + S^{2-} \longrightarrow CdS$$

$$CdS + H_2SO_4 \longrightarrow CdSO_4 + H_2S$$

$$H_2S + I_2 \longrightarrow 2HI + S$$

Procedure: To 10ml of the sample in a 50ml capacity beaker was added 10ml of cadmium acetate solution. The precipitate formed was allowed to settle and the clear supernatant liquid was discarded through a filter paper. The precipitate was transfered to the paper and washed with water. Into a 250 ml wide mouth conical flask was placed 100ml distilled water, 10ml diluted sulphuric acid and 20 ml iodine solution. The filter paper was then dropped into this mixture and the stopper quickly inserted while vigorously shaking the flask to complete the solution of the sulphide. The excess iodine was titrated against the standard sodium thiosulphate solution using starch as indicator near the end point.

A blank titration was also carried out and the whole procedure was repeated twice more.

The difference between the blank titre, V_1, and the experimental titre, V_2, gives the volume of the iodine consumed. The results are shown in table 3.9.

Calculation

$$\text{Sulphide as } S^{2-} = \frac{(V_1 - V_2)\ 2000}{V_3} \text{ mg/l}$$

where

V_1 = volume of sodium thiosulphate consumed for blank

V_2 = volume of sodium thiosulphate consumed by sample

V_3 = volume of sample used.

11. Determination of Hardness

The accurate method for determining hardness is to compute[23] it from results of complete mineral analysis. Although this method is considered to yield higher accuracy, it was not used for the present work since a complete mineral analysis was not undertaken.

The complexiometric method, being more suitable, was used. This involved the use of the disodium salt of ethylene diamine tetraacetic acid (EDTA), which is more soluble than the pure acid itself as a titrant for the calcium and magnesium ion in the sample by direct titration.

EDTA and it's sodium salt form soluble hexadentate chelates[24] with calcium and magnesium ions in a basic medium, (pH 10), releasing two moles of hydrogen ions for each mole of alkaline earth ion complexed.

$$Ca^{2+} + H_2Y^{2-} \longrightarrow CaY^{2-} + 2H^+$$
$$Mg^{2+} + H_2Y^{2-} \longrightarrow MgY^{2-} + 2H^+$$

Procedure

(a) Determination of Total Hardness: To 50ml of sample were added 1ml of ammonium chloride/ammonium hydroxide buffer and two drops of Eriochrome Black T. The wine-red solution was

titrated with 0.01M EDTA solution to a clear blue end point with dropwise addition of the titrant towards the end point.

(b) Determination of Calcium Hardness: 25ml of the sample was diluted to 50ml with distilled water, 2ml of 1M sodium hydroxide and 1g of murexide indicator were added and the wine-red solution titrated to a clear-blue end point.

The results are shown in table 3.10.

Calculation:

$$\text{Total hardness as mg/l } CaCO_3 = \frac{A \times B \times 1000}{\text{ml sample}}$$

$$\text{Calcium hardness as mg/l } CaCO_3 = \frac{A \times B \times 1000}{\text{ml sample}}$$

where

A = volume of titrant for sample

B = milligram $CaCO_3$ equivalent to 1.0ml EDTA titrant at the end point.

(c) Magnesium hardness = Total Hardness - Calcium hardness.

12. Determination of Metal Ions by Flame Emission and Atomic Absorption Spectrophotometry

(a) Flame Emission

Principle: When atoms of an element are heated in a flame[25] some of the heat energy is absorbed by a few of the atoms which

become excited, that is, there is a transition by one or more electrons from the ground state to higher energy levels. On reverting to the ground state the electrons lose this energy which is emitted as electro-magnetic radiation. The wavelength of the emitted radiation is governed by the energy change involved in the transition. For each element there are certain permitted shifts giving rise to a series of lines, each series being characteristic of the element. The intensity of any one line is governed principally by flame temperature, other atomic species present and the number of atoms of the element in the flame at any one instant.

The basis of quantitative flame photometry is that, if operating conditions are kept constant, the intensity of radiation will be a measure of this number.

(b) Atomic Absorption Spectrophotometry

Principle: Atomic absorption spectra are formed by the absorption of radiation of certain wavelengths by atoms whose electrons are in the ground state. On absorbing this energy the atoms become excited. The extent of absorption is dependent on the number of atoms in the ground state in the path of the radiation beam at any one time and can thus be used as a quantitative method of determining this number.

In practice, a solution of the element is sprayed into a relatively cool flame in which the atoms tend to remain in the ground state. Radiation of a characteristic wavelength from a hollow cathode discharge lamp is passed through the flame and the decrease in intensity is measured using a monochromator and detector system. This decrease is related to the concentration of the element in solution.

Analysis of Samples: The samples were quantitatively analysed for sodium, potassium and calcium ions by flame emission spectroscopy; and sodium, potassium calcium, copper, magnesium, lead, iron and Zinc by atomic absorption spectrophotometry.

(1) Flame Emission Spectroscopy

Reagents: Sodium chloride Analytical Reagent

Potassium chloride Analytical Reagent

Anhydrous calcium carbonate Analytical Reagent

Procedure: Standard solutions were prepared to obtain calibration curve for each metal ion as follows:-

Sodium Standard: A stock solution containing 1000 ppm sodium was prepared by dissolving 2.542g sodium chloride, (which had been dried at 140°C for 1 hour and cooled), in water and made up to 1 litre. From this solution standard solutions were made of 0 to 10 ppm by diluting 0.1ml of the stock to 100ml to give 1ppm and so on.

Potassium Standard: A stock solution containing 1000 ppm potassium was prepared by dissolving 1.9068g potassium chloride, (dried at 110°C for 1 hour and cooled), in distilled water and made up to 1 litre. 0 to 20 ppm standard solutions were then prepared by diluting, for example, 0.1ml of the stock to 100ml with distilled water to give a 1ppm potassium standard solution, and so on.

(c) Calcium Standard

A 1000ppm calcium stock solution was prepared by dissolving 2.4973g dry calcium carbonate in 200ml distilled water containing 5ml concentrated hydrochloric acid. This was heated to drive off carbon dioxide, cooled and made up to 1 litre with distilled water. 0 to 100ppm calcium working standards were then prepared by diluting appropriate volumes of the stock solution to 100ml with distilled water.

Pretreatment of Samples: Most of the industrial effluent samples required no pretreatment. However, a few samples had to be pretreated to enhance complete availability of the metal ions of interest in solution. The pretreatment procedure used involved: Addition of 0.5ml concentrated sulphuric acid to 150ml of unfiltered sample. This was boiled down to the white fume stage, cooled and 1ml 60% perchloric acid ($HClO_4$) and 5ml concentrated nitric acid were added. This was evaporated until solution was clear without allowing the solution to dry up. The clear solution was filtered into a 100ml volumetric flask and the volume made up to the mark with distilled water. The standards for all the pretreated samples were also treated as above.

(2) Atomic Absorption Spectrophotometry

The procedure followed for the preparation of standard solutions were as follows:-

(a) Calcium Standard: 1000ppm calcium stock solution was prepared by dissolving 2.7693g calcium chloride in 100ml water and diluted to 1 litre with distilled water. 0 to 10 ppm solutions were prepared from this by diluting appropriate volumes of the stock solution with distilled water.

(b) Copper Standard: 1000ppm copper stock solution was prepared by dissolving 3.7980g hydrated copper nitrate, $Cu(NO_3)_2.3H_2O$, in 250ml distilled water and the solution made up to one litre with distilled water. 0-10ppm standard solutions were then prepared from this stock solution by dilution with distilled water.

(c) Iron Standard: 1000ppm iron stock solution was prepared by dissolving 4.8400g hydrated ferric chloride, ($FeCl_3.6H_2O$), in 200ml distilled water and the solution diluted to 1 litre with distilled water. 0 to 2 ppm iron solutions were then prepared by diluting 0.1ml of the stock to 100ml with distilled water to give a 1 ppm iron solution, and so on.

(d) Lead Standard: 1000 ppm lead stock solution was prepared by dissolving 1.5980g lead nitrate, $Pb(NO_3)_2$ in 100ml distilled water and the solution made up to 1 litre with distilled water 0 to 8 ppm lead standard solutions were then prepared by diluting appropriate volumes of the stock solution to 100ml with distilled water.

(e) Magnesium Standard: 1000 ppm Magnesium stock solution was prepared by dissolving 3.9160g hydrated magnesium chloride, $MgCl_2.6H_2O$ in 200ml water and the solution diluted to 1 litre

with distilled water 0 to 1.4ppm magnesium standards were then prepared from the stock solution.

(f) Potassium Standard: 1000ppm potassium stock solution was prepared by dissolving 1.9070g of dry potassium chloride, KCl in 250ml water and the solution made up to 1 litre. 0 to 5ppm potassium standard solutions were then prepared from the stock solution.

(g) Sodium Standard: 1000ppm sodium was prepared by dissolving 2.5420g sodium chloride, NaCl in 200ml water, making the solution to 1 litre with water and 0 to 5 ppm standards prepared from it.

(h) Zinc Standard: 1000ppm zinc stock solution was prepared by dissolving 1.2450g Zinc oxide, ZnO, in 5ml water followed by 25ml 5M hydrochloric acid and the solution diluted to 1 litre with distilled water. 0 to 5 ppm standards were prepared from this.

13. Treatment of Water Samples With Coagulating and Flocculating Agents

Principle: Coagulation[26] is a process which describes the effect produced by the addition of a chemical to a colloidal dispersion resulting in particle destabilization by a reduction

$$Al(H_2O)_6^{3+} + H_2O \longrightarrow Al(H_2O)_5OH^{2+} + H_3O^+$$

$$Al(H_2O)_5^{2+} + H_2O \longrightarrow Al(H_2O)_4(OH)_2^{+} + H_3O^+$$

$$Al(H_2O)_4(OH)_2^{+} + H_2O \longrightarrow Al(H_2O)_3(OH)_3 + H_3O^+$$

The same thing applies to hydrolysis of iron.

Reagents: Aluminium sulphate. Analytical Reagent

of the forces tending to keep the particles apart. This is achieved by adding appropriate chemicals which cause particles to stick together when contact is made. Rapid mixing leads to uniform dispersion of the chemicals and in increased particle-to-particle contact.

In contrast to coagulation, where the primary force is electrostatic, flocculation occurs by a chemical bridging or physical enmeshment mechanism and is obtained by a gentle and prolonged mixing which converts the submicroscopic coagulated particles into discrete, visible, suspended particles, which at this stage are large enough to settle rapidly and can be filtered.

The use of aluminium and iron salts as coagulants has been known for over a century, although the precise mechanism of their operation has not been clearly worked out. The original concept that the positively charged tripositive aluminium and iron ions formed in solution neutralized the negatively charged turbidity particles, which removed the repulsive force between them, and resulting in agglomeration is now known to be incorrect. The current view is that, it is the products of hydrolysis of aluminium and iron, and not the metal ions that are the coagulating agents. The hydrolytic[27] reaction involved is:

where

A = weight of empty dish + dried residue

B = weight of empty dish alone

C = volume of sample used.

(b) suspended solid (mg/l) = $\frac{(A_1 - B_1) \times 1000}{C}$

where A_1 = A in (a)

B_1 = B in (a)

C = C in (a)

(c) Dissolved solid (mg/l) = Total solids - suspended solids.

The results obtained are shown in tables 3.17 (I-VI).

RESULTS OF ANALYSES

The results of the various analyses are given in tables 3.1 - 3.17

TABLE 3.1: Results of Determination of Electrical Conductivity with the corresponding Temperatures

Sample		Temperature (^{o}C)	Electrical Conductivity (mho/cm) ($X10^{2}$)
Well	1	29	6.87 ± 0.06
"	2	29	3.07 ± 0.06
"	3	28.5	1.83 ± 0.06
"	4	28	2.50 ± 0.04
"	5	27	3.30 ± 0.04
"	6	29	2.80 ± 0.00
"	7	26	2.10 ± 0.05
"	8	26.5	2.20 ± 0.00
ZWW(R)		25.5	0.53 ± 0.06
ZWW(T)		26	1.23 ± 0.06
TW		25	1.07 ± 0.06
Jos(D)		29	0.10 ± 0.00
KDJ		26.5	0.23 ± 0.06
MAK 1		29	2.50 ± 0.05
MAK 2		28.5	4.03 ± 0.06
MAK 3		29	2.07 ± 0.02
MAK 4		28	1.73 ± 0.06
MAK 5		28	7.33×10^{1} ± 0.06
AREWA		26	2.57×10^{1} ± 0.06

TABLE 3.1 CONT'D

Sample	Temperature (°C)	Electrical Conductivity (mho/cm) ($X10^2$)
UNTL	28	$7.03 \times 10^1 \pm 0.06$
KTL I	27	$2.07 \times 10^1 \pm 0.06$
KTL II	27	$1.33 \times 10^1 \pm 0.06$
BRYTEX	26.5	0.57 ± 0.06
ASBESTOS	26	$9.03 \times 10^1 \pm 0.06$
SP I	28	$3.10 \times 10^2 \pm 0.05$
SP II	27	$3.93 \times 10^2 \pm 0.06$
NORTH BREW	27	2.63 ± 0.06
NIC. BREW.	29	$1.77 \times 10^1 \pm 0.06$

KTLI and II - Effluents from Sewage treatment tanks I and II from Kaduna Textiles Ltd.

BRYTEX - Effluent from Brytex Soap and Detergent Company in Jos.

ASBESTOS - Effluent from Turners Asbestos Co., Kaduna

SP I and II - Effluents from treatment plant of Kaduna Superphosphate Fertilizer Co.

NORTH BREW. - Effluent (total) from North Brewery, Kano.

NIG. BREW. - Effluents (total) from Nigeria Brewery, Kaduna

TABLE 3.2: Measurement of pH

Sample		pH
Well	1	7.27 ± 0.06
"	2	6.77 ± 0.06
"	3	6.63 ± 0.06
"	4	7.17 ± 0.06
"	5	6.50 ± 0.10
"	6	6.83 ± 0.06
"	7	6.40 ± 0.00
"	8	6.50 ± 0.00
ZWW(R)		6.40 ± 0.10
ZWW(T)		7.23 ± 0.06
TW		7.27 ± 0.06
Jos (D)		6.73 ± 0.06
KDJ		6.07 ± 0.06
MAK I		7.43 ± 0.06
MAK 2		6.30 ± 0.00
MAK 3		6.90 ± 0.00
MAK 4		8.73 ± 0.06
MAK 5		2.47 ± 0.06
AREWA		5.23 ± 0.06
UNTL		11.23 ± 0.06
KTL I		10.20 ± 0.00
KTL II		10.20 ± 0.00
BRYTEX		7.87 ± 0.06
ASBESTOS		12.20 ± 0.10
SP I		3.20 ± 0.00
SP II		3.10 ± 0.00
NORTH BREW		8.27 ± 0.06
NIG. BREW.		11.73 ± 0.06

TABLE 3.3: Results of Determination of Suspended, Dissolved and Total Solids

Sample	Suspended Solids (mg/l)	Dissolved (Solids (mg/l)	Total Solids (mg/l)
Well 1	198 ± 0.58	19 ± 0.15	218 ± 0.15
" 2	201 ± 0.10	132 ± 0.10	333 ± 0.10
" 3	190 ± 0.10	85 ± 0.10	275 ± 0.58
" 4	223 ± 0.10	98 ± 0.10	321 ± 0.0
" 5	205 ± 0.10	61 ± 0.58	266 ± 0.58
" 6	196 ± 0.58	61 ± 0.0	257 ± 0.58
" 7	200 ± 0.58	62 ± 0.15	263 ± 0.58
" 8	187 ± 0.53	67 ± 0.58	256 ± 0.58
ZWW(R)	4 ± 0.00	0 ± 0.0	4 ± 0.00
ZWW(T)	1 ± 0.10	2 ± 0.0	3 ± 0.15
TW	3 ± 0.15	1 ± 0.0	4 ± 0.15
Jos(D)	1 ± 0.00	3 + 0.15	4 ± 0.15
KDJ	3 ± 0.15	76 ± 0.10	79 ± 0.15
MAK 1	7 ± 0.15	198 ± 0.58	205 ± 0.10
MAK 2	97 ± 0.15	258 ± 0.15	355 ± 0.10
MAK 3	8 ± 0.15	197 ± 0.0	205 ± 0.58
MAK 4	6 ± 0.00	154 ± 0.53	160 ± 0.53
MAK 5	45 ± 0.15	472 ± 0.10	517 ± 0.53
AREWA	71 ± 0.58	168 ± 0.58	238 ± 0.58
UNTL	3 ± 0.00	316 ± 0.58	319 ± 0.58
KTLI I	3 ± 0.00	2,505 ± 0.58	2,507 ± 0.58
KTL II	7 ± 0.00	1,933 ± 0.10	1,940 ± 0.10
BRYTEX	1 ± 0.00	5 ± 0.0	6 ± 0.00
ASBESTOS	58 ± 0.15	3,368 ± 0.10	3,426 ± 0.53
SP I	317 ± 0.10	15,633 ± 0.53	15,950 ± 0.10
SP II	342 ± 0.53	16,552 ± 0.10	16,894 ± 0.58
NORTH BREW.	440 ± 0.53	202 ± 0.53	642 ± 0.58
NIG. BREW.	90 ± 0.58	46 ± 0.10	136 ± 0.58

TABLE 3.4: Results of Alkalinity Determinations

Sample	Phenolphthalein Alkalinity (mg/l $CaCO_3$)	Methyl Orange or Total Alkalinity (mg/l $CaCO_3$)
Well 1	0.00 ± 0.00	1.63 ± 0.06
" 2	0.00 ± 0.00	1.83 ± 0.06
" 3	0.00 ± 0.00	1.05 ± 0.10
" 4	0.00 ± 0.00	1.64 ± 0.01
" 5	0.00 ± 0.00	2.23 ± 0.06
" 6	0.00 ± 0.00	3.03 ± 0.06
" 7	0.00 ± 0.00	0.36 ± 0.0
" 8	0.00 ± 0.00	2.71 ± 0.01
ZWW(R)	0.00 ± 0.00	0.65 ± 0.0.01
ZWW(T)	0.19 ± 0.01	0.87 ± 0.01
TW	0.18 ± 0.01	0.87 ± 0.01
Jos(D)	0.00 ± 0.00	0.29 ± 0.01
KDJ	0.00 ± 0.00	0.88 ± 0.01
MAK 1	0.00 ± 0.00	1.54 ± 0.01
MAK 2	0.00 ± 0.00	0.64 ± 0.01
MAK 3	0.00 ± 0.00	0.63 ± 0.01
MAK 4	0.00 ± 0.00	0.63 ± 0.01
MAK 5	0.00 ± 0.00	0.0 ± 0.0
ARSWA	0.00 ± 0.00	1.61 ± 0.02
UNTL	1.10 ± 0.01	0.53 ± 0.06
KTL I	2.32 ± 0.01	29.83 ± 0.06
KTL II	1.10 ± 0.01	20.53 ± 0.01
BRYTEX	1.00 ± 0.00	0.47 ± 0.06
ASBESTOS	37.00 ± 0.05	39.03 ± 0.06
SP I	1.00 ± 0.01	0.0 ± 0.0
SP II	1.00 ± 0.00	0.0 ± 0.0
NORTH BREW	0.00 ± 0.00	2.23 ± 0.06
NIG. BREW	9.25 ± 0.05	13.23 ± 0.06

Determination of Residual Chlorine

For the exception of the Zaria Water Works treated sample (ZWW T) and the laboratory tap water sample (TW) whose values are:-

ZWW(T)	0.51 ± 0.01
TW	0.51 ± 0.01

The residual chlorine values for all the other samples analysed were below detection limit or negligible.

TABLE 3.5: Determination of Dissolved Oxygen (DO)

Sample	Dissolved Oxygen (mg/l)
Well 1	2.97 ± 0.03
" 2	3.12 ± 0.08
" 3	4.21 ± 0.04
" 4	3.25 ± 0.05
" 5	6.63 ± 0.15
" 6	4.12 ± 0.07
" 7	5.09 ± 0.10
" 8	16.95 ± 0.09
ZWW(R)	7.17 ± 0.15
ZWW(T)	7.42 ± 0.03
TW	7.54 ± 0.15
Jos(D)	6.82 ± 0.08
KDJ	29.22 ± 0.10
NAK 1	4.14 ± 0.07
NAK 2	5.38 ± 0.01
NAK 3	4.37 ± 0.01
NAK 4	5.11 ± 0.03
NAK 5	5.18 ± 0.01
AREWA	6.61 ± 0.01
UNTL	6.21 ± 0.02
KTL I	7.92 ± 0.01
KTL II	7.72 ± 0.01
BRYTEX	4.58 ± 0.02
ASBESTOS	6.31 ± 0.01
SP I	0.00
SP II	0.00
NORTH BREW	5.50 ± 0.02
NIG. BREW	5.12 ± 0.07

TABLE 3.6: Results of Determination of Biochemical Oxygen Demand, (BOD)

Sample	Biochemical Oxygen Demand (mg/l)
Well 1	5.39 ± 0.02
" 2	6.09 ± 0.04
" 3	6.89 ± 0.06
" 4	5.28 ± 0.04
" 5	8.19 ± 0.03
" 6	6.33 ± 0.02
" 7	7.21 ± 0.02
" 8	21.53 ± 0.03
ZWW(R)	10.67 ± 0.06
ZWW(T)	11.08 ± 0.08
TW	10.88 ± 0.15
Jos(D)	9.30 ± 0.05
KDJ	40.08 ± 0.09
MAK 1	6.86 ± 0.04
MAK 2	7.90 ± 0.06
MAK 3	6.95 ± 0.03
MAK 4	7.00 ± 0.02
MAK 5	7.95 ± 0.02
AREWA	8.32 ± 0.02
UNTL	8.25 ± 0.07
KTL I	10.36 ± 0.06
KTL II	10.14 ± 0.05
BRYTEX	7.11 ± 0.01
ASBESTOS	9.11 ± 0.09
SP I	0.00
SP II	0.00
NORTH BREW	7.74 ± 0.02
NIG. BREW	6.99 ± 0.02

TABLE 3.7: Results of Determination of Total Nitrogen

Sample	Total Nitrogen (mg/l)
Well 1	7.17 ± 0.01
" 2	9.85 ± 0.01
" 3	10.75 ± 0.01
" 4	7.16 ± 0.01
" 5	7.17 ± 0.01
" 6	48.55 ± 0.01
" 7	9.86 ± 0.01
" 8	7.35 ± 0.01
ZWW(R)	0.00
ZWW(T)	0.00
TW	0.00
Jos(D)	0.00
KDJ	10.52 ± 0.03
MAK 1	0.00
MAK 2	0.00
MAK 3	0.00
MAK 4	0.00
MAK 5	0.00
AREWA	0.00
UNTL	0.00
KTL I	0.00
KTL II	0.00
BRYTEX	0.00
ASBESTOS	0.00
SP I	11.25 ± 0.05
SP II	0.00
NORTH BREW	2.81 ± 0.01
NIG. BREW	0.00

TABLE 3.8: Results of Determination of Sulphate

Sample	Sulphate (mg/l)
Well 1	543 ± 0.15
" 2	544 ± 0.10
" 3	536 ± 0.00
" 4	608 ± 0.00
" 5	599 ± 0.00
" 6	635 ± 0.58
" 7	614 ± 0.58
" 8	560 ± 0.58
ZWW(R)	569 ± 0.58
ZWW(T)	729 ± 0.10
TW	740 ± 0.58
Jos (D)	571 ± 0.58
KDJ	498 ± 0.10
MAK 1	519 ± 0.58
MAK 2	603 ± 0.15
MAK 3	587 ± 0.58
MAK 4	666 ± 0.53
MAK 5	666 ± 0.58
AREWA	671 ± 0.58
UNTL	868 ± 0.10
KTL I	516 ± 0.15
KTL II	529 ± 0.58
BRYTEX	645 ± 0.10
ASBESTOS	783 ± 0.15
SP I	743 ± 0.10
SP II	731 ± 0.58
NORTH BREW	628 ± 0.15
NIG. BREW.	545 ± 0.15

TABLE 3.9: Determination of Sulphide

Sample	Sulphide as S^{2-} (mg/l)
Well 1	11 ± 0.10
" 2	41 ± 0.15
" 3	101 ± 0.10
" 4	51 ± 0.58
" 5	21 ± 0.53
" 6	91 ± 0.10
" 7	122 ± 0.53
" 8	90 ± 0.58
ZWW(R)	161 ± 0.15
ZWW (T)	239 ± 0.58
TW	248 ± 0.10
Jos (D)	221 ± 0.15
KDJ	161 ± 0.10
MAK 1	80 ± 0.58
MAK 2	119 ± 0.58
MAK 3	180 ± 0.58
MAK 4	100 ± 0.58
MAK 5	60 ± 0.53
AREWA	41 ± 0.53
UNTL	200 ± 0.53
KTL I	280 ± 0.58
KTL II	221 ± 0.58
BRYTEX	60 ± 0.58
ASBESTOS	180 ± 0.58
SP I	260 ± 0.58
SP II	140 ± 0.58
NORTH BREW	141 ± 0.53
NIG. BREW	180 ± 0.10

TAN:E TABLE 3.10: Results of Determination of Hardness

Sample	Calcium Hardness (mg/l) $CaCO_2$)	Magnesium Hardness (mg/l $CaCO_3$)	Total Hardness (mg/l $CaCO_3$)
Well 1	118 ± 0.0	61 ± 0.58	179 ± 0.58
" 2	53 ± 0.10	24 ± 0.00	77 ± 0.10
" 3	45 ± 0.10	24 ± 0.58	69 ± 0.58
" 4	52 ± 0.58	22 ± 0.10	74 ± 0.53
" 5	52 ± 0.10	34 ± 0.58	86 ± 0.53
" 6	74 ± 0.10	24 ± 0.58	98 ± 0.53
" 7	27 ± 0.15	54 ± 0.10	81 ± 0.58
" 8	80 ± 0.58	41 ± 0.10	121 ± 0.53
ZWW(R)	8 ± 0.53	27 ± 0.15	36 ± 0.58
ZWW(T)	56 ± 0.10	32 ± 0.58	88 ± 0.58
TW	32 ± 0.58	60 ± 0.10	92 ± 0.53
Jos (D)	4 ± 0.0	13 ± 0.10	17 ± 0.10
KDJ	13 ± 0.58	36 ± 0.58	49 ± 0.10
MAK 1	93 ± 0.15	16 ± 0.58	109 ± 0.53
MAK 2	135 ± 0.58	13 ± 0.10	148 ± 0.58
MAK 3	68 ± 0.58	8 ± 0.58	77 ± 0.10
MAK 4	57 ± 0.15	20 ± 0.00	77 ± 0.15
MAK 5	129 ± 0.58	52 ± 0.00	181 ± 0.58
AREWA	52 ± 0.10	964 ± 0.58	1,016 ± 0.53
UNTL	32 ± 0.0	28 ± 0.10	60 ± 0.10
KTL I	32 ± 0.58	17 ± 0.15	50 ± 0.53
KTL II	35 ± 0.10	36 ± 0.58	71 ± 0.15
BRYTEX	22 ± 0.53	32 ± 0.58	54 ± 0.53
ASBESTOS	832 ± 0.58	592 ± 0.58	1,424 ± 0.0
SP I	110 ± 0.0	27 ± 0.15	137 ± 0.15
SP II	113 ± 0.58	24 ± 0.10	137 ± 0.53
NORTH BREW	27 ± 0.10	12 ± 0.00	39 ± 0.10
NIG. BREW	21 ± 0.58	12 ± 0.10	33 ± 0.15

TABLE 3.11: Results of Determination of Sodium and Potassium by Flame Photometry

Sample	Sodium (mg/l)	Potassium (mg/l)
Well 1	410 + 0.58	525 + 0.58
" 2	215 ± 0.58	175 ± 0.58
" 3	94 ± 0.58	165 ± 0.0
" 4	158 ± 0.58	206 ± 0.58
" 5	218 ± 0.58	240 ± 0.0
" 6	151 ± 0.15	331 ± 0.15
" 7	71 ± 0.10	286 ± 0.10
" 8	110 ± 0.58	630 ± 0.58
ZWW (R)	87 ± 0.10	36 ± 0.10
ZWW(T)	25 ± 0.00	6 ± 0.10
TW	26 ± 0.00	6 ± 0.00
Jos (D)	94 ± 0.58	24 ± 0.0
KDJ	90 ± 0.00	24 ± 0.0
MAK 1	121 ± 0.10	56 ± 0.58
MAK 2	145 ± 0.58	125 ± 0.15
MAK 3	112 ± 0.58	65 ± 0.58
MAK 4	117 ± 0.58	281 ± 0.53
MAK 5	145 ± 0.15	142 ± 0.53
AREWA	18 ± 0.58	30 ± 0.58
UNTL	181 ± 0.58	13 ± 0.58
KTL I	185 ± 0.53	245 ± 0.15
KTL II	149 ± 0.58	208 ± 0.58
BRYTEX	52 ± 0.58	238 ± 0.58
ASBESTOS	420 ± 0.00	36 ± 0.10
SP I	49 ± 0.15	25 ± 0.58
SP II	38 ± 0.15	21 ± 0.53
NORTH BREW	47 ± 0.15	6 ± 0.53
NIG. BREW	153 ± 0.06	18 ± 0.58

TABLE 3.12: Determination of Sodium and Potassium by Atomic Absorption Spectrophotometry

Sample	Sodium (mg/l)	Potassium (mg/l)
Well 1	415 ± 0.15	529 ± 0.10
" 2	216 ± 0.15	179 ± 0.58
" 3	98 ± 0.58	166 ± 0.0
" 4	160 ± 0.58	208 ± 0.53
" 5	221 ± 0.10	242 ± 0.15
" 6	153 ± 0.0	335 ± 0.52
" 7	73 ± 0.58	287 ± 0.15
" 8	113 ± 0.58	632 ± 0.53
ZWW (R)	88 ± 0.15	37 ± 0.58
ZWW (T)	26 ± 0.10	8 ± 0.58
TW	27 ± 0.58	9 ± 0.0
Jos (D)	97 ± 0.53	27 ± 0.58
KDJ	90 ± 0.58	25 ± 0.10
MAK 1	124 ± 0.10	58 ± 0.58
MAK 2	147 ± 0.0	29 ± 0.58
MAK 3	114 ± 0.58	67 ± 0.0
MAK 4	122 ± 0.58	277 ± 0.0
MAK 5	148 ± 0.15	144 ± 0.0
AREWA	21 ± 0.58	32 ± 0.15
UNTL	183 ± 0.10	15 ± 0.15
KTL I	189 ± 0.58	248 ± 0.15
KTL II	151 ± 0.52	212 ± 0.58
BRYTIX	55 ± 0.53	241 ± 0.58
ASBESTOS	423 ± 0.53	39 ± 0.58
SP I	53 ± 0.53	27 ± 0.53
SP II	40 ± 0.58	25 ± 0.52
NORTH BREW	50 ± 0.10	7 ± 0.0
NIG. BREW	151 ± 0.581	19 ± 0.58

TABLE 3.13: Determination of Calcium by Flame Photometry and Atomic Absorption Spectrophotometry

Sample	Calcium (mg/l) by Flame	Calcium (mg/l) by AAS
Well 1	119 ± 0.58	121 ± 0.15
" 2	56 ± 0.10	58 ± 0.58
" 3	48 ± 0.58	50 ± 0.58
" 4	53 ± 0.58	55 ± 0.15
" 5	54 ± 0.53	53 ± 0.10
" 6	77 ± 0.10	80 ± 0.58
" 7	29 ± 0.58	31 ± 0.58
" 8	84 ± 0.0	85 ± 0.58
ZWW (R)	14 ± 0.58	16 ± 0.53
ZWW (T)	57 ± 0.58	58 ± 0.53
TW	36 ± 0.0	37 ± 0.15
Jos (D)	6 ± 0.0	9 ± 0.15
KDJ	14 ± 0.58	17 ± 0.58
MAK 1	96 ± 0.58	97 ± 0.58
MAK 2	137 ± 0.10	137 ± 0.58
MAK 3	70 ± 0.58	70 ± 0.15
MAK 4	58 ± 0.58	59 ± 0.15
MAK 5	132 ± 0.0	133 ± 0.10
AREWA	56 ± 0.10	57 ± 0.0
UNTL	36 ± 0.58	36 ± 0.58
KTL I	33 ± 0.58	34 ± 0.10
KTL II	38 ± 0.0	37 ± 0.58
BRYTEX	24 ± 0.0	27 ± 0.10
ASBESTOS	837 ± 0.10	837 ± 0.58
SP I	114 ± 0.0	117 ± 0.58
SP II	113 ± 0.58	115 ± 0.53
NORTH BREW	30 ± 0.10	31 ± 0.0
NIG. BREW	24 ± 0.10	25 ± 0.58

TABLE 3.14: Determination of Magnesium and Zinc by Atomic Absorption Spectrophotometry.

Sample	Magnosium (mg/l)	Zinc (mg/l)
Well 1	64 ± 0.15	179 ± 0.53
" 2	27 ± 0.0	172 ± 0.15
" 3	25 ± 0.58	126 ± 0.58
" 4	24 ± 0.15	62 ± 0.15
" 5	35 ± 0.58	99 ± 0.58
" 6	27 ± 0.58	81 ± 0.15
" 7	56 ± 0.58	111 ± 0.58
" 8	43 ± 0.58	85 ± 0.58
ZWW (R)	31 ± 0.58	180 ± 0.15
ZWW (T)	35 ± 0.53	260 ± 0.58
TW	62 ± 0.52	179 ± 0.53
Jos (D)	16 ± 0.15	145 ± 0.52
KDJ	38 ± 0.58	209 ± 0.58
MAK 1	19 ± 0.58	111 ± 0.53
MAK 2	16 ± 0.15	142 ± 0.53
MAK 3	10 ± 0.58	142 ± 0.0
MAK 4	24 ± 0.15	81 ± 0.53
MAK 5	54 ± 0.15	631 ± 0.53
AREWA	962 ± 0.06	120 ± 0.58
UNTL	31 ± 0.53	150 ± 0.58
KTL I	20 ± 0.58	121 ± 0.53
KTL II	38 ± 0.15	100 ± 0.58
BRYTEX	35 ± 0.15	112 ± 0.58
ASBESTOS	596 ± 0.15	172 ± 0,53
SP I	29 ± 0.58	171 ± 0.15
SP II	25 ± 0.53	154 ± 0.15
NORTH BREW	13 ± 0.58	20 ± 0.58
NIG. BREW	13 ± 0.15	36 ± 0.15

TABLE 3.15: Determination of Copper and Iron by Atomic Absorption Spectrophotometry

Sample	Copper (mg/l)	Iron (mg/l)
Well 1	0.00	200 ± 0.58
" 2	0.00	86 ± 0.58
" 3	0.00	10 ± 0.58
" 4	0.00	10 ± 0.00
" 5	0.00	9 ± 0.10
" 6	0.00	10 ± 0.0
" 7	0.00	11 ± 0.15
" 8	0.00	11 ± 0.58
ZWW(R)	0.00	38 ± 0.58
ZWW(T)	0.00	10 ± 0.0
TW	0.00	10 ± 0.0
Jos (D)	0.00	21 ± 0.58
KDJ	0.00	10 ± 0.0
MAK 1	0.00	11 ± 0.15
MAK 2	2 + 0.15	47 ± 0.58
MAK 3	0.00	27 ± 0.15
MAK 4	0.00	11 ± 0.58
MAK 5	59 + 0.58	521 ± 0.58
AREWA	10 ± 0.0	10 ± 0.0
UNTL	2 ± 0.0	28 ± 0.15
KTL I	0.00	11 ± 0.58
KTL II	0.00	10 ± 0.0
BRYTEX	0.00	21 ± 0.15
ASBESTOS	0.00	11 ± 0.15
SP I	4 + 0.10	104 ± 0.15
SP II	6 ± 0.15	123 ± 0.15
NORTH BREW	2 ± 0.0	28 ± 0.58
NIG. BREW	2 ± 0.0	21 ± 0.58

TABLE 3.16: Results of Determination of Lead by Atomic Absorption Spectrophotometry

Sample	Lead (mg/l)
Well 1	31 ± 0.58
" 2	40 ± 0.0
" 3	22 ± 0.15
" 4	31 ± 0.58
" 5	30 ± 0.0
" 6	42 ± 0.0
" 7	11 ± 0.15
" 8	10 ± 0.0
ZWW (R)	19 ± 0.58
ZWW (T)	20 ± 0.0
TW	20 ± 0.58
JOS (D)	21 ± 0.58
KDJ	9 ± 0.58
MAK 1	22 ± 0.58
MAK 2	20 ± 0.0
MAK 3	11 ± 0.0
MAK 4	21 ± 0.58
MAK 5	161 ± 0.58
AREWA	8 ± 0.58
UNTL	31 ± 0.58
KTL I	11 ± 0.15
KTL II	10 ± 0.0
BRYTEX	20 ± 0.58
ASBESTOS	8 ± 0.58
SP I	6 ± 0.0
SP II	6 ± 0.0
NORTH BREW	12 ± 0.58
NIG. BREW	30 ± 0.0

TABLE 4.17: Results of Determination of Effects of Coagulating agents on water

(i) For 1% (m/V) Coagulant ($Al_2(SO_4)_3$)

Sample	Total Solids (mg/l)	Suspended Solids (mg/l)	Dissolved Solids (mg/l)
Well 1	24.8 ± 0.15	0.8 ± 0.0	24.0 ± 0.15
" 2	23.1 ± 0.10	1.0 ± 0.0	22.1 ± 0.10
" 3	21.4 ± 0.15	1.3 ± 0.0	20.1 ± 0.15
" 4	22.1 ± 0.10	0.8 ± 0.10	21.3 ± 0.06
" 5	20.2 ± 0.10	1.2 ± 0.10	19.0 ± 0.10
" 6	19.7 ± 0.10	1.4 ± 0.06	18.3 ± 0.15
" 7	21.7 ± 0.15	0.5 ± 0.06	21.2 ± 0.06
" 8	20.5 ± 0.10	1.0 ± 0.06	19.5 ± 0.15
KDJ	19.6 ± 0.06	1.3 ± 0.10	18.3 ± 0.06
ZWW (R)	19.1 ± 0.12	1.1 ± 0.0	18.0 ± 0.12
Jos (D)	19.7 ± 0.06	1.0 ± 0.0	18.7 ± 0.06

(ii) For 2% (m/V) Coagulant ($Al_2(SO_4)_3$)

Sample	Total Solids (mg/l)	Suspended Solids (mg/l)	Dissolved Solids (mg/l)
Well 1	24.8 ± 0.06	0.7 ± 0.06	24.1 ± 0.0
" 2	21.7 ± 0.10	0.8 ± 0.0	20.9 ± 0.10
" 3	20.8 ± 0.06	1.2 ± 0.06	19.6 ± 0.10
" 4	24.3 ± 0.06	0.7 ± 0.12	23.5 ± 0.15
" 5	33.6 ± 0.15	1.2 ± 0.0	32.4 ± 0.15
" 6	33.3 ± 0.10	1.2 ± 0.0	32.1 ± 0.10
" 7	18.0 ± 0.06	0.2 ± 0.0	17.8 ± 0.06
" 8	33.1 ± 0.10	1.0 ± 0.0	32.1 ± 0.10
KDJ	27.5 ± 0.10	0.8 ± 0.0	26.7 ± 0.10
ZWW (R)	19.3 ± 0.15	1.3 ± 0.10	18.0 ± 0.06
Jos (D)	18.5 ± 0.15	0.8 ± 0.12	17.7 ± 0.15

(iii) For 5% (m/v) Coagulant ($Al_2(SO_4)_3$)

Sample	Total solids (mg/l)	Suspended solids (mg/l)	Dissolved solids (mg/l)
Well 1	51.0 ± 0.15	0.5 ± 0.06	50.5 ± 0.10
" 2	50.0 ± 0.06	0.5 ± 0.0	49.8 ± 0.06
" 3	49.8 ± 0.06	0.8 ± 0.06	49.1 ± 0.12
" 4	51.4 ± 0.10	0.3 ± 0.10	15.1 ± 0.10
" 5	87.4 ± 0.06	0.4 ± 0.10	87.0 ± 0.10
" 6	86.9 ± 0.10	0.7 ± 0.06	86.2 ± 0.06
" 7	46.5 ± 0.10	0.2 ± 0.06	46.3 ± 0.05
" 8	88.1 ± 0.10	0.8 ± 0.0	87.3 ± 0.10
KDJ	86.4 ± 0.15	0.4 ± 0.06	86.1 ± 0.06
ZWW(R)	47.7 ± 0.06	0.5 ± 0.0	47.2 ± 0.06
Jos (D)	45.9 ± 0.0	0.6 ± 0.0	45.3 ± 0.0

(iv) For 10% (m/v) Coagulant ($Al_2(SO_4)_3$)

Sample	Total solids (mg/l)	Suspended solids (mg/l)	Dissolved solids (mg/l)
Well 1	96.8 ± 0.06	0.4 ± 0.06	96.5 ± 0.06
" 2	94.8 ± 0.10	0.2 ± 0.0	94.6 ± 0.10
" 3	95.6 ± 0.0	0.6 ± 0.0	95.0 ± 0.0
" 4	96.0 ± 0.06	0.1 ± 0.06	96.0 ± 0.12
" 5	188.4 ± 0.07	0.2 ± 0.0	188.2 ± 0.07
" 6	176.2 ± 0.15	0.5 ± 0.0	175.8 ± 0.15
" 7	98.0 ± 0.06	0.1 ± 0.0	97.9 ± 0.06
" 8	177.0 ± 0.0	0.5 ± 0.06	176.5 ± 0.06
KDJ	184.2 ± 0.07	0.2 ± 0.0	184.0 ± 0.07
ZWW(R)	95.5 ± 0.10	0.3 ± 0.0	95.2 ± 0.10
Jos (D)	96.2 ± 0.10	0.3 ± 0.0	95.9 ± 0.10

(v) For 15% (m/N) Coagulant ($Al_2(SO_4)_3$)

Sample	Total solids (mg/l)	Suspended solids (mg/l)	Dissolved solids (mg/l)
Well 1	118.6 ± 0.12	0.2 ± 0.0	118.4 ± 0.12
" 2	140.1 ± 0.15	0.1 ± 0.0	140.0 ± 0.15
" 3	136.7 ± 0.12	0.3 ± 0.06	136.3 ± 0.06
" 4	138.6 ± 0.0	0.1 ± 0.0	138.5 ± 0.0
" 5	273.1 ± 0.12	0.1 ± 0.0	273.0 ± 0.12
" 6	272.0 ± 0.0	0.2 ± 0.0	271.8 ± 0.0
" 7	144.2 ± 0.12	0.0	144.2 ± 0.12
" 8	266.7 ± 0.06	0.3 ± 0.0	266.4 ± 0.06
KDJ	273.3 ± 0.15	0.1 ± 0.0	273.2 ± 0.12
ZWW(R)	142.6 ± 0.10	0.1 ± 0.0	142.5 ± 0.10
Jos(D)	142.4 ± 0.0	0.1 ± 0.0	142.3 ± 0.0

(vi) For 20% (m/N) Coagulant ($Al_2(SO_4)_3$)

Sample	Total solids (mg/l)	Suspended solids (mg/l)	Dissolved solids (mg/l)
Well 1	192.1 ± 0.06	0.0	192.1 ± 0.06
" 2	402.9 ± 0.0	0.0	402.9 ± 0.0
" 3	190.2 ± 0.12	0.2 ± 0.0	190.0 ± 0.12
" 4	191.0 ± 0.0	0.0	191.0 ± 0.0
" 5	378.6 ± 0.06	0.0	378.6 ± 0.06
" 6	374.3 ± 0.10	0.1 ± 0.0	374.2 ± 0.10
" 7	201.0 ± 0.06	0.0	201.0 ± 0.06
" 8	118.2 ± 0.0	0.1 ± 0.0	118.1 ± 0.0
KDJ	377.3 ± 0.15	0.0	377.3 ± 0.15
ZWW(R)	196.9 ± 0.0	0.0	196.9 ± 0.0
Jos (D)	196.1 ± 0.10	0.1 ± 0.0	196.0 ± 0.10

C H A P T E R IV

DISCUSSION AND CONCLUSION

The results of this study could be more appropriately discussed in terms of:

(a) How the various water samples analyzed compare with one another, and how they measure up to stipulated quality standards for potability and industrial usage.

The quality standards stipulated by the World Health Organization[28] are given in table 4.1.

(b) How the quality of effluent waste waters compare with that of well, or dam water supplies studied, with emphasis on the chemical stresses various industries impose on our urban water supplies.

TABLE 4.1: Acceptable water quality standards.[28]

Substances or Parameter	Highest Desirable level	Maximum Permissible
pH	7.0 - 8.5	6.5 - 9.2
Total Hardness ($CaCO_3$)	100 (mg/l)	500 (mg/l)
Calcium	75 "	200 "
Chloride	200 "	600 "
Copper	0.05 "	0.05 "
Iron	0.1 "	1.0 "
Magnesium	30 "	150 "
Sulphate (SO_4^{2-}	200 "	400 "
Zinc	5 "	15 "
Lead	0.1 "	0.1 "

Source: Deirdre, K. G. and Borne, B. J., Textile Wastewaters; Treatment and Environmental Effects, J. Chem. Ed. August, 1978. pp. 344

4.1 pH VALUES

In respect of pH, it is interesting to note that all but one, (well 7), of the wells have pH values within the maximum permissible range, and that two of them (wells 1 and 4) have values within the highest desirable level. By the criterion of acidity, the wells sampled are acceptable sources for human consumption.

The raw supply to the Zaria water works (ZWW R) has a pH 6.4 which is slightly lower than the acceptable range. The treated

water is, of course, well within the highest desirable level. This also applies to the stream sample (KDJ) from Kaduna.

Table 4.1 shows that most effluents have pH values that are well beyond the acceptable limits. Those on the high pH side are the samples from the Asbestos and the Nigerian Breweries, whereas SP I, SP II and MAK 5 produce effluents of unacceptably high acidity.

4.2 SUSPENDED AND DISSOLVED SOLIDS

As might be expected, suspended solids are relatively high in all the well samples and in some of the industrial effluents such as SP I, SP II and North Brewery. It is remarkable that the level of suspended solids in the North Brewery effluents is so appreciably different from that of Nigerian Breweries. This might be due to the fact that the Nigerian Breweries' effluent is adequately treated before being discharged into the surrounding environment while that of the North Brewery does not receive any meaningful treatment, safe for the recovery of any desirable constituent, before being discharged into the nearby water course; and thus a source of pollution.

The results are even more dispersed when dissolved solids are considered. As a reflection, perhaps, of the nature of soil at the well locations, total quantities of dissolved solids in the

various well samples are relatively small when compared with some of the industrial effluents. SP I and SP II seem to have high dissolved solid contents, KTL I, KTL II and the Asbestos companies also dispose a lot of dissolved solids with their effluents. An effort should be made to treat these effluents to bring them to acceptable ranges, although this will require a detailed knowledge of the exact nature of the suspended and dissolved solids.

4.3 ALKALINITY

As might be expected, the alkalinity results reflect those obtained from pH measurements; and the conclusions from that section of the Discussion are also applicable to this one.

However, it may be noted in passing that the high acidity of effluent samples from SP I and SP II is due to the production of concentrated sulphuric acid in that company, leading to the necessity of complete neutralization of the effluent before being discharged into the nearby water course With the Asbestos effluent, the low acidity can be said to be due to the production of calcium and other hydroxides during the process of cement production in the company.

4.4 RESIDUAL CHLORINE

The results show that only ZWW(T) and TW have any residual chlorine in them, although the values are surprisingly low when

viewed against the levels recommended by the World Health Organization, because the chlorine content of an aqueous solution is not stable and decreases rapidly.

It can also be seen that none of the effluents shows any residual chlorine even though the industries utilize treated water for their various production processes. This suggests that, either through heating, exposure or chemical reactions, all the residual chlorine in the intake water has been driven off or used up; and that, being devoid of chlorine, the effluents might present additional health hazards as a source of mineral-rich, non-sterile water for microbial growth.

4.5 DISSOLVED OXYGEN

The level of dissolved oxygen lies within a relatively narrow range and its accurate knowledge is essential in the biological, chemical and sanitary investigations of water as it is one of the most important indicators of the condition of a water supply. However, from the table of result, it is generally lower for the well samples than for the others, most probably due to negligible plant growth but significant population of microorganisms; and absolutely absent for SP I and SP II which is possibly due to absolute lack of plant growth. Dissolved oxygen in well 8 is much more than twice the amount of any of the other wells.

This might be due to the fact that this well is extensively used and thus leading to frequent aeration of the water by users through continuous agitation. KDJ has the highest content of dissolved oxygen which is obviously due to significant plant growth around the source, it being a stream sample.

4.6 BIOCHEMICAL OXYGEN DEMAND

The values for the biochemical oxygen demand for the various samples very closely reflect those for dissolved oxygen. Indeed, the correlation coefficient for the two sets of values is very high (0.9897). The SP I and SP II samples show zero values for biochemical oxygen demand as with the values for dissolved oxygen. Once again, KDJ and well 8 show the highest values.

4.7 TOTAL NITROGEN

The amount of total nitrogen[29] present in a body of water might be a reflection of the amount of organic matter in the sample. It is perhaps, not surprising, therefore, that all the wells contain relatively large amounts of total nitrogen; although well 6 seems to have about five times (48.55) the amount found in any of the other wells. This might be due to the fact that this particular well is rather fairly polluted by domestic sewage.

The 'amount of the total nitrogen in KDJ is very high which is possibly due to its exposure to decayed plant and animal matter.

Unlike SP II, SP I has a high total nitrogen content. In view of the fact that the other results for these two samples are very similar it might be worthwhile to carry out further investigations to determine the cause of the wide difference in the total nitrogen contents. It should be noted that the total nitrogen in both KDJ and SP I exceed the stipulated upper limit of 10mg l^{-1} for good drinking water.[30]

4.8 SULPHATE

As has been stated earlier, good drinking water should contain no more than 250mg l^{-1} of sulphate because of the cathartic[31] effect which the ion exerts on the human body in the presence of sodium and magnesium ions. By this criterion, all the samples contain, unacceptably high levels of sulphate. Not even the various treated supplies come anywhere near the acceptable limits. These results suggest that treatment works should include processes aimed at reducing the levels of sulphate in domestic water supplies.

4.9 SULPHIDE

Since one important source of sulphide is the biological reduction of sulphate, it might have been expected that relatively close values of sulphate content among the various samples would lead to comparatively little variation in their sulphide content. The results seem however to contradict this expectation.

The levels of sulphide are unexpectedly high in the treated water samples, ZWW(T) and TW; also Jos(D) and KDJ. Surprisingly the sulphide levels of most of the wells are very low although, from the smells of some of the well samples, (wells 5 and 6), much higher levels may have been expected. One wonders, therefore, if the soluble sulphide present has been converted into gaseous hydrogen sulphide which continuously escapes from the main body of the water.

4.10 HARDNESS

In general, the various water samples show comparable extent of hardness; but there are some remarkable examptions. The untreated dam sample at Zaria water works (ZWW R) is considerably less in calcium hardness than the various well samples. But the magnesium hardness of the two samples are comparable. The treatment of the water seems to increase its calcium ion hardness seven fold while it has little effect on its magnesium ion hardness; although

it might be useful to point out that some calcium hydroxide ($Ca(OH)_2$) is added to the water during treatment to give a desirable pH for drinking water.

Compared to the other samples, Jos (D) is exceptionally low in total as well as calcium hardness.

Two particular industries discharge effluents with very high total hardness values. One is the Arewa Textiles, which, while having little effect on calcium hardness, greatly increases the magnesium hardness, and, therefore, the total hardness of water. The other industry, the Asbestos company creates a drastic increase in both the calcium and the magnesium hardness. In respect of hardness, therefore, these two industries would be excellent candidates for legally - imposed waste treatment measures, for producing effluents of much higher hardness values (1000 mg l^{-1}) than the recommended value[32] of about 150 mg l^{-1}.

4.11 METAL IONS

The determination of sodium, potassium and calcium ions by both flame photometry and atomic absorption spectroscopy show a remarkable degree of agreement.

The level of sodium are generally higher than those of potassium. However, there are some reversals particularly with Mak 4, KTL I and Brytex. The levels of these two ions are quite high in the

well samples compared to those in the surface and chemically treated water samples. Wells 1 and 8 deserve particular attention, especially in respect of users who may have the need to go on a diet of low sodium ion concentration. The effluents from UNTL, KTL I, KTL II, Brytex, Asbestos and Nigerian Breweries are very rich in one or both of these metals.

The magnesium ion concentrations in most of the water samples are within the descrable limits. Apart from Arewa and Asbestos, the others are within tolerable limits. These two industries introduce large amounts of magnesium ions into their effluents.

The zinc ion concentrations in all the samples are beyond tolerable limits. Ironically, the values for treated water are even greater than those for well waters. Considering possible health hazards that might result from these large concentrations, it might be worthwhile to introduce treatment measures that would reduce the concentration of this ion in water for human consumption.

It is interesting to note that the breweries' effluents contain considerably lower concentrations of zinc ions than do the treated waters. This might suggest that the production processes in these breweries lead to a reduction in the concentration of zinc. It would be worthwhile to determine whether the reduced concentrations of zinc in the breweries effluents is due to increased concentrations of zinc in the breweries product.

Most samples contain no detectable concentrations of copper The important exceptions are SP I, SP II, Arewa, and, especially MAK 5. MAK 5 contains a surprisingly large amount of copper ions. There would seem to be an urgent need for the installation of treatment works, by this company, that will drastically cut down on this ion.

As with zinc, all the samples have higher than tolerable limits of concentration of iron ions. Compared to the others, wells 1 and 2 have particularly high values. There seems to be no immediately obvious reason for this difference. Among the effluent samples, MAK 5 has a notably high iron ion concentrations.

The results for lead also deserve some attention. Every sample contains much higher values than the tolerable limits. Once again, MAK 5 tops the list of the bad offenders. If account is taken of the fact that lead poisoning tends to be cummulative, then there is real cause for concern that even the treated water contains up to 200 times the maximum acceptable limits of this ion.

4.12 COAGULATION STUDIES

The studies were undertaken in order to examine the relationship between the concentration of coagulants used and their efficiency in the removal of suspended solids from the water samples.

It is clear from the results given in tables 3.17 (I-VI) that the use of coagulant considerably suppresses the amount of suspended solids.

The comparison of the results in tables 3.3 and 3.17 (I-VI) shows that the lowest concentration of coagulant used (1% (m/V)) was as effective as the highest concentration of 20% (m/V). In other words, for economical purposes, there seems to be no need for the use of coagulant concentrations higher than 1% m/V).

It is evident from the results shown in tables 3.17 (I-VI) that the amounts of dissolved solids increase with increased coagulant concentration. This is due to the increasing concentration of the dissolved coagulant.

SUGGESTIONS

1. The Local Government Health Centres should put warning signs (such as "Only for Washing," etc.,) near the wells indicating the appropriate use of well water. This also means that alternative source of potable water for domestic uses should be provided by the Government, especially where the well water samples are not fit for drinking purposes.

2. As regards the treated waters it is advisable that a frequent and thoroughly routine tests should be carried out at the treatment works. This calls for closer supervision by the

Ministries of Health in order to control health hazards.

3. The various industrial effluents are sources of gross chemical pollution to our environment. With increasing industrialization, the Government should enact laws for industrial effluent treatment before their disposal. Preferably, the industrial wastes should be treated, if possible, at a Local Government central sewage works, where adequate facilities and expert supervision should be made available; rather than having a number of small and inefficient treatment plants.

REFERENCES

1. Valkovic, C., Trace Element Analysis, Taylor and Francis Ltd., London, 1975, pp.50.

2. Encyclopadia Britanica, 15th Edition, Micropaedia Volume IX, 1975, pp. 392.

3. Ember, L. R., Uncertain Science, Pushes Love Canal Solutions to Political, Legal Arenas, Chem. and Eng. News, Aug. 11, 1980, pp. 22-29.

4. Dagani, R., Aquatic Toxicology, Chem. and Eng. News, June, 30, 1980, pp. 18-23.

5. Ember, L. R., Acid Rain Focus of International Cooperation, Chem. and Eng. News, Dec. 3, 1979, pp. 15-17.

6. Hand-book of Treatment Process of Drinking water by Zaria Water Works, Zaria, 1980.

7. McGuiness, W. J., and Stein, B., Building Technology: Mechanical and Electrical Systems, John Wiley and Sons, New York, 1977, pp. 195.

8. U. S. Environmental Protection Agency, Manual of Methods for Chemical Analysis of Water and Wastes, 1974, pp. VI.

9. Vogel, A. I., Textbook of Quantitative Inorganic Analysis, 3rd Edition, The English Language Book Society and Longman, 1961, pp. 235.

10. American Water Works Association, Standard Methods for the Examination of Water and Wastewater, 14th Edition, 1976, pp. 317.

11. Hanson, N. W., Official, Standardized and Recommended Methods of Analysis, 2nd Edition, Heffers Printers Ltd., Cambridge, 1973, pp. 366.

12. American Water Works Association, Standard Methods for the Examination of Water and Wastewater, 14th Edition, 1976, pp. 205.

13. Instruction Booklet on Type Mc 3, EIL Portable conductivity Bridge, Electronic Switchgear Ltd., 1972.

14. Golterman, H. L., Chemical Analysis of Fresh Waters, Blackwell Scientific Publications, Oxford and Edinburgh, 1969, pp.25.

15. American Water Works Association, Standard Methods for the Examination of Water and Wastewaters, 14th Edition, 1976, pp. 403.

16. Golterman, H. L., Chemical Analysis of Fresh Waters, Blackwell Scientific Publications, Oxford and Edinburgh, 1969, pp.27.

17. American Water Works Association, Standard Methods for the Examination of Water and Wastewaters, 14th Edition, 1976, pp. 316.

18. Aransiola, Y., M.Sc. Thesis, Ahmadu Bello University, Zaria, 1977, pp. 31.

19. American Water Works Association, Standard Methods for the Examination of Water and Wastewaters, 14th Edition, 1976, pp. 546.

20. American Water Works Association, Standard Methods for the Examination of Water and Wastewaters, 14th Edition, 1976, pp. 437.

21. Rahman, M. M., M.Sc. Handout on Proximate Analysis, Department of Biochemistry, Ahmadu Bello University, Zaria, 1980.

22. The Society for Analytical Chemistry, Official Standardized and Recommended Methods of Analysis, 2nd Edition, Heffers Printers Ltd., Cambridge, 973, pp. 460.

23. American Water Works Association, Standard Methods for the Examination of Water and Wastewaters, 14th Edition, 1976, pp. 202.

24. Singh, K., Classical Analysis for M.Sc. Analytical Chemistry Students, Ahmadu Bello University, Zaria, 1980.

25. Allen, S. E., Grimshaw, H. M., Parkinson, J. A., and Quarmby, C., Chemical Analysis of Ecological Materials, Blackwell Scientific Publications, Oxford, London, 1974, pp. 384.

26. American Water Works Association, Water Quality and Treatment, 10th Edition, 1971, pp. 79.27

27. Kovac, T. W., Chemistry of Water Supply Treatment and Distribution, Ann Arbor Science Publishers inc. Michigan, 1974, pp. 160.

28. Deirdre, K. G., and Borne, B. J., J. Chemical Education, Textile Waste waters: Treatment Environmental Effects, August, 1978, pp. 344.

29. American Water Works Association, Standard Methods for the Examination of water, Sewage and Industrial wastes, 3rd Edition, 1955, pp. 149.

30. American Water Works Association, Water Quality and Treatment, 10th Edition, 1971, pp. 155.

31. Andelman, J. B., Chemistry of Water Supply Treatment and Distribution, Ann Arbor Science Publishers inc. Michigan, 1974, pp. 423.

32. Tebutt, T. H. Y., Water Pollution Control in United Kingdom, A Seminar at Civil Engineering Department, 16th Jan., 1981.

FIG. 1: SODIUM CALIBRATION CURVE BY FLAME EMISSION

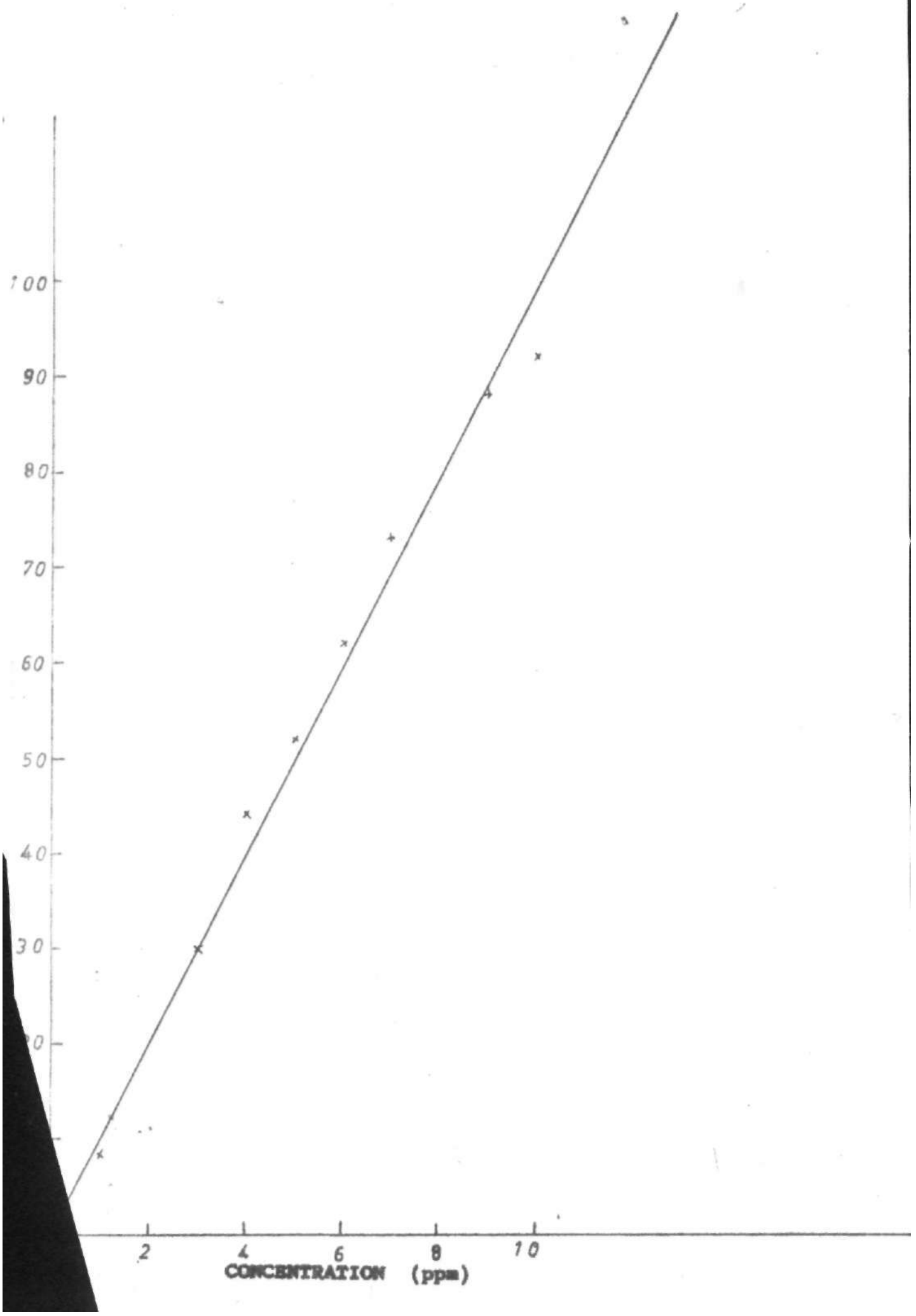


FIG. 2. POTASIUM CALIBRATION CURVE BY FLAME EMISSION

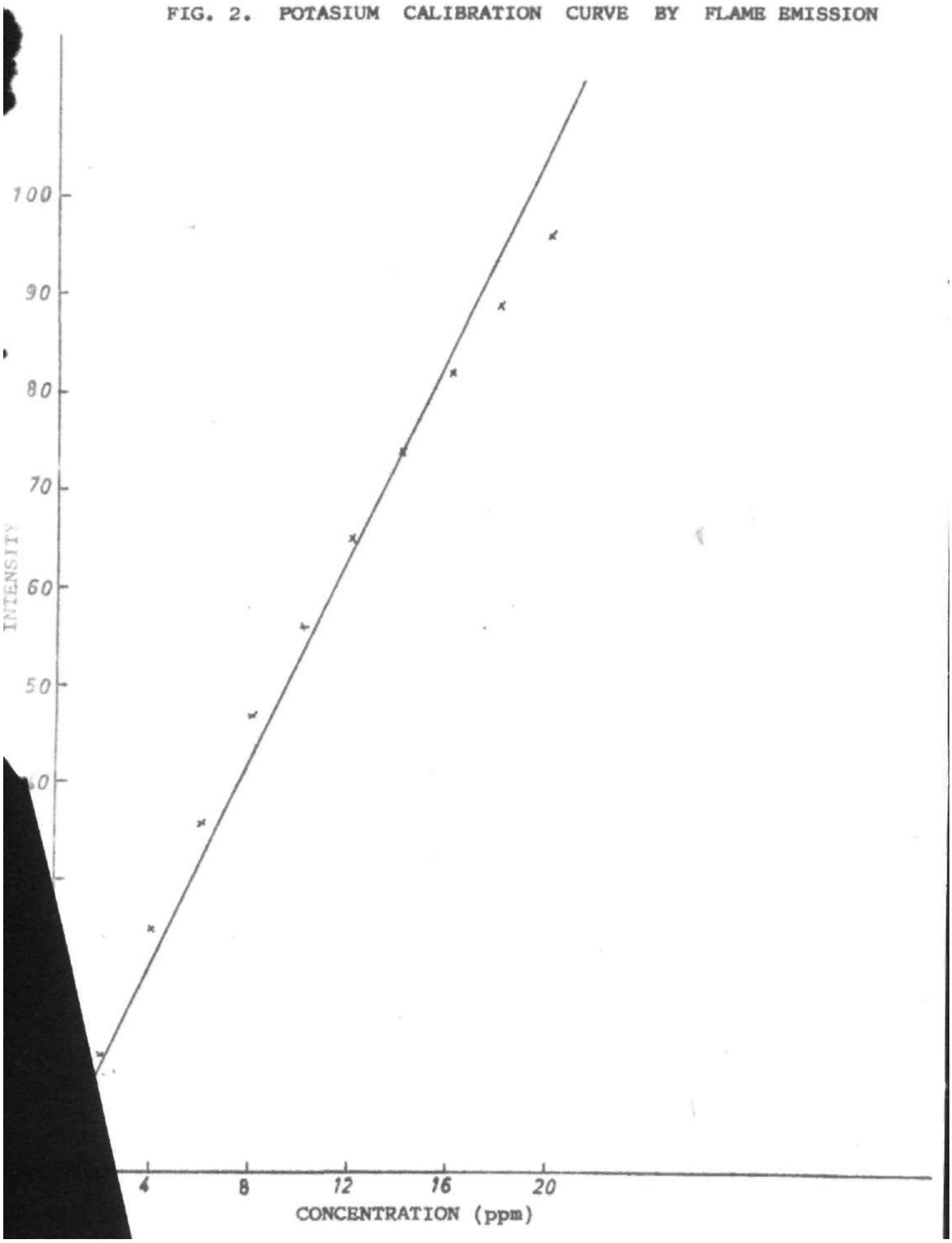


Fig. 3. Calcium Calibration Curve by Flame Emission

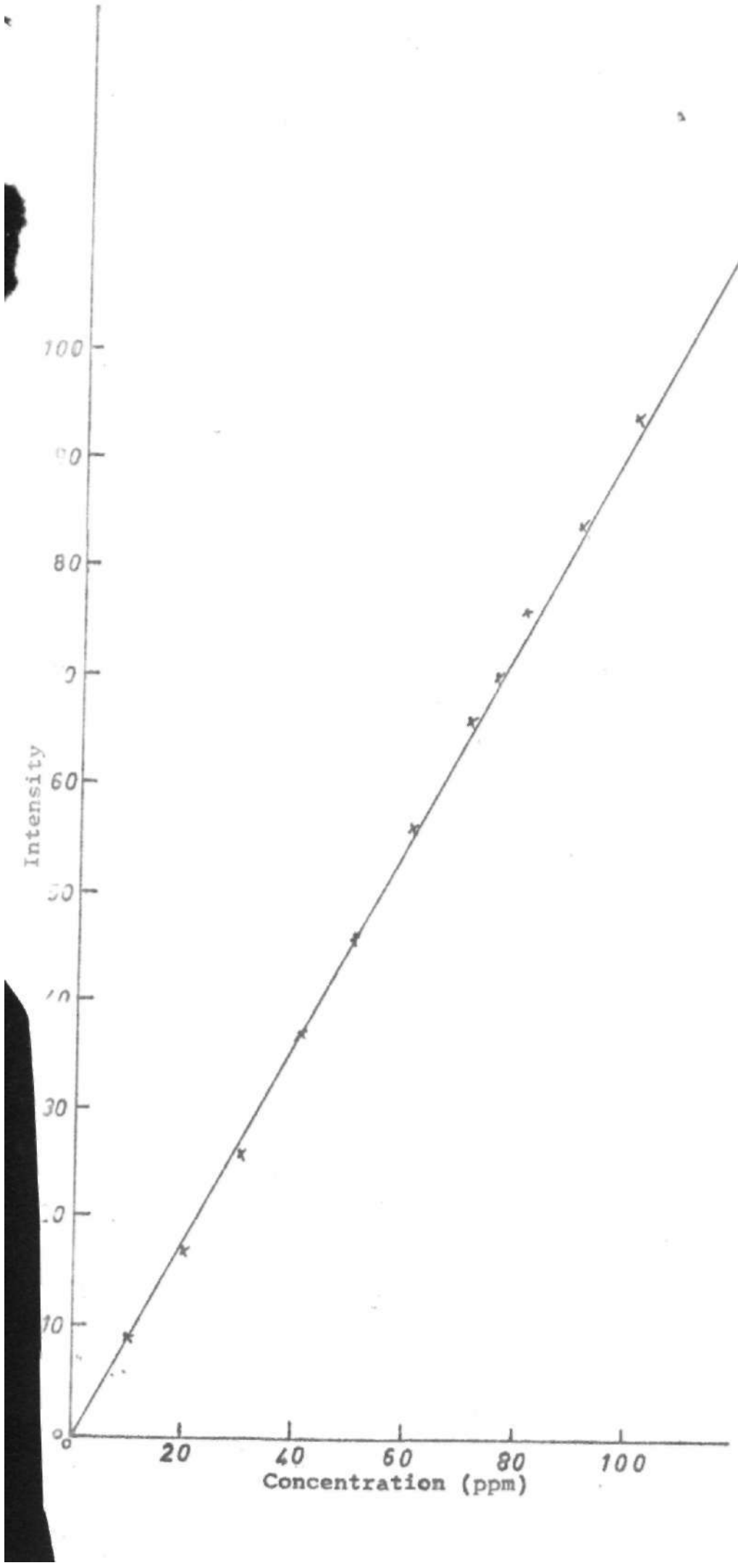


FIG. 4: SODIUM CALIBRATION CURVE BY ATOMIC ABSORPTION SPECTROSCOPY

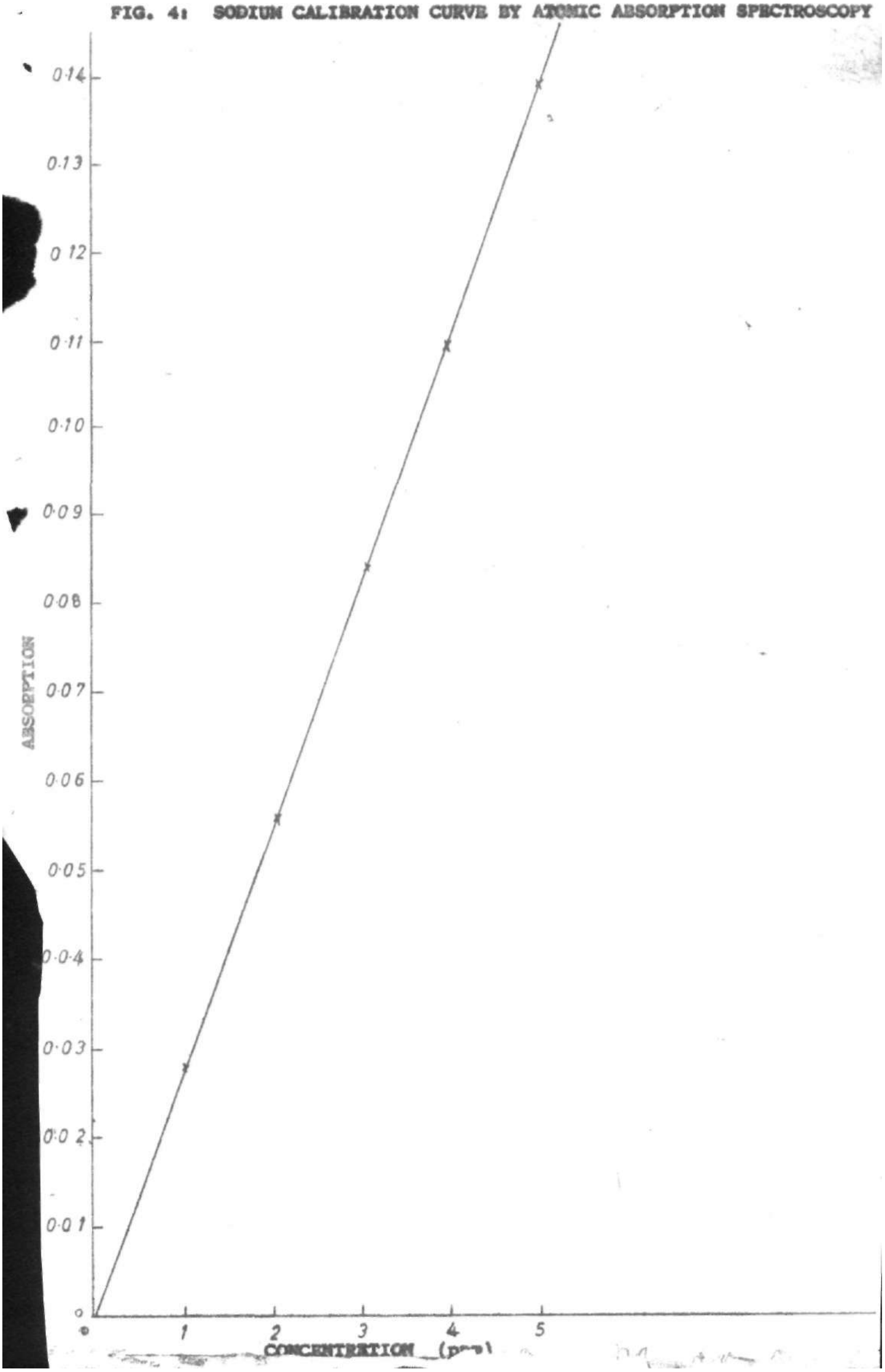


FIG. 5. POTASSIUM CALIBRATION CURVE BY A.A.S.

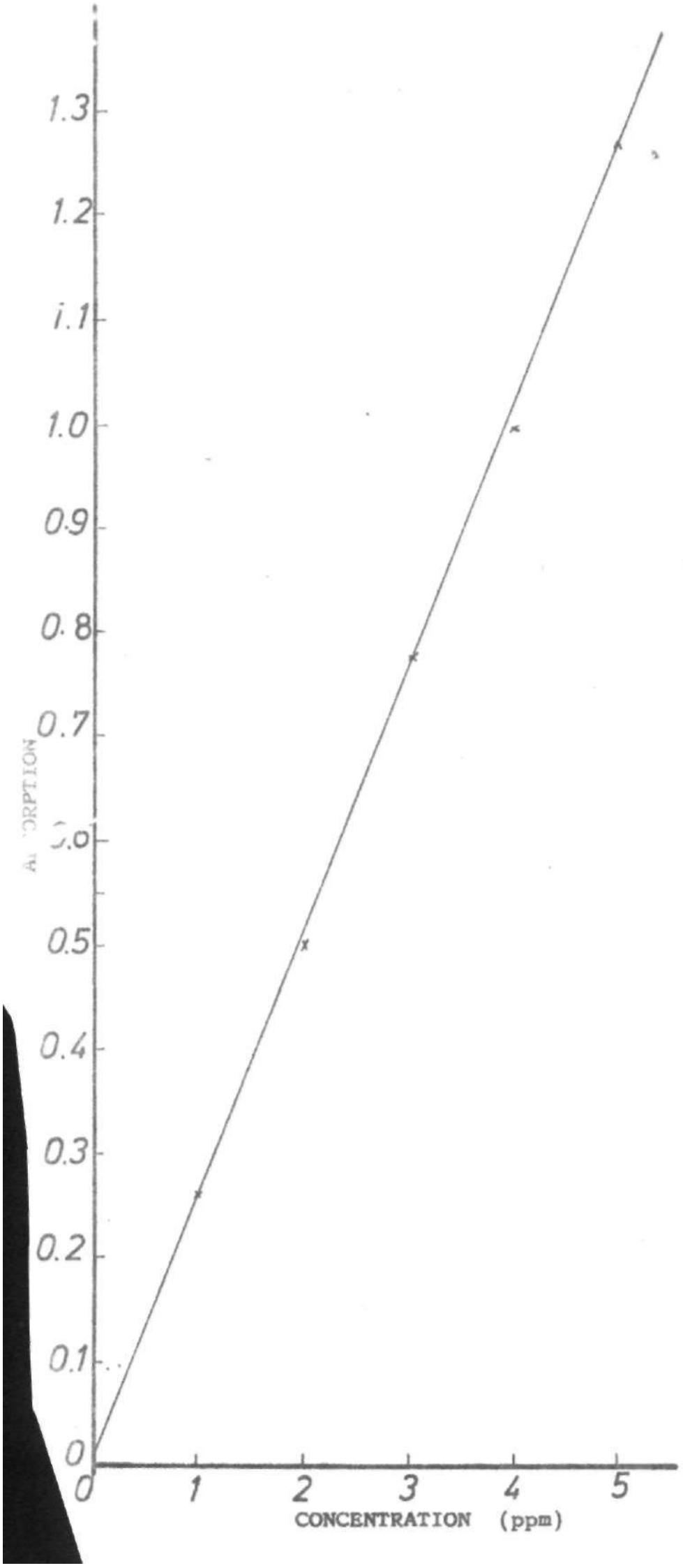


FIG 6 : CALCIUM CALIBRATION CURVE BY AAS

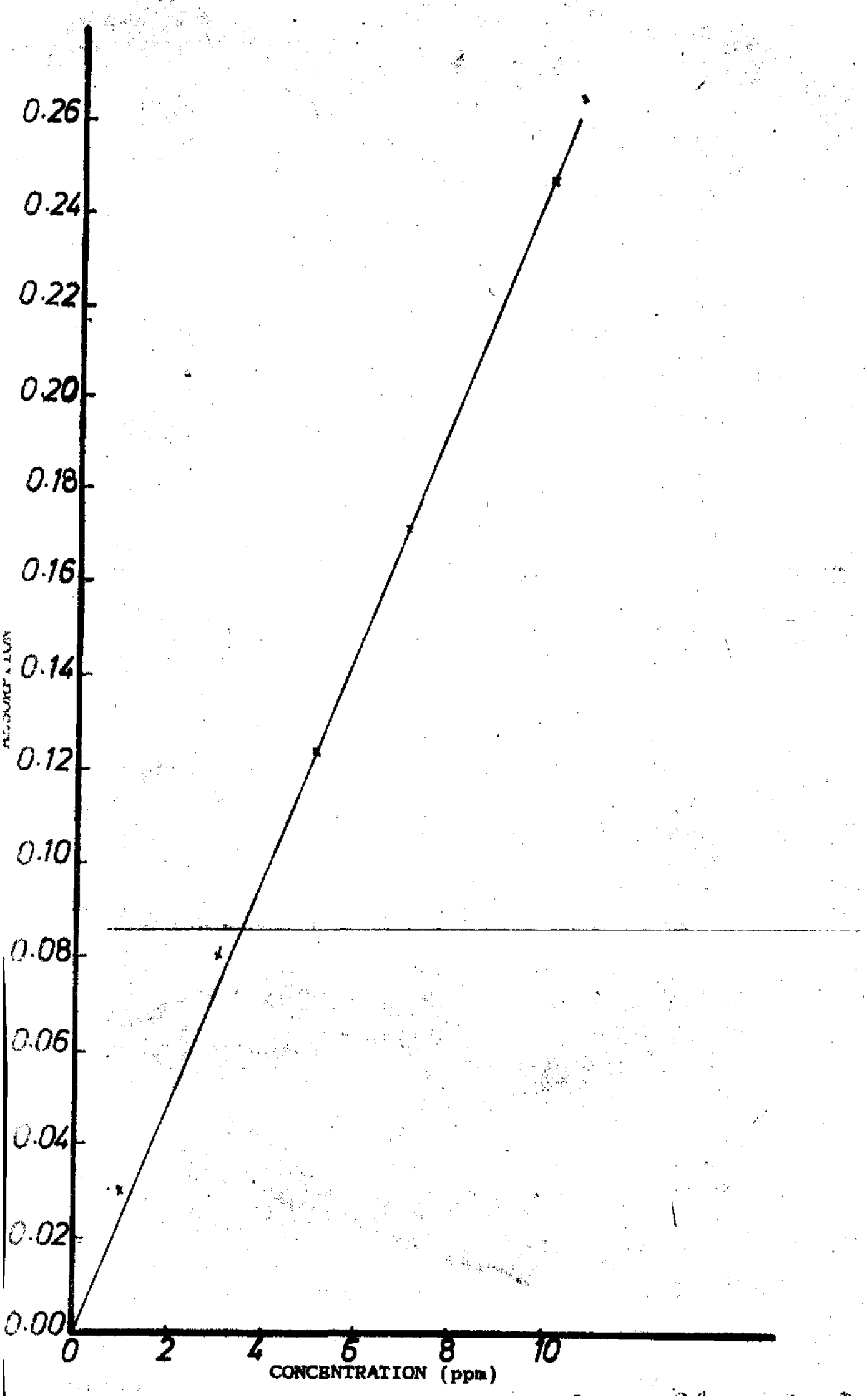


FIG. 7: MAGNESIUM CALIBRATION CURVE BY A.A.S.

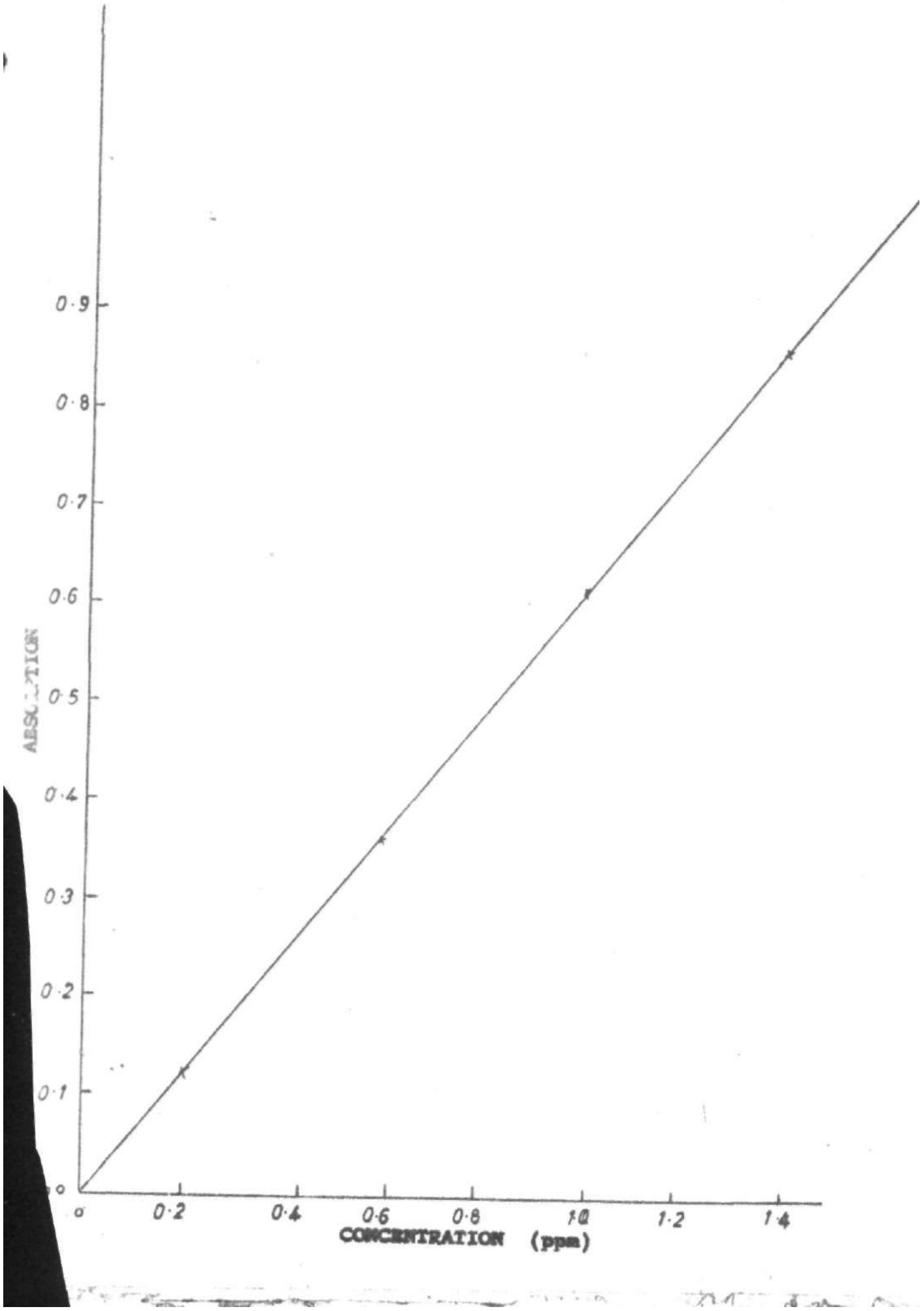


FIG. 8. IRON CALIBRATION CURVE BY A.A.S.

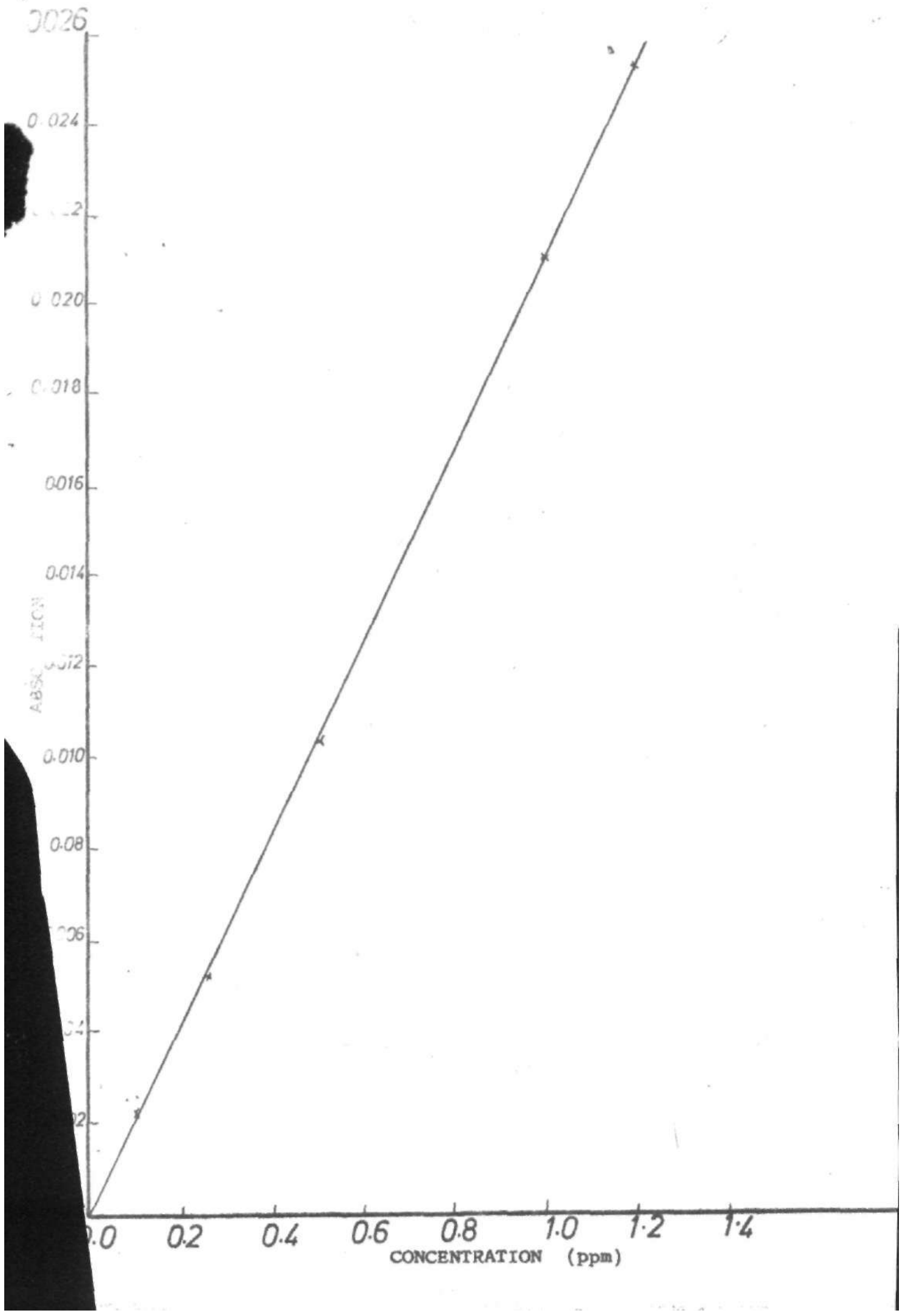


FIG. 9: LEAD CALIBRATION CURVE BY A.A.S.

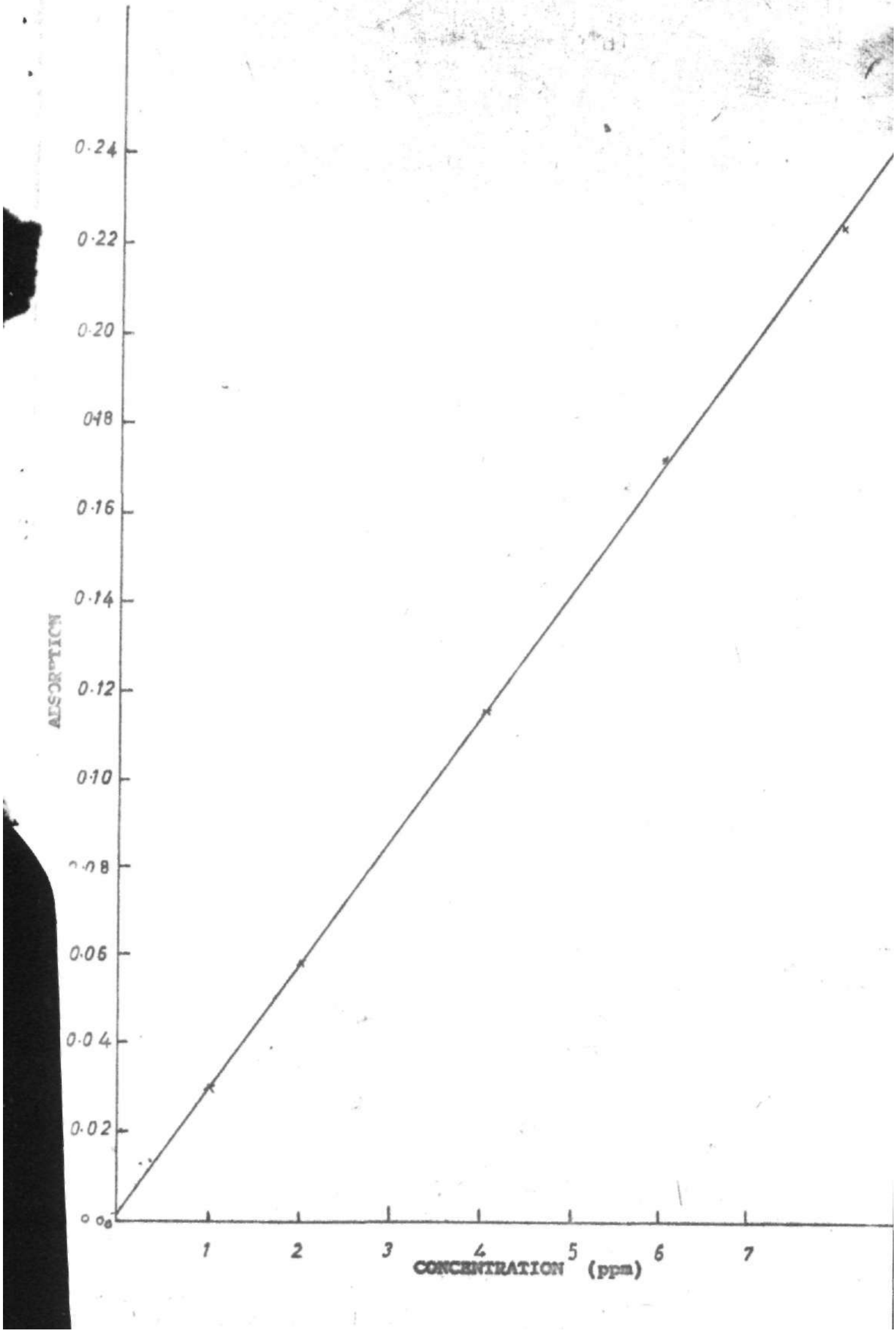


Fig. 10. Copper Calibration Curve by A.A.S.

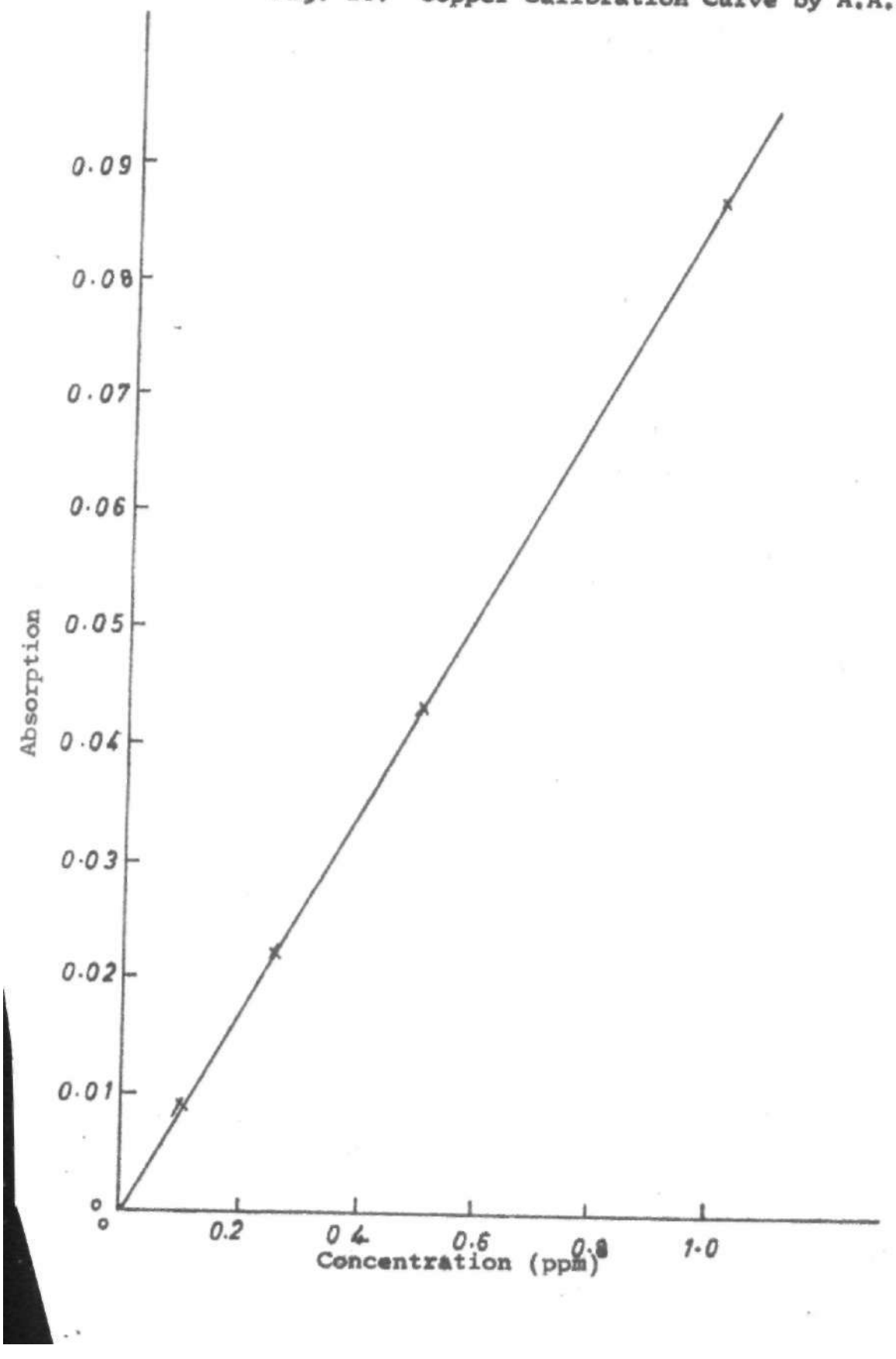


FIG. 11: ZINC CALIBRATION CURVE BY A.A.S.

