EFFECT OF DIFFERENT IMPURITIES IN POTABLE WATER ON IODINE

by

Reba Paul

A thesis submitted to the Department of Civil Engineering of Bangladesh University of Engineering and Technology, Dhaka in partial fulfilment of the requirements for the degree

of

MASTER OF SCIENCE IN CIVIL ENGINEERING

Department of Civil Engineering
Bangladesh University of Engineering & Technology, Dhaka

December, 1996

This Thesis is dedicated to my Family

&

to my best Teachers

EFFECT OF DIFFERENT IMPURITIES IN POTABLE WATER ON IODINE

by

Reba Paul

A Thesis approved as to style and content for the degree of M.Sc. Engg. (Civil):

Dr. Md. Delwar Hossain
Associate Professor
Department of Civil Engineering
BUET, Dhaka-1000.

Chairman
(Supervisor)

Dr. M. Azadur Rahman
Professor & Head
Department of Civil Engineering
BUET, Dhaka-1000.

Member

Dr. M. Feroze Ahmed
Professor, Department of Civil Engineering
&
Dean, Faculty of Civil Engineering
BUET, Dhaka-1000.

Member

Dr. Md. Monimul Huque
Professor and Head
Department of Chemistry
BUET, Dhaka-1000.

Member
(External)

23rd December, 1996

DECLARATION

I hereby declare that the research work reported in this thesis has been performed by me and this work has not been submitted elsewhere for any other purpose. To the best of my knowledge and belief, the thesis contains no material previously published or written by any other person except when due reference is made in the text of the thesis.

23 rd December, 1996

Reba Paul

ACKNOWLEDGEMENT

First of all, the author wishes to express her deepest gratitude to Almighty God for giving her this opportunity and for enabling her to complete the thesis successfully.

She would like to express her heartfelt thanks and indebtedness to her supervisor, Dr. Md. Delwar Hossain, Associate Professor of Department of Civil Engineering of Bangladesh University of Engineering and Technology (BUET), Dhaka for his continued and valuable guidance, generous advice, constructive comments, endless encouragement and unfailed enthusiasm given throughout the research and preparation of the thesis. His active interest in this practical topic and valuable guidance were the source of inspiration of the author.

The author is highly obliged to Dr. Md. Monimul Haque, Professor and Head, Dr. Md. Rafiqullah and Dr. Motiur Rahman, Associate Professor; M. Nurul Islam, Assistant Professor of Department of Chemistry, BUET for their valuable suggestions and discussions on various aspects of this research.

The author also acknowledges the co-operation and encouragement of Dr. A.B.M. Badruzzaman, Dr. Ashraf Ali, Assistant Professor of Department of Civil Engineering and Dr. Sadrul Islam, Professor of Department of Mechanical Engineering, BUET.

The author is very grateful to Dr. M. Azadur Rahman to give her the opportunity in using the computer facilities and also to her friends for their co-operation.

The author extends her hearty thanks to environmental laboratory assistants, Mr. Abdur Rahman and Mr. Abbas for their services and also to Md. Hossain Ali for his neat typing.

Lastly the author would like to transfer her sincere indebtedness to the Department of Civil Engineering for offering her eighteen months teaching assistantship and BUET-Alberta linkage project scholarship under gender issue for bearing her educational expenses during her study in M.Sc. Engineering in BUET.

ABSTRACT

In this research an investigation has been carried out to observe the behavior of iodide salt in impure water at different conditions of water. Potable water has different impurities. Treated water more often contains free chlorine for use of excess bleaching powder or chlorine gas in water to safe guard against the disease producing microorganisms. Ground water contains iron due to geological formation of the aquifer. In some locations these impurities exceed allowable limits and may exist in water in high concentration. In this study different experiments have been conducted to observe the behavior of iodide salt in distilled water containing these two different impurities independently at different temperatures, with elapsed time at various temperatures and pH conditions.

The study reveals that if iodide salt is used in chlorinated water, free iodine will liberate. Due to volatile nature of iodine, the liberated free iodine will escape into air under exposure condition even at low temperature with elapsed time. The loss in free residual iodine increases with increase in temperature and with increased elapsed time at constant temperature under exposure to open air. Acidic condition of water accelerates the evaporation rate of iodine. Iodine that is used in table salts as iodide form exists in water with a trace amount. If this trace quantity of iodine reacts with chlorine in water, the liberated free iodine will escape into air instantaneously. But when iodine is used as iodate form in table salts, no effect of chlorine is noticeable on iodine.

The reaction of ferric iron with iodide salt is very slow due to precipitate form of iron in water as ferric hydroxide. The instantaneous reaction depends on both ferric iron and iodide ion concentration in water. The experimental results show that no rapid reaction of ferric iron with iodide ion is observed even in water containing 10 ppm ferric iron. A rapid reaction occurs at 15 ppm iron concentration in water with 90 ppm iodine as iodide form. This states that there is no significant effect of iron on iodine if iodine is used as iodide form in table salts.

A field survey on iodine deficiency disorders and people's argument about iodized table salts has been carried out in different districts of Bangladesh. The survey shows that now a days most of the people in Bangladesh, use iodized table salts to mitigate iodine deficiency in their bodies. In the coastal zone of Bangladesh where sea foods are available and soil contains iodine, goitrous problem and other iodine deficiency disorders are insignificant. But in the northern zone of Bangladesh these problems are very severe. Because people in those areas are in crisis of sea foods and soil lacks iodine. Poor people specially women suffer much more than males from iodine deficiency disorders.

CONTENTS

CHAPTER 1: INTRODUCTION

CHAPTER 2: IMPORTANCE OF IODINE AND PUBLIC AWARENESS ABOUT IODINE

CHAPTER 3: IODINE AND DIFFERENT IMPURITIES OF POTABLE WATER

CHAPTER 4: METHODOLOGY

CHAPTER 5: RESULTS AND DISCUSSIONS

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS

AWWA	American Water Works Association
Dept. of ME	Department of Mechanical Engineering.
DPHE	Department of Public Health Engineering
hr	hour.
ICCIDD	International Council for the Control of Iodine Deficiency Disorders
ICDDRB	International Centre for Diarrhoeal Disease Research, Bangladesh.
ID	Iodine Deficiency
IDD	Iodine Deficiency Disorders
IMGD	Imperical Million Gallons per Day
LGD	Local Government Division
mcg/d	Microgram per day
mins	minutes
mg/l	Miligram per litre
MLG	Ministry of Local Government
NTU	Nepholomatric Turbidity Unit
NYS	Not Yet Stated
ppm	Parts Per Million
RD&C	Rural Development and Cooperatives
SWCR	State of the World Children Report
TCU	True Color Unit
TDS	Total Dissolved Solid
THC	Thana Health Centre
UIE	Urinal Iodine Excretion
UNDP	United Nations Development Program
UNICEF	United Nations Children Emergency Fund
WBWSP	World Bank Water and Sanitation Program
WHO	World Health Organisation

CHAPTER ONE

INTRODUCTION

CHAPTER - 1

INTRODUCTION

1.1 GENERAL

Iodine is a vital element for health. It is an element of halogen group but least available among all halogens. It can not be found in free state in nature. There is no minerals which can be described as ores of iodine. The only source of the element being the iodide present in sea water and in some springs and well waters and iodide present in nitre deposits, particularly those in chiles (Vogel, 1961). Therefore soil in most areas away from sea shore lack iodine concentration. The thyroid gland in human body does not function properly unless iodine bearing substances are included in the diet. The requirement is very small which is about 150 mcg/d for adults (Ferrao, 1990) but very essential for human body. If this amount is not met, an enlarged thyroid gland called goitre is then endemic (Fair et al., 1968). This rarely happens to those who live close to the sea because they usually have plenty of sea foods. To safeguard against iodine deficiency much of our table salts now contain a small proportion of iodine as sodium or potassium iodide (NaI or KI) which is about 0.02% (Bernard, 1952) or potassium iodate (KIO_3) (Dept. of ME, BUET). People take this salt through drinking or cooking with foods for consumption.

In Bangladesh ground water is a vital source of water supply due to expensive treatment of contaminated surface water. Almost entire supply of drinking water comes from the underground sources as it provides a reservoir of potable water for relatively cheap extraction. Only 19 districts are provided with treated surface water from three surface water treatment plants. One is Mohra, another is Chandighat and the other is Narayangonj surface water treatment plant (LGD. et al., 1994). Ground water is generally free from bacterial contamination whereas surface water is highly contaminated by disease producing micro organisms. (Aziz, 1986). Ground water sometimes might be contaminated by municipal and industrial wastes. Now a days, ground water is highly contaminated by disease producing micro-organisms. Therefore for the purpose of making both ground water and surface water safe for drinking and other domestic purposes, people generally use bleaching powder solution and chlorine gas to kill these micro-organisms.

The use of excess amount bleaching powder or chlorine gas makes water impure and sometimes this impurity in water exceeds the allowable limit. On the other hand, the major problem with ground water in Bangladesh is its high concentration of iron and in many locations the concentration is much higher than acceptable limit (Huda, 1995). The iron problem is severe in rural areas where there have no iron treatment plant or equipments for water (LGD et al., 1994). This study investigates how iodide salt, a reducing agent, behaves with different impurities in potable water such as impure water containing different oxidizing agents e.g. free chlorine, ferric iron etc. at different conditions of water.

1.2 RATIONALE OF THE STUDY

The iodine deficiency disorder rate in Bangladesh is very high. According to the latest survey in Bangladesh conducted jointly by ICCIDD, UNICEF and Dhaka University, 100% of the population are at the risk of iodine deficiency in the country. About 69% of the population are biochemically deficient. The total goitre prevalence is 47.1% and the prevalence of cretinism is 0.5% (Yakub, 1995). The remedy for iodine deficiency, however, does not seem to be the introduction of iodides into drinking water even though this was done some time.Distribution of iodide tablets to school children and later the iodization of table salts have proved to be fully as effective and more economical (Mahan, 1975). Nowadays the most popular use of iodine in human diet is, therefore, its addition to table salts as potassium or sodium iodide (Bernard, 1952) or iodate (Dept. of ME, BUET)) to mitigate iodine deficiency in human health. In our country people are extensively using iodized table salts. The Bangladesh government has provided 265 salt crushing plants with iodization machines. Their total capacity is said to be enough to meet not only domestic demand but to export as well. The Parliament passed legislation about iodization of all salt crushing plants in order to achieve the target of iodine deficiency disease prevention Act., 1989 by 1995. But in the meantime people's complaint about the existence of iodine in iodized salt is violent. People sometimes accuse shopkeepers as frauds as their goitre don't get cured even after they have taken iodized salt for a few months. Therefore poor people now like to abandon this useless *medicine* having high price 3 Taka per kilogram more than normal salt.(Yakub, 1995).

Pondering over the importance of iodine, iodine deficiency disorders in Bangladesh, public awareness about iodine, peoples complaint about iodized salt for not preventing goitre, a keen interest of this study was to observe the behaviour of iodide salt with different impurities in water such as chlorine and ferric iron at different conditions of water.

1.3 OBJECTIVES OF THE THESIS

The major objectives of the present research are as follows:

- To observe the behavior of iodide salt with different impurities in potable water.
- To determine free residual iodine liberated from iodide salt used in chlorinated water at different temperatures, with elapsed time some constant temperatures and pH conditions.
- To determine free residual iodine from iodide salt used in iron content water at different temperature and elapsed time.

- To evaluate the existence of iodine in iodized table salts of different salt plants available in the markets of Bangladesh.
- To conduct a survey in different districts of Bangladesh to know about iodine deficiency disorders among people and their ideas about iodized table salts.

1.4 SCOPE OF THE STUDY

To achieve the above mentioned objectives the following tasks can be carried out.

- The concentration limit of different impurities e.g. free chlorine and iron in potable water can be known from environmental engineering books.
- The necessity of iodine to health and its requirements, fierceness of iodine deficiency disorders (IDD) and control of iodine deficiency disorders can be found from different magazines, newspapers or chemistry books.
- Chlorine and ferric iron content samples can be prepared from bleaching powder stock solution and ferric chloride solution respectively.
- Potassium iodide solution can be prepared and stocked as source of iodide salt.
- The constant temperature can be maintained by immersing the flask in a hot water jar having temperature less than the respective temperature for temperatures higher than room temperature and by immersing the flask in a cold water jar having temperature higher than the respective test temperature for temperatures lower than room temperature.

- The temperature range that can be followed for conducting the experiments can be determined from trials for maintaining constant temperatures.

- A survey can be conducted in different districts of Bangladesh to know iodine deficiency disorders among people and their arguments about iodized table salts.

1.5 ORGANIZATION OF THE THESIS

The study is presented in six chapter, the first of which is general introduction. Chapter-2 and Chapter-3 contains a brief and selective review of the relevant literature which provides insight into different properties of iodine, reaction of iodine with different impurities, water impurities and their characteristics, importance of iodine, awareness of people about iodine, control of iodine deficiency disorders in Bangladesh and social consequences of iodine.

In Chapter-4, the experiments have been described for determination of free residual iodide salt used in impure water at different conditions of water. This chapter also describes a survey procedure conducted in different districts of Bangladesh to know iodine deficiency disorders and peoples ideas about iodized table salts. Chapter-5 focuses on the experimental results and discussions - on the effect of different impurities in potable water on iodine. It also includes the detail of survey. Chapter-6 summarizes the conclusion and recommendations for further study.

CHAPTER TWO

IMPORTANCE OF IODINE & PUBLIC AWARENESS ABOUT IODINE

CHAPTER -2

IMPORTANCE OF IODINE AND PUBLIC AWARENESS ABOUT IODINE

2.1 NECESSITY OF IODINE TO HEALTH

Iodine is an important constituent of human body. Medical and Chemical Workers have discovered a very interesting relation between the presence of iodine and the prevalent of certain disorders. The thyroid gland, located in the neck, secretes a compound called thyroxine, containing about 5% iodine (Bernard , 1952). Cronic iodine deficiency in the diet affects thyroxin secretion, a hormone involved in many vital metabolic processes of the body. As a consequence affected people suffer from various physiological and pathological consequences, compounded by general malnutrition (Yakub, 1995). When the thyroid gland receives too little iodine, goiter, an enlargement of the thyroid results, caused apparently by the attempt of the gland to increase its size in order to produce more thyroxin (Bernard, 1952).

Iodine, a trace element first identified in 1815, was known to help the thyroid gland function properly. But how crucial it is for our mental and physical development, was not understood until recent decades. Early biomedical research saw the problem of iodine deficiency (ID) too often as simply one of goiter, an enlargement of the thyroid gland generally reversible with proper intake of iodine. It was taken to be no more than a problem of cosmetic significance. Goiter, of course, is a common manifestation of iodine deficiency but the consequences of iodine deficiency go far beyond goiter and are much more insidious (Yakub, 1995).

Extreme under activity of the thyroid gland in newborn babies and young children may result in cretinism, mental retardation, mishapen, low mentality, sluggishness, deafmutism, squint, dullness, slow heart action, spastic paralysis of the lower limbs, co-ordination abnormalities, impaired learning capacities and dwarfism. It also leads to abortion, stillbirths and congenital anomalies. The most severe thyroid disorders are treated by the use of synthetic thyroxine. (Bernard, 1952 and Yakub, 1995). But a small amount of iodine about 150 mcg (for adults), cost of a cup of tea (Ferrao, 1990) can prevent the all bad consequences mentioned earlier.

Over activity of the thyroid gland often produces the opposite effect—the thin, nervous, highly energetic person whose movements are quick and whose heart action is rapid (Bernard, 1952).

2.2 IODINE AS TABLE SALTS

To safeguard against iodine deficiency much of our table salts now contain a small proportion of sodium or potassium iodide or potassium iodate. In 1942 first iodine was used in table salts as potassium iodide (Garrett, 1968). Table salt contains about 0.020 percent potassium iodide (Bernard, 1952). Human body (adult) requires only 150 mcg iodine as daily intake and 3 gm in lifetime (Ferrao, 1990).

2.3 IODINE AS DISINFECTANT

Iodine may be used to disinfect potable and swimming pool waters. For waste waters, Iodine has limited applications. Use of iodine is generally restricted to personal or remote water supplies where ease of application, storage, stability and inartness toward organic matter are important considerations. Some swimming pool waters use iodine to lessen eye burn among swimmers and to provide a stable disinfectant residual less affected by adverse environmental conditions.

Iodine is applied in the elemental form or produced in situ by the simultaneous addition of an iodide salt and a suitable oxidant. In the latter case, an excess amount of iodide, may be maintained to serve as a reservoir for iodine production; the determination of iodine is desirable for disinfection control.

Because of hydrolysis, active iodine exists in the form of elemental iodine, hypoiodous acid (HOI) or a form, thereof, hypoiodation (OI-) and in the presence of excess iodide, the triaodide ion (I_3^-). Most analytical methods use the oxidizing power of all forms of active iodine for its determination and the results usually are expressed in equivalent concentration of elemental iodine. (Black et al., 1967). Elemental Iodine is available in tincture of iodine. Tablets of tetraglycine hydroperiodide have been developed for field use (Fair et al., 1968).

2.4 GERMICIDAL PROPERTIES OF IODINE

The germicidal properties of iodine are due to the diatomic form of this element. Iodine in diatomic form has a wide antimicrobial spectrum, being a highly effective veridical, sporicidal and bactericidal agent. The diatomic form of iodine is about 10 to 100 times as effective viricidal as the usual tri-iodide form. Animal tests point to a very low toxicity index for diatomic iodine, inspite its germicidal effectiveness. For treating some infections caused by micro-organisms such as fungi or viruses where current antibiotics are practically useless, diatomic iodine may find application (Notes and News, 1956).

2.5 IODINE AS CLEANSING AGENT

Wescodyne, a complex nonionic synthetic detergent with iodine, produced by West Disinfecting Co. is claimed to enhance the bactericidal activity of iodine while rendering it nontoxic, non-irritating and non-staining. It consists of 7.75% polyethoxy polypropoxy ethanol-iodine complex, 3.75% non-phenyl ether of polyethylene glycoliodine complex, thermainders inert ingredients. The complex is usually held in an acid solution of pH ranging from 3 to 4. About 15-20% of the iodine is chemically bound to the detergent and unavailable for use in disinfection. The remainder is very loosely bound and provides 1.6% available iodine. The detergent serves a dual function of a cleansing agent and as an agent solubilizing the iodine. As it is used, the color fades. However as long as any color is retained prompt germicidal action is assured within 2 minutes. (Notes and News, 1956).

2.6 OTHER IMPORTANCE OF IODINE

The chief use of iodine is in the preparation of tincture of iodine, a solution of iodine and potassium iodide in ethyl alcohol, which is an excellent antiseptic. (Bernard, 1952).

2.7 GLOBAL THINKING ABOUT IODINE DEFICIENCY

Now a days iodine deficiency is recognised worldwide as the single most common, preventable, cause of brain damage and mental retardation. The present and future quality of individual people and whole communities therefore depend on whether or not enough of this vital micro-nutrient is being consumed regularly. The International Council for the control of Iodine Deficiency Disorders (ICCIDD) in association with the World Health Organization (WHO) and the United Nations Children Fund (UNICEF) presented a global summary of the prevalence of IDD in July 1993, based on the most recent information available.

From detailed country by country counts the docubirth weighs the infant and young child mortality. The 1990 WHO report estimated that some 26 million people worldwide, including six million cretins, suffered from brain damage due to ID.

In the past decade the world has been waking up to the magnitude of IDD and the realisation that universal action must be taken to eliminate iodine deficiency. The beginning of the nineties saw several conferences pledging to eradicate IDD by the turn of the country.

The world Health Assembly, the World Summit for children, the conference on Ending Hidden Hunger and the World Declaration and plan of Action for Nutrition have all pledged the goal of IDD elimination.

Two previous surveys - the East Pakistan Nutrition Survey of 1962-64 and the National Goitre Prevalence Study of 1981-82 showed goitre prevalence rates to be 20.0 and 10.5 percent respectively. The dramatic increase, 47.1 percent, in the 1993 survey is said to be due to the depletion of iodine from the land as a result of frequent flooding whereby iodine enters the food chain of human and animals.

Such a high level of iodine deficiency is believed to affect the overall mental ability, or intelligence of the entire nation apart from contributing to the large number of neonatal deaths. But a trace quantity of 150 mcg iodine per day (for adults) can prevent all the above problems in a human body. (Ferrao, 1990). Of the babies born each year, 127 out of a thousand die before age five. Due to iodine deficiency the under-one mortality rate is 97% (Yakub, 1995).

To eradicate this iodine deficiency disorder, the whole world is now fighting to provide people iodine as iodized table salts. (Yakub, 1995). Iodine in table salts are used as potassium iodide or potassium iodate (Bernard, 1952). The recommended amount of potassium iodate in salt is about 50 ppm (Dept. of ME, BUET).

2.8 FIERCENESS OF IODINE DEFICIENCY DISORDERS IN BANGLADESH

Now in Bangladesh iodine deficiency disorder is quite alarming. Bangladesh shares with other nations in South East Asia the largest rate of IDD. The total number of at-risk population in the world exceeds 1,570 million (29% of the world population) and the global goitre prevalence rate is 12 percent.

According to the latest national survey in Bangladesh conducted jointly by ICCIDD, UNICEF and Dhaka University, 100% of the population are at risk of iodine deficiency in the country, 69% of the population are biochemically deficient. The total goitre prevalence is 47.4% and the prevalence of cretinism is 0.5% (Yakub, 1995).

The percentage of women suffering from different degrees of iodine deficiency in the age group 15-44, is as high as 55.6% while for males in the same age group it is 30.6%. This means that virtually the entire population is at risk. The implications of such widespread deficiency on this nation of 11.5 million are extremely disturbing considering that its effects on the quality of the human material - what with the general poverty, protein energy malnutrition and lack of education are as clear as today.

The most severe consequences of ID are critinism, mental retardation, deafmutism, squint, spastic paralysis of the lower cimbs, co-ordination abnormalities, impaired learning capacities and dwarfism (Yakub, 1995 & Benard, 1952). It also leads to abortion, stillbirths, congenital anomalies, low million are at risk and 176 million are goitrous (Yakub, 1995).

virtually the entire population is at risk. But IDD is more severe in females than males, a fact abandoned wives for producing stillborn babies.

Considering the scandalous nutritional status of children in Bangladesh it is a miracle that life goes on! Half the babies are born underweight, 66 percent infants under four are moderate to severely underweight and signs of wasting and stunting are more the rule than exception.

The vicious circle begins in the womb. Goitrous and malnaurished women suffer twice as many neonatal deaths as normal women. A direct consequence of severe iodine deficiency during the first trimester of pregnancy is the birth of cretins, and the hidden tragedy is that for every cretin born there are an additional three people who have been mentally impaired to some degree because of lack of iodine in mother's diet.

According to the State of the World Children Report, 1994 because of the lack of iodine during pregnancy at least 30,000 babies are stillborn every year, and over 120,000 are born cretins—mentally retarded, physically stunted, deafmute or paralysed. Thousands more suffer from lowered intelligence at least 10 points below their potential.

Even when born normal, iodine deficiency in young children can still do lasting harm through reduced intelligence, trapping them in mental dullness and apathy. An iodine deficient child is not one to be up and going, preferring to be withdrawn rather than active. They are less able to leave in their childhood and less able to earn as adults, says the SWCR.

There is no doubt that iodine deficiency is endemic in Bangladesh and that this has grave implications for the present and future status of our human resource. (Yakub, 1995).

2.9 CONTROL OF IDD IN BANGLADESH

The Bangladesh Government for its part has passed the iodine Deficiency Disease Prevention Act, 1989. The aim was to achieve universal iodization of edible salt by January 1994, with UNICEF as an active partner in realizing the goal. All 265 salt crushing plants were supplied with iodization machines. Their total capacity is said to be enough to meet not only domestic demand, but to export as well. The Parliament passed legislation about iodization of all salt crushing plants in order to achieve the target by 1995. Till 1992, 30 salt crushing plants were iodized (Yakub, 1995).

The reality on the ground is that though iodizing salt is quite simple, and has been made easy by UNICEF support, we are still a long way from ensuring that only iodized salt is made available for all and at affordable price.

According to UNICEF estimates universal iodization would cost about one taka per person per year--minuscule by comparison with the expenditure on other government programmes. But the dividend this measly one taka would yield would be unbelievably high. It would mean several rungs up the intelligent quotient ladder for future generations, better scope for realising their full potential and most certainly a brighter mental make-up for Bangladesh. That makes it imperative that all women of reproductive age have adequate iodine stores so that future generations are well protected. The worst damage happens in the womb where a significant degree of neurological development occurs within weeks of conception, (Yakub, 1995).

2.10 SOCIAL CONSEQUENCES OF IDD

At the social level mental impairment in males often goes unnoticed unless it produces markedly abnormal behaviour, people of lower intelligence may lead perfectly normal lives even though considered 'slow' or 'simple'. But under similar circumstances mentally deficient women are discriminated against more severely than are women of normal intelligence. Girls with goitre find it particularly difficult to get married. And there have been cases where husbands have abandoned wives for producing still born babies.

Akhtar a dwarfish twenty year old, had given birth to three babies. She and every body else blames her repeated 'JINNS' and her husband now has taken another wife.

A cretin is an obvious burden however much parents, particularly the mother, may love the child. Because of impaired neurological development such a child may be badly handicapped and thus be dependent on the mother throughout life.

Iodine deficiency together with the general undernourishment and other micronutrient deficiencies must be tackled aggressively to enhance the quality of the majority of the population. Without physical and mental health and well being of the human resource Bangladesh would be ill-equipped to exploit its full potential (Yakub, 1995).

CHAPTER
THREE

IODINE AND DIFFERENT IMPURITIES OF POTABLE WATER

CHAPTER - 3

IODINE AND DIFFERENT IMPURITIES OF POTABLE WATER

3.1 SOURCES OF IODINE

Iodine is the least available of all halogens. It can not be found in free state in nature (Vogel, 1961). There is no minerals which can be described as ores of iodine. The only source of the element being the iodide present in sea water and in some springs and well waters and iodide present in the nitrite deposits, particularly those in chilli. Therefore most areas away from sea shore lack iodine concentration. It is found in very small amount in many biological products and in soil. Butter, spinach, beans and particularly sea foods are sources of iodine (Fair et al., 1968).

Iodine is present as iodide form in the sea, in very low concentrations (one pound per 10,000 tons of sea water). Sponges, corals and some seaweed's have a remarkable ability to extract iodine from the sea so much so that at one time most of the iodine for commerce was obtained from. Now-a-days iodine is obtained from the brine of certain oil wells and from sodium iodate ($NaIO_3$) that occurs with vast deposits of sodium nitrate in northern chile (Graham et al., 1959).

Iodine in the form of complex organic compounds is found in the human body, particularly in the thyroid gland, which is in the neck. This gland can't function properly unless iodine bearing substances are included in the diet. The requirement is very small, 150 mcg/day for adults (Ferrao, 1990), but if it is not met, conditions like goitre develop. This rarely happens to those who live close to the sea for they usually eat plenty of sea food. To guard against an iodine deficiency much of our table salt now contains a small proportion of sodium iodide and hence the name iodized salt (Graham et al., 1959).

Sources of Iodine:

1. *Sea water (very small amount).*
2. *$NaIO_3$ in chilean nitrate deposits*
3. *Oil well brines of california*
4. *Thyroid gland in human body*
5. *Iodine as other chemical forms such as potassium iodide, sodium iodide-commercial iodine*

(*Source:* Nebergall et al., 1959)

3.2 SOURCES AND CHARACTERISTICS OF WATER IN BANGLADESH

There are two sources for water supply in Bangladesh. The one is surface water supply and the other is Ground Water Supply. Ground water is a vital source of water supply for Bangladesh due to expensive treatment of contaminated surface water.

Rural Water Supply in Bangladesh:

About 96% of rural people get their drinking water from tubewells. In less densely populated areas tubewell water is less accessible but still widely available. Surface water is plentiful but contaminated. There are about 1,86,00 Govt. hand pump tubewells in the rural areas of Bangladesh and numerous privately owned. But public tubewells are seldom closer than the nearest source of surface water and the incentive to use tubewell water for nondrinking purposes is often outweighed by the convenience of the household pond (LGD et al., 1994).

Urban Water Supply in Bangladesh:

Ground water is the preferred water source in all urban centers except Chittagong where 20 of 34 IMGD is produced through the Mohra surface water treatment plant. Of the 145 IMGD water produced in Dhaka, 96% is from a network of 172 deep wells linked in a grid, to minimize costs of transmission and pumping, while the remaining is from the chandighat surface water treatment plant. Only 19 district towns partially depend on surface water.

DWASA provides water to only 55% of the 5.5 million population within its service area. About 2.7 million people have house connections and additional 300,000 obtain water from 1209 street hydrants, the remaining population rely on private hand tubewells, lake or river water. In Chittagong, in city of about two million people, the total coverage by piped water is 50% of which is through house connections and about 10% by public standpoints. Specific data on coverage by hand tubewells in the core areas of both Dhaka and Chittagong are not available but according to the WASA's shuch coverage is insignificant. However the 1991 national survey found that over 69% of the population in urban slums and fringe areas use water from private wells and over 23% use water from public wells. Table 3.1. Shows the water supply status in cities and towns.

Only 20% of 1.2 million population in Khulna city is covered by public water supplies of which 10% have access through house connections, 3% through public standposts and 7% obtain from public hand tubewells. The water supply coverage in Rajshahi, another city with a population of about 0.8 million, is 40% with 14% having access through house connections and 7% through public standposts. About 19% of the Rajshahi city population obtain water from hand tubewells.

Table 3.1: Public Water Supply Status in Cities and Towns

City/category	Dhaka	Chittagong	Zila Towns	Thana Towns
Present Total Coverage (Percent of population)	55%	50%	19%	50%
Total population(million)	5.5	2.0	6.5	no data
Physical Facilities Water Production (IMGD)	145	34	958	0.3
Production wells	172	29	319	19
Surface water plants	1.0	1	20	-
Water mains (km)	1240	425	1850	-
House connections	124000	23000	90700	2152
Standpoints	1209	680	4192	30
Hand tubewells	-	-	23000	nodata

(*Source*: LGD et al., 1994)

The 60 Zila towns, with over 6.5 million people, vary in size from 40,000 to 500,000 people. Piped water supply coverage; estimated to serve only 19% of the population, is generally limited to the core areas. Another 27% depend on public hand tubewells. The remaining population use private wells, ponds and rivers.

The water supply coverage in thana towns is primarily based on handpumps. Based on DPHE data on 155 thana towns, an estimated 50% of all thana town population is covered by public handpumps. About 60% of the tubewells are public and the rest are either private or installed by other agencies. Of the 460 thana towns only 46 have pourashavas of which 10 towns have limited piped water supply.

A recent study on Water Supply System in urban slums and fringes found that in slum areas, occupied by 22% of the urban population, there is one operating tubewell per 527 persons.

As access to public tubewells remains limited, slum residents obtain water from a variety of sources. Around 50% of an estimated one million slum dwellers in Dhaka use street hydrants. As 14% have access to community tubewells estimated locally, and the remaining 36% obtain from neighbors or nearby lakes or rivers *(LGD et al., 1994).*

Characteristics of Surface Water in Bangladesh

This water is generally obtained from streams, lakes, ponds, reservoirs, rivers and oceans. It picks up many substances as it flows back to the ocean like microorganisms, organic matter, minerals and other polluting substances. The surface waters are therefore characterised by the suspended impurities. The suspended matter often contains the pathogenic or disease producing bacteria (*Aziz, 1986*). As such surface waters are not considered to be safe for water supply without the necessary treatment though this water is usually not hard, nor does it often contain iron, manganese or other objectionable dissolved materials in sufficient quantity to require special treatment (*Hussain; 1978*).

The primary causes of deterioration of surface water quality are municipal and domestic wastewater, industrial and agricultural wastes (organic, inorganic, heat) and solid and semisolid refuse (*Clark et al., 1977*). The major aquatic pollutants which causes the aquatic pollution are: oxygen demanding wastes, disease producing agents, plant nutrients (N,P), synthetic compounds, oil, inorganic chemicals and mineral substances, sediments, radioactive substances and heat. More than 95% of urban sewage is discharged directly into surface water without any treatment. There are about 30,000 industrial units in Bangladesh of which about 24,000 are small and cottage industries discharging their effluent directly into the river and causing both lethal and sublethal impact on fish even human (*DOE, 1991*).

A municipality obtaining surface water source therefore may find it so fouled by wastes and toxic chemicals that it is unsuitable or too costly to use as a water supply. However in urban areas there are a few surface water treatment plants to mitigate the domestic water requirement of urban people partially. They use large quantities of bleaching powder to make water free from organisms and thus make water impure by adding excess free residual chlorine in water which may interfere with other substances coming in water.

Ground Water Characteristics

Groundwater is usually preferred as source of drinking water to surface waters due to its superiority. Most groundwater taken far below the earth's surface are clear, colorless with little or no suspended matter and from disease producing microorganisms and has a relatively constant temperature (*Aziz, 1986 & Huda, 1995*). This good quality of groundwater is due to the natural filtering capacity of under ground soil strata during passage of surface water. However, ground water has higher salt content than surface water, as slow moving water remains in contact with the substrata for longer periods, increasing the soluble mineral content until a condition of equilibrium is reached (*Huda, 1995*). Substantial chemical changes may take place in rocks, if the dissolving power of solution of water increases for any reason (*Rethati, 1983*).

Ground water quality is also influenced by the quality of source. Changes in source water or degraded quality of normal supplies may seriously impair the quality of the ground water supply. Municipal and industrial wastes entering an aquifer are major sources of organic and inorganic pollution of groundwaters. Large scale organic pollution of ground waters is infrequent, however, since significant quantities of organic wastes usually can not be easily introduced in underground. The problem is quite different with inorganic solutions, since these move easily through the soil and once introduced are removed only with great difficulty. In addition, the effects of such pollution may continue for inadequate periods since natural dilution is slow and artificial flushing or treatment is generally impractical or too expensive. *(Clark et al., 1977).*

The followings are among the more important chemical substances and properties of groundwaters which are of great interest to the public health engineers: Iron, manganese, chloride, pH, hardness, sulphate nitrate, total dissolved solids, fluoride and dissolved gases such as oxygen, hydrogen sulphide and carbon dioxide. Iron is a major problem of groundwater in Bangladesh which has been discussed in details in Section 3.8 of Chapter 3.

3.3 WATER QUALITY STANDARDS FOR DRINKING WATER IN BANGLADESH

The water quality standards for drinking water in Bangladessh has been shown in table 3.2 below.

Table 3.2: Water Quality Standard for Drinking Water

Water Quality Parameters	Unit	WHO Standard	Bangladesh Standard	Remarks
pH	-	6.5-8.5	6.5-8.5	
Iodine	ppm	-	NYS	
Color	TCU	5	15	
Turbidity	NTU	5	10	
Odor		Unobjectionable	Odorless	
TDS	ppm	1000	1000	
Suspended Solids	ppm	10	-	
Chloride, Cl^-	ppm	250	150-600*	*For coastal area 1000 mg/l and in extreme case in
Total Alkalinity	ppm	-	NYS	
Total Hardness	ppm	500	200-500	

Contd. to next page

Table 3.2 (Contd.)

Water Quality Parameters	Unit	WHO Standard	Bangladesh Standard	Rematks
Fluoride, F	ppm	1.5	1.0	coastal area 1500 mg/l. # in some areas 5 mg/l for want of better drinking water source.
Iron, Fe	ppm	0.3	0.3-1#	
Chlorine (residual)	ppm	-	0.20	
Manganese, Mg.	ppm	0.10	0.10	
Calcium, Ca	ppm	100	75	
Magnesium Mg	ppm	-	30-50	
Al	ppm	0.20	0.20	
Arsenic	ppm	0.05	0.05	
Barium	ppm	0.01	0.50	
Boron	ppm	-	1.0	
Cadmium	ppm	0.005	0.005	
Mercury	ppm	0.001	0.001	
Nickel	ppm	-	0.10	
Zinc	ppm	5	5	
Sodium	ppm	200	200	
Dissolve Oxygen	ppm	-	6	
BOD	ppm	-	0.20	
COD	ppm	- -	4.0	
Coliform	n/100 ml	0	0	
Temperature	^{0}C	-	20-30	
CO_2	ppm	-	-	
SO_4	ppm	400	400	
NO_3	ppm	10	10	

(Source: DOE, 1991)

3.4 SOURCES OF FREE CHLORINE IN DOMESTIC WATER SUPPLY

Dissolved free chlorine is not found in natural waters. Its presence in treated water results from disinfection with chlorine and the leaving of a residual for the sake of safety against the existence of pathogenic bacteria *(Aziz, 1986)*. Both ground water and surface water supply may be contaminated by municipal and industrial wastes. To safe guard against any contamination that occur through leaky joints or cracks in pipes, some free available chlorine is desired as residue in water supply systems.

Disinfection can be done by various methods such as chlorination, by iodine and bromine, ozonization, ultraviolet radiation radioactive substances etc. But disinfection by chlorination using bleaching powder is the most wide spread and practical method in United states and in other countries including Bangladesh *(AWWA, 1990)*. The available chlorine in bleaching powder vary from 25 to 33 percent. It looses strength due to long storage or exposure. The customary residual is 0.1 to 0.5 ppm. Residuals upto 2 ppm are successfully carried but may result in wide spread complaints of unpleasant tastes.

3.5 SANITARY SIGNIFICANCE OF CHLORINE

Chlorine is the one most commonly used disinfectant throughout the world in water supply and waste water treatment plant *(Fair, et al., 1968)*. It is an ideal disinfectant since it has an immediate and disastrous effect on most forms of organisms *(Aziz, 1986)*.

The chlorination of water supplies and polluted waters serves primarily to destroy or deactivate disease producing microorganisms. A secondary benefit is the overall improvement in water quality resulting from the reaction of chlorine with ammonia, iron, manganese, sulfide and some organic substances.

Chlorination may produce adverse effects. Taste and odor characteristics of phenols and other organic compounds present in water supply may be intensified. Combined chlorine formed on chlorination of ammonia or amine bearing waters adversely affects some aquatic life. To fulfill the primary purpose of chlorination and to minimize any adverse effect, it is essential that proper testing procedures be used with a fore knowledge of the limitations of the analytical determination *(AWWA , 1990)*.

Table 3.3: Minimum Chlorine residuals for Domestic Water at 20°C temperature

pH	6-7	7-8	8-9	9-10
Free available chlorine after 10 mins in ppm	0.2	0.2	0.4	0.8
Combined available chlorine after 60 mins in ppm	1.0	1.3	1.5	1.5

(Source: Aziz, 1986)

3.6 SOME CHEMICAL CHARACTERISTICS OF CHLORINE

Reaction of chlorine as bleaching powder with water:

When chlorine is added in water in the form of bleaching powder it forms free chlorine and calcium hydroxide *(Vogel, 1961)*

$$Ca(OCl)Cl + H_2O \Leftrightarrow Cl_2 + Ca(OH)_2$$

Reaction of Chlorine with water:

When chlorine in the form of chlorine gas is added to water, two reactions take place—hydrolysis and ionization *(Azíz 1986).*

$$Cl_2 + H_2O \Leftrightarrow HOCl + H^+ + Cl^-$$

$$HOCl \Leftrightarrow H^+ + OCl^-$$

Reaction of chlorine with water in hot condition in presence of sunlight:

In hot condition or in presence of sunlight chlorine produce hydrochloric acid and oxygen.

$$2H_2O + 2Cl_2 = 4HCl + O_2$$

Reaction of chlorine with water in very cold conditions:

If chlorine is passed in water at $0^{o}C$ temperature, it forms chlorine decahydrate crystals.

$$Cl_2 + 10H_2O = Cl_2.10H_2O$$

Reaction of chlorine with alkalies:

At low temperature:

In cold water chlorine reacts with alkali and forms chloride and hypochlorite.

$Cl_2 + NaOH = NaCl + NaOCl + H_2O$

At hot temperature:

At higher temperature (at $90^{o}C$) if chlorine is added to alkaline water it forms chloride and chlorate.

$3Cl_2 + 6NaOH = 5NaCl + NaClO_3 + 3H_2O$

Reaction With Acid:

No significant reaction takes place. Because chlorine is acidic in nature.

3.7 SOURCE OF IRON IN DOMESTIC WATER SUPPLY

Groundwater is a vital source of safe water supply for drinking purposes in Bangladesh specially to its rural population. But ground water contains a high concentration of iron *(Huda, 1995)*. Groundwater comes to intimate contact with various minerals which are soluble in water to varying degrees. Iron is the most important one. The dissolved minerals determines the usefulness of the water for various purposes and the presence of some minerals beyond certain limits may make it unsuitable for drinking, domestic and other purposes *(Garg, 1978)*. At present in the rural areas hand pump tubewells are regarded as the only means for collecting groundwater for drinking and other domestic purposes because of numerous socioeconomical and technical reasons. *(Ahmed et al., 1989)*. Bangladesh is mainly a rural country. The problem of iron removal as it is faced by municipalities and industrial supplies is easily handled because they have large aeration equipments and can use coagulation methods for precipitation and filtration. The main problem that arises in removing iron from rural water supplies e.g. hand pump tubewells etc. is that the rural people have any equipment for aeration nor any chemical for coagulation and flocculation. Hence people are to use high concentration of iron bearing water everyday. *(Ali, 1990)*.

3.8 CONCENTRATION OF IRON IN MANY AREAS OF BANGLADESH

Groundwater in Bangladesh carries a high concentration of iron and in many locations the concentration is much higher than the acceptable or allowable limit. Figure 3 shows the distribution of iron in groundwater of Bangladesh. The map has been prepared compiling the available information about the groundwater quality of the shallow aquifiers. It has been observed that iron content of groundwater in most of the places of Bangladesh is greater than 1.0 mg/l and in many locations the iron

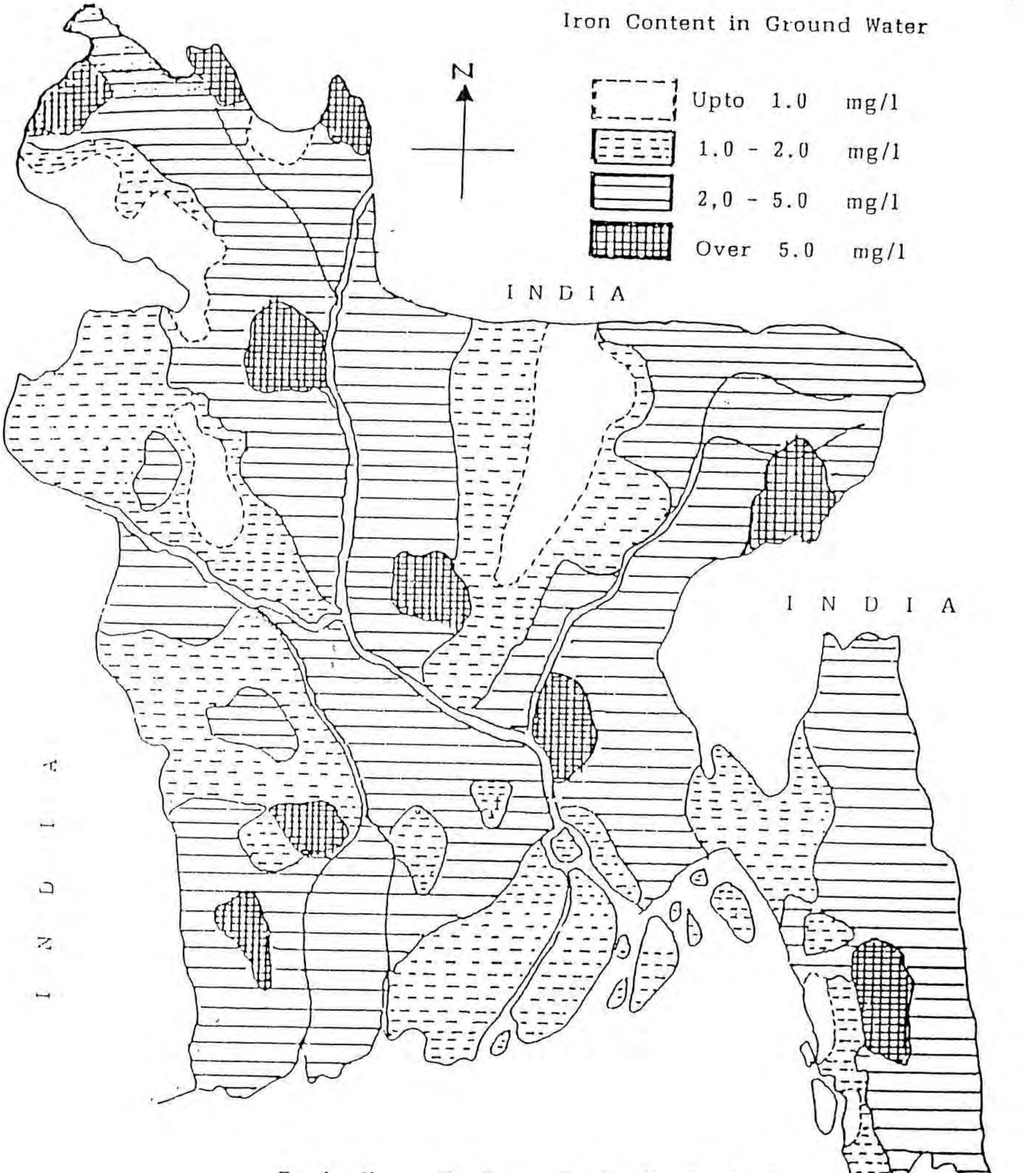


Figure 3: Iron Content of Handpump Tubewell Water in Bangladesh. *(Ahmed et al., 1989)*

content of ground-water is more higher than 5 mg/l. Figure 3 also indicates that ground water of about 65% of the area of Bangladesh has average iron content more than 2 mg/l. The WHO *(1983)* suggested a guide line value of 0.3 mg/l for iron in drinking water. The limit can hardly be maintained in rural water supply in Bangladesh. For this reason Department of Environmental *(DOE)*, Bangladesh recommended a desirable limit of 1 mg/l of iron in drinking water. But in the case of hand pump tubewell in rural areas, the maximum tolerable limit was set at 5 mg/l in the absence of better source. This local standard *(high concentration)* is being followed in rural water supply in Bangladesh.

Based on the distribution of iron bearing aquifers, allowable limits in Bangladesh and people's acceptability, the country may be divided into three iron problem areas.

<u>Area Type-I</u> *(Iron free zones)*
Iron content of hand pump tubewell water is less than 1 mg/l. Rural people accept it as excellent water.

<u>Area Type-II</u> *(Moderate Iron Problem Zone)*
Iron Content of hand pump tubewell water is between 1 and 5 mg/l.

<u>Area Type-III</u> *(Acute Iron problem Zones)*
Iron content of tubewell water is higher than 5 mg/l. In some places iron content has been found as high as 25 mg/l *(Ali, 1990)*.

3.9 SANITARY SIGNIFICANCE OF IRON

Ground water of our country usually has a high iron content and in some areas deposits go far beyond the tolerance of local people. The presence of iron is objectionable because of the precipitates of this metal and its compounds. Iron bearing water is often called ferruginous water. They impart a brown colored deposit on vegetables during washing and cooking. Iron bearing water also generally favours the growth of several groups of bacteria which require a small amount of air to grow *(Ali, 1990)*.

Human suffers no harmful effects from drinking water containing iron. Such waters, when exposed to the air to that oxygen can enter, become turbid and highly unacceptable from the aesthetic point of view due to the oxidation of iron. Iron interfere with laundering operations, impart objectionable stains to plumbing fixtures and causes difficulties in distribution systems by incrustation of well screens and plugging of pipes. Iron also imparts a taste to water which is detectable at very low concentration. For this reason the WHO recommends that water supply should not contain more than 0.3 mg/l of iron. Bangladesh drinking water standard for iron is 0.3 - 1 mg/l, maximum being 5 mg/l *(Aziz, 1986) & Ali, 1990)*.

3.10 SOLUBILITY OF IRON

In natural groundwater soluble iron exists mainly in the bivalent state. Some trivalent ferric iron may also exist in solution especially in aquifers where low pH values are encountered. In alkaline water devoid of sulfides, phosphates and organic compounds, iron will precipitate from aqueous solution as ferrous hydroxide depending on the concentration of oxidizing agents and pH *(Ali, 1990)*.

In many alkaline natural water, the solubility of ferrous iron is limited by the solubility of ferrous carbonate to a pH of 9 above which the solubility equilibria of ferrous hydroxide becomes limiting again. Theoretically iron that precipitates from a supersaturated solution of this type would be either ferrous carbonate or ferrous hydroxide depending on pH agents, iron is oxidized from the ferrous to the ferric form. Once oxidized, the solubility of iron is severely limited over a wide pH range 4 to 13 restriction *(Ali, 1990)*.

3.11 KINETICS OF IRON OXIDATION AND PRECIPITATION

Various investigators have studied the rate of iron oxidation. All have concluded that the rate of ferrous iron oxidation is of the first order with respect to the ferrous iron concentration and the partial pressure of oxygen. In addition, the oxidation rate has been found to be strongly dependent on pH. It has been shown that oxidation of ferrous iron should be expected to occur rapidly in well-oxygenated waters of pH values exceeding 7.2. In case of water having low pH, the pH value is increased by stripping carbon-dioxide or adding lime. Alternately the rate of oxygenation may be increased by the use of catalyst *(Ali, 1990)*.

3.12 RATE OF IRON PRECIPITATION

When ground waters supersaturated with respect to ferrous carbonate are aerated, the pH increases because of the loss of carbondioxide, thereby further increasing the degree of supersaturation. As a result, the precipitate formed may be expected to contain both ferrous carbonate and ferric hydroxide. The rate of precipitation of iron would therefore be determined by the rate of oxidation of ferrous iron plus the rate of ferrous carbonate precipitation *(Ali, 1990)*.

Oxidizing Agents of Iron:

Chlorine and chlorine dioxide:

These gases are powerful oxidizing agents and can be used to oxidize iron. Normally only chlorine is found to be used since chlorine dioxide is expensive. The reactions with chlorine in the presence of calcium bicarbonate alkalinity are as follows:-

$$2\,Fe(HCO_3)_2 + Cl_2 + Ca(HCO_3)_2 = 2Fe(OH)_3 + CaCl_2 + 6CO_2$$

This reaction takes place over a wide range of pH from 4 to 10 but the optimum pH is 7. The colder the water, the slower are the reactions which make as long as 60 minutes retention time to complete. Oxidation by chlorination alone, without aeration or can also work effectively with colored waters and chelated iron. Potassium permanganate is also an oxidizing agent of iron. *(Ali, 1990).*

3.13 CHEMISTRY OF IRON

Iron (II) (Fe^{2+}) is chemically a reduced and soluble form which exists in a reducing environment (absence of dissolved oxygen and low pH). These conditions exist in groundwater and anaerobic reservoir water. When it is pumped from underground or an anaerobic hypolimnion, CO_2 and H_2S are released, raising the pH. In addition, water become exposed to air creating an oxidizing environment. The reduced iron starts transforming to its stable, oxidized insoluble form of Iron (III) (Fe^{3+}). The rate of oxidation of iron depends upon the type and concentration of oxidizing agent, pH, alkalinity, organic content and presence of catalysts. *(Ali, 1990).*

3.14 PHYSICAL PROPERTIES OF IODINE AND SOLUBILITY OF IODINE IN WATER

Iodine is a grayish - black crystalline solid. *(Nebergall et al., 1959).* It vaporizes. even at room temperature. The interesting property of Iodine is that it undergoes transmission from solid to a vapour without passing through a liquid stage. When solid iodine is heated, it gives a violet vapor which is diatomic upto about 700°C *(Hicks, 1963).* The vapour condenses on a cool surface to form crystals of iodine *(Emeleus et al., 1962).* If heated rapidly it melts at 114°C and boils at 184°C . Its vapour is irritating, and poisonous *(Hicks, 1963)*. The transition from solid to vapour without going through a liquid state is called sublimation. This sublimation property of iodine is used in the separation of iodine from nonvolatile impurities *(Nebergall et al., 1959)*.

Iodine is sparingly soluble in water imparting a perceptible brown color to the solution *(Seager et al., 1979)*. However it readily dissolves in many organic solvents forming a brown solution if they contain oxygen and a violet solution if they do not *(Hicks, 1963)*. Thus in alcohol and ether iodine imparts brown solutions. The solvents in which iodine combines with the solvent molecules (solvation) are the ones which give brown solutions. In chloroform carbon disulfide and many hydrocarbons iodine forms violet solutions. In chloroform iodine, and the violet color is like that of iodine in the vapour state, where it is also molecular solutions of hydrogen iodide, potassium iodide or other iodides dissolve iodine very rapidly. Here the iodine and iodide ion combine reversibly, form the complex ion I_3^-

$$I^- + J_2 = I_3^-$$

The negative iodide ion, when close to a large iodine molecule, the outer electrons of which are far from the positive nuclei disturbs these electronic arrangements enough to induce a dipole upon the molecule. An attraction them exists between the negative iodide ion and the positive end of the polar iodine molecule compounds containing the complexes I_3 , Br_3^- and Cl_3^- have also been reported *(Cotton et al., 1992)*.

Solubility of Iodine in Water:

As mentioned earlier the solubility of iodine in water is low. Only 0.335g of Iodine dissolves in 1 litre of water at 25°C *(Jabber et al., 1972)*. Moreover aquous solutions of iodine have an appreciable vapour pressure of iodine so that the concentration gradually decreases, especially when handled.

In order to avoid these difficulties an iodine solution is prepared by dissolving pure iodine in a solution of potassium iodide, in which iodine is highly soluble.

The increased solubility is due to the formation of the triodide ion *(Hutchinson, 1964)*

$$I^- + I_2 = I_3^-$$

The equilibrium constant for this reaction is 77.0 at room temperature. This solution has an appreciably less vapour pressure than a solution of iodine in pure water. When this solution is titrated with a reducing agent the free iodine react with the reducing agent so the equilibrium is shifted towards the left and more iodine is liberated from the triodide ion. In this manner all the tri-iodide decomposes giving all the iodine; the solution thus behaves exactly like free iodine solution.

The equation for reduction of Iodine to iodide ion is

$$I_2 + 2e = 2I^-$$

So that the equivalent weight of iodine is equal to its atomic weight i.e. 126.904 *(Jabbar, 1972)*.

Table 3.4: Some Physical Properties of Iodine:

Properties	Value/State/Colour
Atomic weight	126.91
Atomic No	57
State at room temperature	Solid
Solubility in water (g/100g at 20°C)	0.034
Melting point	114°C
Boiling point	183°C
Color of gas	Violet
Density of solid g/ml.	4.9

(Source: Graham, 1959)

3.15 CHEMICAL PROPERTIES OF IODINE

Oxidizing Agent:

Considering only the naturally occuring hallogens, the iodine atom has the least attraction for an additional electron. This is due to its large radius and greater number of electron shells. Thus iodine is the weakest oxidizing agent of the four hallogens and the iodide ion is the most easily oxidized halides.

$$2I^- \rightarrow I_2 + 2e^-$$

Reaction with Metals:

Almost all metals react with iodine at various conditions and with different rates some react very vigorously and others slowly under heated conditions. They normally form iodides of the metals with high oxidation state.

$$nI_2 + 2M = 2\ MI_n$$

Reaction with Nonmetals:

Although iodine does not oxidize the other halide ions, it will remove electrons from certain other nonmetal ion such as sulfide ions, S^{--}

$$S^{--} + I_2 \rightarrow S\downarrow + 2I^-$$

Reaction with Water:

Iodine (halogen) shows slight activity with water and reacts in two ways

In the first type

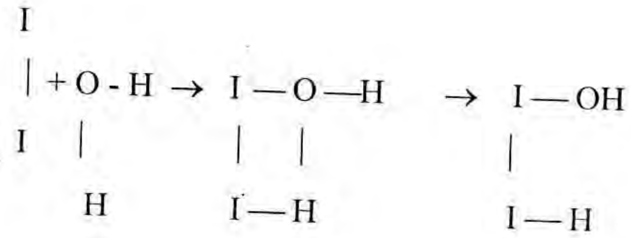
$$2I_2 + 6H_2O = 4H_3O^+ \quad + 4I^- + O_2$$

The halogen displaces oxygen from the water.

In the 2nd type,

$$I_2 + H_2 O = H_30^+ + HOI. + I^-$$

Iodine is converted to both the I⁻ and the iodation states. Such a reaction may be called an hydrolysis reaction, since in principle both the iodine and water molecules are split apart giving initially HI and IOH species illustrated



$$\begin{array}{c} I \\ | \\ I \end{array} + \begin{array}{l} O-H \\ | \\ H \end{array} \rightarrow \begin{array}{l} I-O-H \\ |\quad\ \ | \\ I-H \end{array} \rightarrow \begin{array}{l} I-OH \\ | \\ I-H \end{array}$$

The HI species, a strong acid, ionizes almost completely in water giving hydronium ions and I⁻ ions *(Garrett et al., 1968).*

Reaction with Alkali Solutions:

In dilute aqueous alkali solutions iodine undergoes auto oxidation or, more precisely, a disproportionation reactions in which iodine is converted to -1 and +1 oxidation states. The color of I_2 disappears by hydrolysis in aqueous alkaline solutions.

$$NaOH + X_2 = XOH + NaX$$

The elementary iodine again reappears by an acidification of the alkali solution indicating reversible process.

In hot solutions, HOI (Hypoiodites) are further oxidized (auto-oxidation) to IO_2^- and IO_3- ions together with I⁻ ion.

Thus iodine in hot solution gives:

$3\ I_2 + NaOH = 5NaI + NaIO_3 + 3H_2O$

Iodine in cold alkali solution gives:

$I_2 + 2NaOH = NaI + NaOI + H_2O$

Reaction with acid:

No significant reactions.

$I_2 + 10\ HNO_3 = 2HIO_3 + 5N_2O_4 + 4H_20$

Reaction with Starch:

Iodine reacts with starch to form a deep blue color. Even a trace quantity of the element is able to happen this change. This is a very sensitive test for elementary iodine.

Decomposition of I_2:

The density of iodine vapour shows that it consists of molecules of iodine. When the temperature is raised to 700°C , decomposition begins and increases as the temperature is raised until at 1700°C , the decomposition is complete *(Nebergall et al., 1959).*

$$I_2 \Leftrightarrow 2I \quad \_\_\_\_\_\_ 28500\ \text{Cal.}$$

Reaction with reducing agents:

The halogen elements will react with strong and moderately strong reducing agents such as sulfides, sulfites, arsine, AsH_3, many metal ions such as sn^{+2} , Iron II (Fe^{+2}) and a great many organic compounds.

The reaction is the basis of most iodomatric methods of analysis e.g. in the determination of Cu^{+2}. The formation of $S_4O_6^{-2}$ ions occurs only with weak oxidizing agents such as I_2. Strong oxidizing agent converts the $S_4O_6^{-2}$ ions to SO_4^{-2} ions. $Na_2S_2O_3$ is also used to remove excess chlorine in the bleaching industry.

Reaction of potassium dichromate with acidic iodide solution:

Potassium dichromate oxidizes iodide ion and liberates free iodine in acidic solution.

$$Cr_2O_7^{--} + 14H^+ + 6I^- = 3I_2 + 2Cr^{+3} + 7H_2O$$

There are a few significant sources of error in carrying out the reaction:

(1) The solution should be strongly acidic; insufficient acidity causes incomplete reaction of dichromate by iodide ion.

(2) In order to avoid oxidation of hydrochloric acid (formed from excess iodide and acid) by air a reducing atmosphere should be provided; this may conveniently be done by adding some solid sodium bicarbonate to the solution;
(Source: Jabber, 1972).

3.16 REACTIONS OF IODINE

In this section some important reactions for the study have been thoroughly described.

(1) Reaction of chlorine with potassium iodide salt:

Iodine can not replace other halogen from its bivalent element but iron, chlorine and bromine can replace iodine from iodide complex. The reactions are cited in *Haider, 1973* and are shown below:

$$2KI + Cl_2 = 2KCI + I_2$$

$$2FeCl_3 + 2KI = 2FeCl_2 + I_2 + 2KCl$$

(2) Reaction of potassium iodide with iodine:

Iodine is highly soluble in solution of potassium iodide, hydrogen iodide and other iodide and forms tri-iodide in solution (Abrash et al., 1981).

$$KI + I_2 \Leftrightarrow KI_3$$

But the soluble iodine in this type of iodide solution behaves like free iodine.

(3) Reaction of iodine with Sodium thiosulphate:

Sodium thiosulphate is a reducing agent. It reduces free iodine to colorless sodium iodide and is oxidized itself to sodium tetrathionate. As a result the brown color of iodine disappears and the solution becomes a colorless one.

$$I_2 + 2Na_2 S_2 O_3 = Na_2 S_4 O_6 + 2NaI.$$

The reaction is rapid and quantitative and has a convenient indicator—Starch solution, showing blue color which is a very sensitive test of free iodine.

(a) There is a danger of the loss of iodine vapour; the flask should, therefore, be kept closed in dark place except during the titration and vigorous shaking should be avoided;

(b) As the reaction between dichromate and iodide is not instantaneous, after adding the reagents the solution should be allowed to stand for a while in dark place. The solution should not be allowed to stand for a long time as air oxidation of the iodide may take place.

Reaction of potassium iodate with sodium bi sulphite:

If sodium bi-sulphite is added to potassium iodate solution, it may be reduced to free iodine

$NaIO_3 + NaHSO_3 = 3NaHSO_4 + 2\ Na_2\ SO_4 + I_2 + H_2O.$

Reaction of iodide with oxygen:

Potassium iodide may be oxidized to free iodine by oxygen in air if it allowed to stand in open air for a long time.

$$2KI + [O] \Leftrightarrow I_2 + 2KOH$$

CHAPTER FOUR

METHODOLOGY

CHAPTER 4
METHODOLOGY

4.1 INTRODUCTION

Bleaching powder solution or chlorine gas is generally used in water supply to provide safe water to consumers in different parts of the world *(Aziz, 1986)*. The chlorine gas or liberated free chlorine from bleaching powder acts as disinfectant in water. People generally use these chemicals in excess than required to safeguard against disease producing micro-organisms. The excess chlorine makes water impure. On the other hand, ground water contains high concentration of iron and in different areas of Bangladesh the concentration is much higher than the allowable limit. These impurities may react with iodide salt used in table salts and thus may affect the effectiveness of iodine in human health.

This chapter deals with different experiments to observe the behaviour of iodide salt with these oxidizing agents (chlorine and ferric iron) at different conditions of water such as temperature, pH, elapsed time etc. Moreover, a field study has been carried out in different parts of Bangladesh to know people's ideas about iodized table salts and iodine deficiency disorders among people.

4.2 MATERIALS AND METHODS

Artificial chlorine and iron content contaminated waters were prepared with distilled water as described later in Section 4.4.1 and 4.4.2 from stock solutions of bleaching powder and ferric chloride respectively. Iodine stock solution prepared from commercially available potassium iodide salt with distilled water was used as source of iodine as iodide form.

The standard method *(AWWA, 1985)* was used to determine free residual chlorine in water. The same method was used for the measurement of free residual iodine in water. The free residual iodide in solution was determined using the standard method for the standardization of sodium thiosulphate by potassium dichromate solution *(AWWA, 1985)*.

4.3 PROCESS FOR MAINTAINING CONSTANT TEMPERATURE

A crude procedure was followed in this study to maintain a constant temperature due to unavailability of constant temperature bath in the laboratory. For temperature higher than room temperature, constant temperature was maintained by immersing the flask in a hot water jar having temperature slightly less than the respective test temperature. In case of temperature lower than room temperature constant temperature was maintained by immersing the flask in a cold water jar having temperature slightly higher than the respective test temperature. Again to maintain water temperature in jars, sometimes hot or cold water was poured.

Limitation of the Procedure

It is very difficult to maintain a constant temperature for a long time in this way and even for a short time near boiling point of water or temperature at which water starts to solidify. Therefore it was not possible to conduct the experiments near boiling temperature of water as well as near temperature at which water tends to solidify. The temperature range that was possible to maintain as constant in this study was 10°C to 65°C. From trial tests it was observed that a constant temperature can be maintained as long as for 30 minutes if temperature ranges from 10°C to 40°C, and for five minutes for a temperature range of 40°C to 65°C. Based on the observation on the procedure about ±1°C temperature error was observed in this study.

4.4 PREPARATION OF SAMPLE

4.4.1 Preparation of Chlorinated Water Sample

After vigorous shaking, the available free residual chlorine in bleaching stock solution was determined. Required amount of distilled water was taken into a conical flask. The temperature of the distilled water was brought to a desired temperature. The temperature was raised by an electric heater or lowered by immersing the flask in an ice containing jar. The temperature was measured by a thermometer. After heating, water in the flask was brought to the previous mark by adding distilled water of the same temperature . Considering the temperature effect on chlorine described in section 5.2 required amount of bleaching stock solution was mixed with distilled water to obtain 1.135 ppm free residual chlorine in the solution at a desired test temperature. The constant temperature for contact time was maintained following the procedure as described in Section 4.3.4 and the 1.135 ppm free residual chlorine at a test temperature was verified by measuring free residual chlorine in water.

4.4.2 Preparation of Iron Contained Water Sample

Required amount of distilled water was taken into a conical flask. The temperature of the water was brought to a desired temperature. Required amount of iron from ferric iron stock solution was added to the water to get a desired iron contained water.

To prepare iron contained water having different pH, the pH of distilled water was adjusted by adding sodium hydroxide or hydrochloric acid.

4.5 EXPERIMENTAL PROCEDURE

4.5.1Measurement Of Free Residual Chlorine In Chlorinated Water At Different Temperatures

After vigorous shaking the available chlorine in bleaching stock solution was measured according to the standard method *(AWWA, 1985)* Required amount of distilled water was taken into a conical flask and the temperature of water was brought to a desired temperature. The temperature was maintained constant for five minute contact time following the procedure described earlier. The temperature in this study was varied ranging from 10°C to 65°C. Residual chlorine changes with temperature. Required amount of bleaching stock solution was added with distilled water to obtain 1.135 ppm free residual chlorine. In all cases the quantity of residual chlorine was verified to maintain 1.135 ppm chlorine after five minute contact time. The results have been discussed in Section 5.2.

To observe the evaporation rate of chlorine with elapsed time at 20°C, a test was carried out. 1.135 ppm chlorinated water prepared as previously were taken in four separate flasks. The flasks were allowed to stand under exposure to open air for 5 min, 10 min, 15 min and 30 min respectively. The temperature during this time was maintained as constant. After elapsed time free residual chlorine was measured. The results have been discussed in Section 5.2.

4.5.2Measurement Of Free Residual Iodine In Chlorinated Water At Different Conditions Of Water

4.5.2.1 At Different Temperature

About 10.20 ppm iodine as iodide form from iodide stock solution was mixed with 1.135 ppm chlorinated water prepared at a test temperature. The free residual iodine in the test sample was measured following the standard method *(AWWA, 1985)* for five minute contact time. The constant temperature was maintained following the procedure described in section 4.3. The excess iodide ion in solution was measured according to the method mentioned in section 4.2. The same test temperatures as followed in determination of free residual chlorine in water were considered in this study. The results have been tabulated in table-5(a). and discussed in section 5.3.

4.5.2.2 With Elapsed Time at Some Constant Temperatures

Following the same procedure described earlier the test sample was taken in three separate flasks. One was brought under determination of free residual iodine in solution for contact time of five minutes. Between the rest two flasks, one was allowed to stand under exposure to open air for 15 minutes and the other for 30 minutes. During this time the temperature was maintained constant. After elapsed time free residual iodine in two flasks were measured. The following constant temperature ranges from 10°C to 40°C. The constant temperatures was possible to maintain for about 30 minutes. The results have been tabulated in table A2 and discussed in section 5.3.2.

4.5.2.3 At Different pH Conditions

Following the same procedure as described in section 4.5.1 free residual iodine was measured with elapsed time. The results have been tabulated in table A3 and discussed in section 5.3.3.

The pH range that followed in this experiment was 4 to 8.

4.5.2.4 At Different Iodide Concentration

The same procedure was followed as described in section 4.5.2 for 20°C temperature. The test was repeated for different iodide concentration.

The iodide concentration followed in this study ranges from 7.25 ppm to 14.5 ppm. The results have been tabulated in table A5 and discussed in section 5.3.4.

4.5.3Measurement of Free Residual Iodine From Iodide Salt In Iron Contaminated Water At Different Water Conditions

4.5.3.1 In Different Iron Contained Waters

In this experiment 1,2,3,4,5,10 and 15 ppm different iron contained water were taken in seven separate conical flasks. 3 ppm iodine as iodide form was added in each flask.

After slight shaking the flasks were made stoppered and kept in dark and cool place for 10 minutes for completion of reaction. After 10 minutes the stoppers were released and rinsed with a little water. The water was collected in respective flask. 1 ml starch was added successively in each flask. The experiments were conducted at room temperature that varied from 26°C to 28°C.

The solution in the flasks showing blue color as an indicator of the existence of free residual iodine was titrated according to the standard *(AWWA, 1985)* method. The other flasks showing no blue color were allowed to stand under exposure to open air. The blue color appeared with time. The free residual iodine in those flasks were measured.

The test was repeated varying the iodide concentration by 5, 10, 20, 30, 40, 50, 60, 70, 80 and 90 ppm successively. The results have been discussed in section 5.4.1.

4.5.3.2 At Different Temperatures

The flasks containing different amount iron solutions as described were heated to raise temperature of solution by 40°C, 50°C and 60°C or immersed in an ice containing water jar to lower temperature by 20°C and 15°C . Then 80 ppm iodide solution was added in each flask. Following the same procedure as described in section 4.5.3.1, the solutions in the flasks were allowed to stand in dark and cool place for 10 minutes. The constant temperature during this time was maintained following the procedure as described in section 4.3.

The test was repeated for iodide concentration of 90 ppm. The iodine appeared in different flasks with time were measured. The results have been discussed in Section 5.4.2.

4.5.3.3 With Elapsed Time at Constant Temperature

In four separate flasks 15 ppm iron solution were taken and 90 ppm iodine as iodide form was added in each flask.

After reaction time following the same procedure described in section 4.5.3.1 the flasks were allowed to stand for 5minutes,10 minutes,15 minutes and 30 minutes at constant 30°C temperature. The free residual iodine in different flasks were measured. The results have been described in section 5.4.3.

4.5.4 FIELD STUDY

A survey on people's ideas about iodized table salts and iodine deficiency disorders among them has been carried out in different parts of Bangladesh based on the questionnare shown in Appendix-A. In some districts data was not collected in a random manner. The survey area covers Kutirpara Village of Rangpur, Khaturia and Jaldhaka Villages of Nilfamari, Farmehat and Pamuli Villages of Dinajpur, Chandangati and Shellbaria Villages of Sirajganj, Murapara Village of Narayanganj, Basail Village of Tangail, Nizgram & Baliadanga Village of Khulna, Khulna Sadar of Khulna, Baxiganj and Talukshuval Village of Kurigram, Sundarpur Village of Gaibandha, slum area near BUET campus of Dhaka, and some staffs' and teachers quarters of BUET in Dhaka. The results have been discussed in Section 5.6.

Moreover, the existence of iodine in iodized table salts as iodate and iodide form was verified using tartaric acid and chlorine respectively. Starch was added as indicator of iodine. Violet colour and blue colour proved the existence of iodate and iodide ion respectively.

CHAPTER
FIVE

RESULTS AND DISCUSSIONS

CHAPTER 5
RESULTS AND DISCUSSIONS

5.1 INTRODUCTION

In this chapter, the observations of the behavior of iodide salt in chlorine and iron contaminated water have been discussed. It was observed that the reducing agent potassium iodide reacts with oxidizing agents e.g. chlorine and ferric iron and liberates free iodine in water. The respective reactions have been described in section 3.16. The reaction of potassium iodide salt with chlorine is rapid but that with ferric iron is very slow. The test results have been discussed successively in this chapter in separate sections.

5.2 FREE RESIDUAL CHLORINE AT DIFFERENT TEMPERATURES AND WITH ELAPSED TIME

Free residual chlorine for a constant dose were measured at different temperature. The results are shown in figure 5.1. From the figure it is observed that free residual chlorine in water decreases with increase in temperature. The rate of loss is very slow from 10°C to 30°C. A sharp change in free residual chlorine occurs at 30°C temperature. This abrupt change may be due to decrease in solubility of chlorine in water. The loss in free residual chlorine may be due to its volatile nature under exposer to open air during handling of bleaching solution from bottle to flask and mixing of it with distilled water. The higher loss in free residual chlorine above 30°C is due to agitation of water molecules. Because as agitation of water molecules increases, more free chlorine molecules escape to the surrounding air from water. In other words temperature increases, the solubility of chlorine in water decreases and therefore more chlorine molecules evaporates at higher temperatures. From tabulated

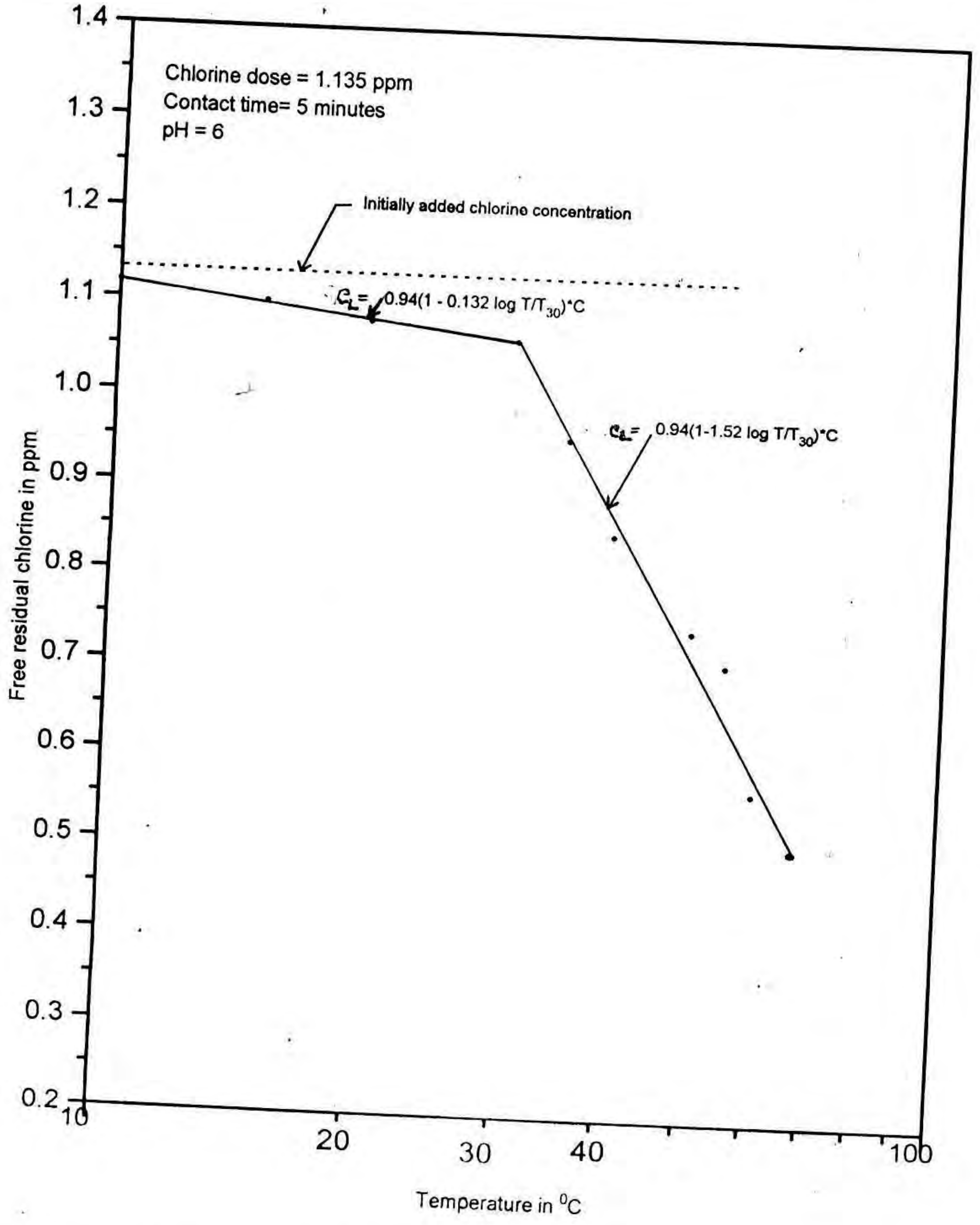


Figure 5.1: . Free Residual Chlorine at Different Temperatures

results in table 5(a) it is observed that only 1.6% loss in chlorine occurs at 10°C while at 65°C the loss is as high as 53.1% of initial chlorine dose. About 3.1%, 4.8%, 6.3%, 5.7%, 25%, 34.4%, 37% and 50% loss in free residual chlorine were found at 15°C , 20°C , 30°C , 35°C , 40°C , 50°C, 55°C and 60°C temperature respectively. Figure 5.1 expresses two linear relationships of free residual chlorine with temperature. One for temperature range 10 °C≤ T≤ 30 °C and the other for temperature range 30 °C≤ T≤ 65°C.

The relationships can be stated as follows:

$$C_L = 0.937\left((1 - 0.131 \log\frac{T}{T_{30}}\right) xC \qquad 10^{\circ}\mathrm{C} \leq T \leq 30^{\circ}\mathrm{C}$$

$$C_L = 0.937\left((1 - 0.152 \log\frac{T}{T_{30}}\right) xC \qquad 30^{\circ}\mathrm{C} \leq T \leq 65^{\circ}\mathrm{C}$$

where, C_L = Free residual chlorine in water after 5 minute contact time in ppm

T = Temperature within the range in °C

C = Concentration of chlorine in ppm

T_{30} = 30°C temperature

In figure 5.2 the variation of free residual chlorine with elased time are shown. It is clear that free residual chlorine decreases with elapsed time. About 0.213 ppm loss in free residual chlorine occurs at 20°C constant temperature for 20 minute contact time in air which is about 18.8% of initial chlorine dose. About

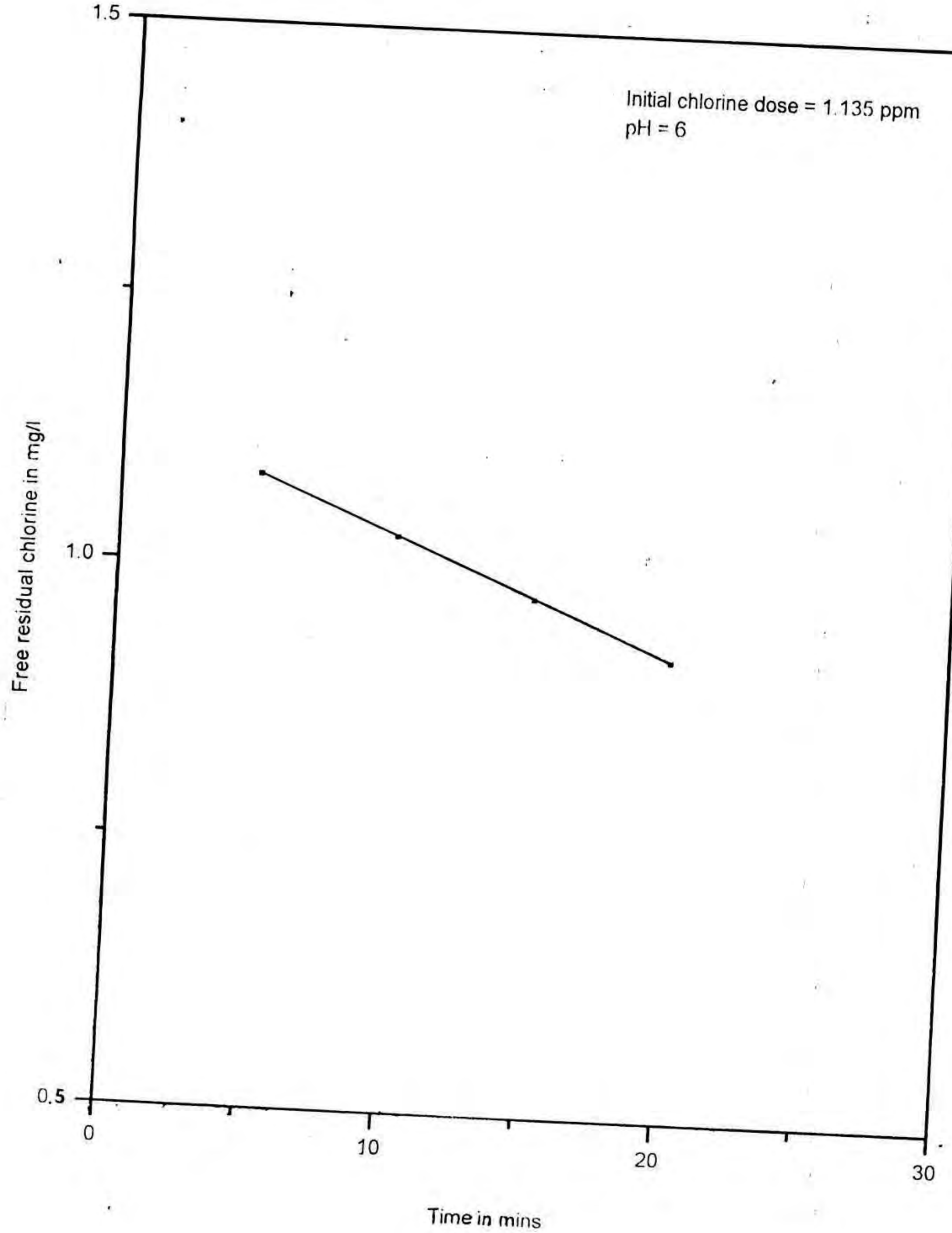


Figure 5.2: Free Residual Chlorine with Elapsed Time at 20°C

4.7%, 9.4% and 14.1% loss in free residual chlorine occur for 5, 10, and 15 minute contact time of free residual chlorine under exposure to open air.

As chlorine evaporates with temperature, chlorine doses required to maintain a constant chlorine concentration at different temperatures to observe the behaviour of iodide salt in chlorine contaminated water were calculated from the loss of chlorine in water at those temperatures and shown in table 5(a).

Table-5(a): Free residual chlorine and evaporation rate of chlorine at different temperatures at pH 6.0 and after 5 minute contact time

Initial Chlorine Dose C = 1.135 ppm

Temperature in ^{o}C	**10**	**15**	**20**	**30**	**35**	**40**	**50**	**55**	**60**	**65**
Free Residual Chlorine in ppm	1.117	1.10	1.081	1.064	0.957	0.851	0.745	0.709	0.567	0.532
Loss in free residual chlorine in ppm	0.018	0.035	0.054	0.071	0.178	0.284	0.390	0.426	0.568	0.603
Loss in free residual chlorine in percentage C_L	1.6	3.1	4.8	6.3	15.7	2.5	34.4	37.5	50	53.1
Calculated chlorine dose required to maintain constant chlorine concentration $C_R=100C/(100-C_L)$	1.153	1.171	1.2	1.211	1.35	1.514	1.73	1.82	2.27	2.4

5.3 BEHAVIOUR OF IODIDE SALT IN CHLORINATED WATER AT DIFFERENT CONDITIONS OF WATER

5.3.1At Different Temperatures

Free residual iodine in 1.135 ppm chlorine contaminated water with 10.20 ppm iodine as iodide form were measured at different temperature. The results are shown in figure 5.3.

From figure 5.3 it is observed that maximum free residual iodine is found at 20°C. From 20°C temperature, as temperature increases the free residual iodine in solution decreases. The pertinent reaction of potassium iodide with chlorine has been described earlier. In Table 5(b) it is noticed that the difference between theoritical and observed free residual iodine is higher below 20°C temperature which is unexpected. Because iodine is less volatile at lower temperature. This discrimination may be due to incomplete reaction of potassium iodide with chlorine at lower temperature that was ensured by determining residual iodide ion in solution after determination of free residual iodine. The reactions have been described in section 3.16. The complete reaction at higher temperature were also ensured by measuring iodide ion after determination of free residual iodine in solution. The results are shown in figure 5.4. At 20°C and above this temperature, the residual iodide ion found was found more or less same as the excess iodide ion to that theoritically required to react with 1.135 ppm residual chlorine in water. In some cases 0.06 ppm iodide ion variation was observed. But below 20°C the residual iodide ion in solution was more than the excess iodide ion to that theoritically required. From above discussion it is clear that 20°C may be the minimum temperature for completion of the reaction. As the determination of residual iodide ion in solutiion is a tedius work only a few tests were done to determine free residual iodide ion in solution.

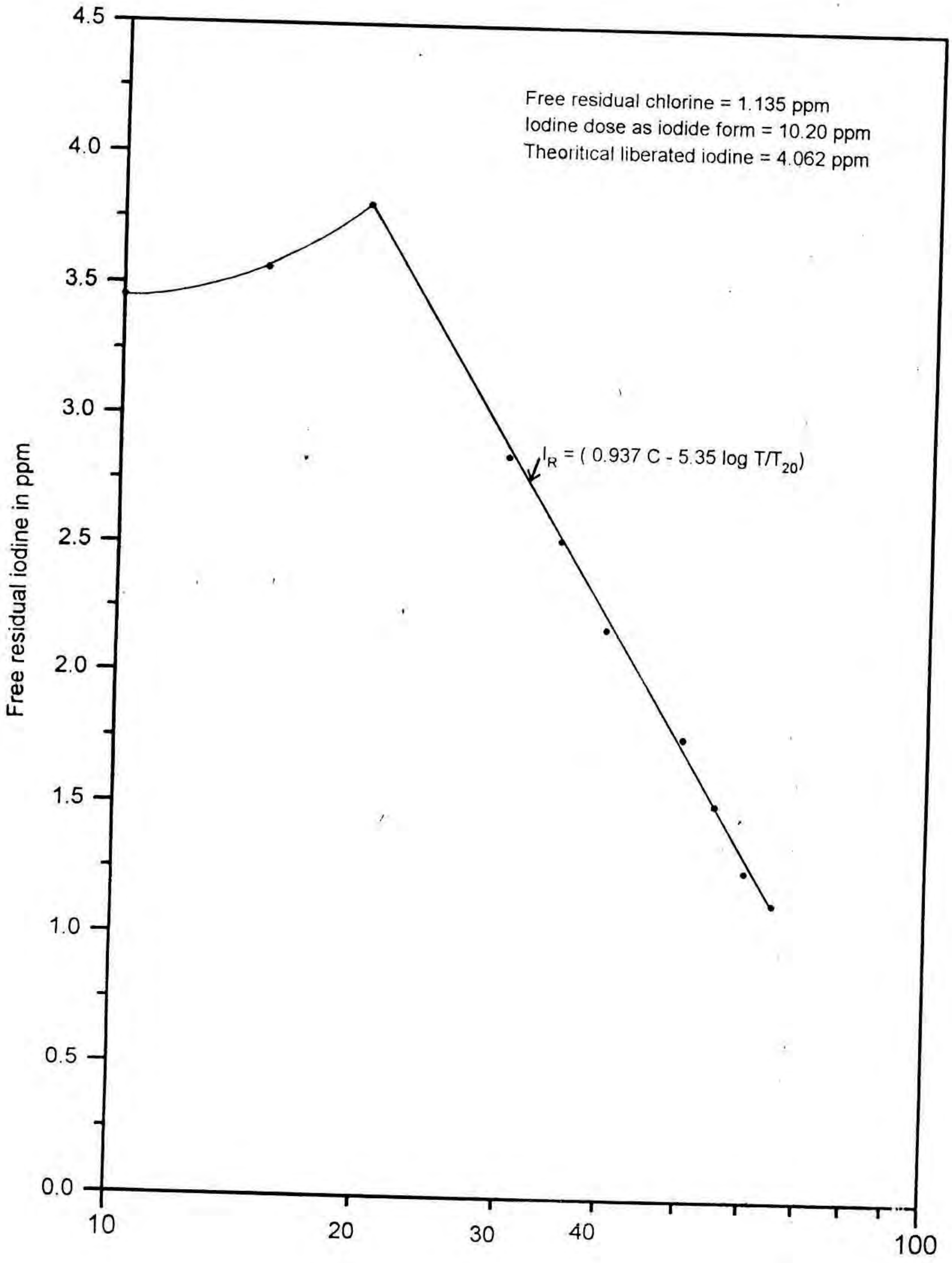


Figure 5.3: Free Residual Iodine at Different Temperatures for five minutes contact time and at pH of 6.

The loss in free residual iodine at any temperature may be due to handling and mixing of solution under exposure to open air. This is because aqueous solutions of iodine have an appreciable vapour pressure of iodine so that concentration gradually decreases. An abrupt change at 20°C may be due to increase in the rate of reaction of potassium iodide with chlorine. The higher loss at higher temperatures may be due to the agitation of water molecules. As temperature increases, the agitation of water molecules increases and therefore more iodine molecules escape to the surrounding air from water molecules at higher temperature.

Table- 5(b): Free Residual Iodine at different temperatures

Free residual chlorine = 1.135 ppm
Iodine dose as iodide form = 10.20 ppm
Theoritical liberated free residual iodine = 4.062 ppm
Contact time = 5 mins.

Temperature in °C	10	15	20	30	35	40	50	55	60	65
Free observed residual iodine in ppm	3.256	3.567	3.807	2.855	2.53	2.184	1.77	1.52	1.264	1.142
Difference between theoritical and observed free residual iodine in ppm	0.608	0.495	0.255	1.207	1.532	1.878	2.292	2.542	2.798	2.922

From plotted results in a semilog paper shown in figure 5.3, a linear relationship between free residual iodine and temperature is found in the temperature range from 20°C to 65°C.

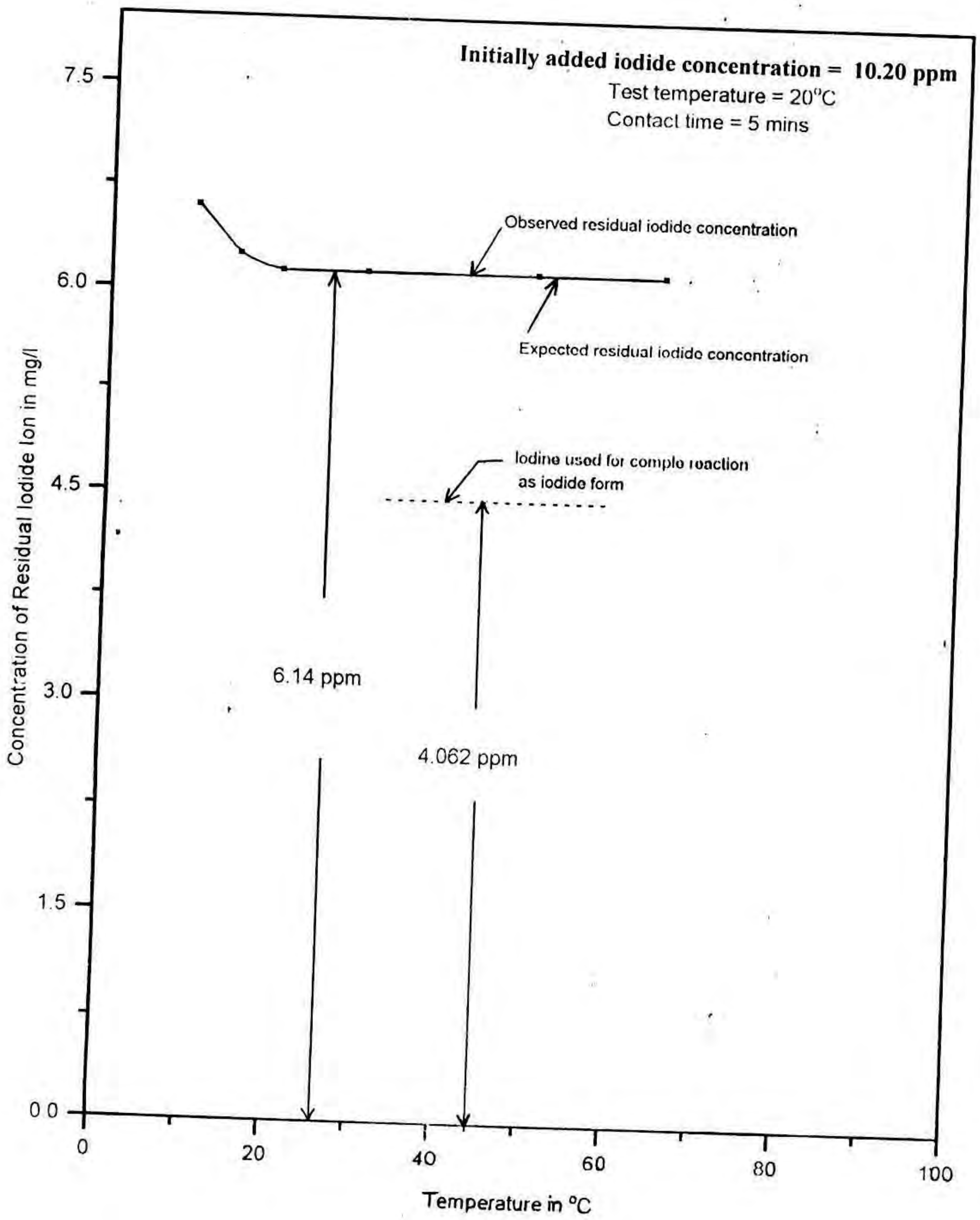


Figure 5.4: : Residual iodide ion in solution of tested samples at different temperatures after ditermination of free residual iodine

The relationship can be stated as follows:

$$I_R = \left(0.937\ C - 5.35\ \log \frac{T}{T_{20}}\right) \qquad 20^{\circ}C \leq T \leq 65^{\circ}C$$

provided iodide concentration is 6.14 ppm in excess to theoritically required

where , I_R = free residual iodine in ppm
C = Theoritical liberated iodine in ppm
T = Temperature in °C within range
T_{20} = 20°C temperature.

No linear relationship is observed between 10°C and 20°C temperature due to incomplete reaction of chlorine with potassium iodide at low temperature.

From figure 5.5 it is seen that from 10°C to 20°C, the loss in free residual iodine increases at a slow rate. A sharp increase in loss of free residual iodine is noticeable between 20°C to 30°C temperature. This sharp change may be due to increase in the rate of reaction. With increase in temperature, the loss increases. Because as temperature increases, the solubility of iodine in water increases. At 10°C the loss is about 3.5% while at 65°C it is as high as 71.9%. In other words about 19 times more loss in free residual iodine occurs at 65°C than that at 10°C. About 4.4%, 6.3%, 29%, 37.7%, 46.2%, 56.4%, 62.6% and 68.6% loss in free residual iodine occurs at 15°C, 20°C, 30°C, 35°C, 40°C, 50°C, 55°C and 60°C temperature respectively. At 30°C temperature about 3.5 times more loss in free residual iodine occcurs than that at 20°C. At 55°C the loss is about 9 times that at 20°C.

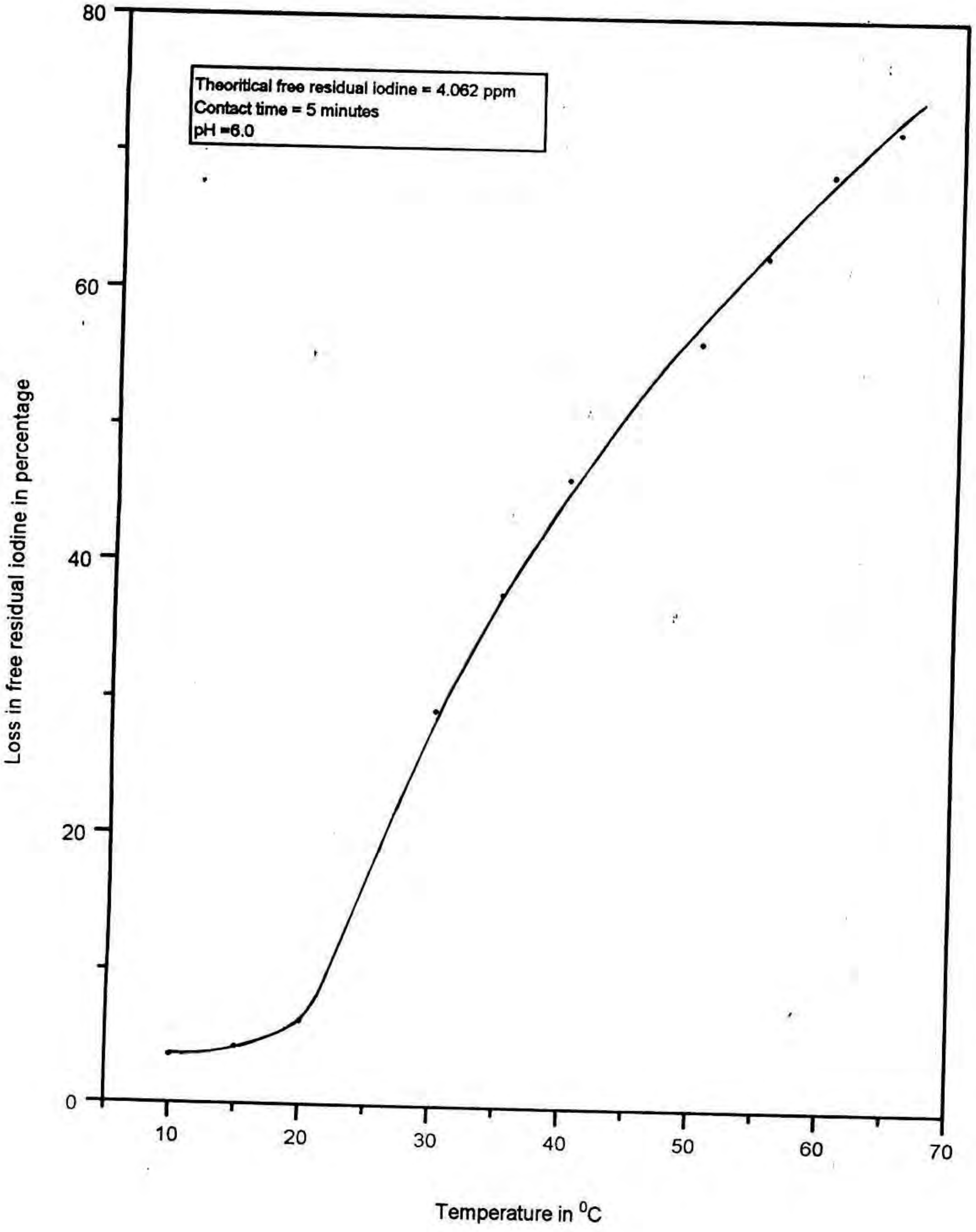


Figure 5.5: Percentage Loss in Free Residual Iodine at Different Temperatures

5.3.2 With Elapsed Time at Different Temperature

Free residual iodine were determined at four different constant temperatures with elapsed time. The results are shown in figure 5.6(a). From the figure it is observed that free residual iodine decreases with elapsed time at any constant temperature. The decreasing trend of free residual iodine increase with increasing temperature. This higher loss at higher temperature may be due to the agitation of water molecules that expedites the evaporation rate of iodine. From figure 5.6(a) it is also noticed that at 10°C the observed free residual iodine is less than that obtained at 20°C for five minutes contact time in air. This may be due to incomplete reaction.

The results of figure 5.6(a) has been plotted in a semilog paper and are shown in figure 5.6(b). From the extended portion of the three curves, it is found that about 0.022 ppm, 0.582 ppm and 0.922 ppm iodine instantaneously evaporates at 20°C, 30°C and 40°C temperature respectively. At 20°C the instantaneous loss is very low. At 30°C temperature the loss is very high. About 26 times the loss at 20°C occurs at 30°C. At 40°C it is about 42 times. Three relationships for 20°C, 30°C and 40°C temperature have been developed for the variation of free residual iodine with elapsed time.

The relationships can be stated as follows:

$$I_R = 0.995\,C - 0.402\log_{10}(t+1) \qquad \text{at } T = 20^{\circ}C$$

$$I_R = 0.837\,C - 0.754\log_{10}(t+1) \qquad \text{at } T = 30^{\circ}C$$

$$I_R = 0.739\,C - 1.288\log_{10}(t+1) \qquad \text{at } T = 40^{\circ}C$$

provided iodide concentration is 6.14 ppm in excess to theoritically required

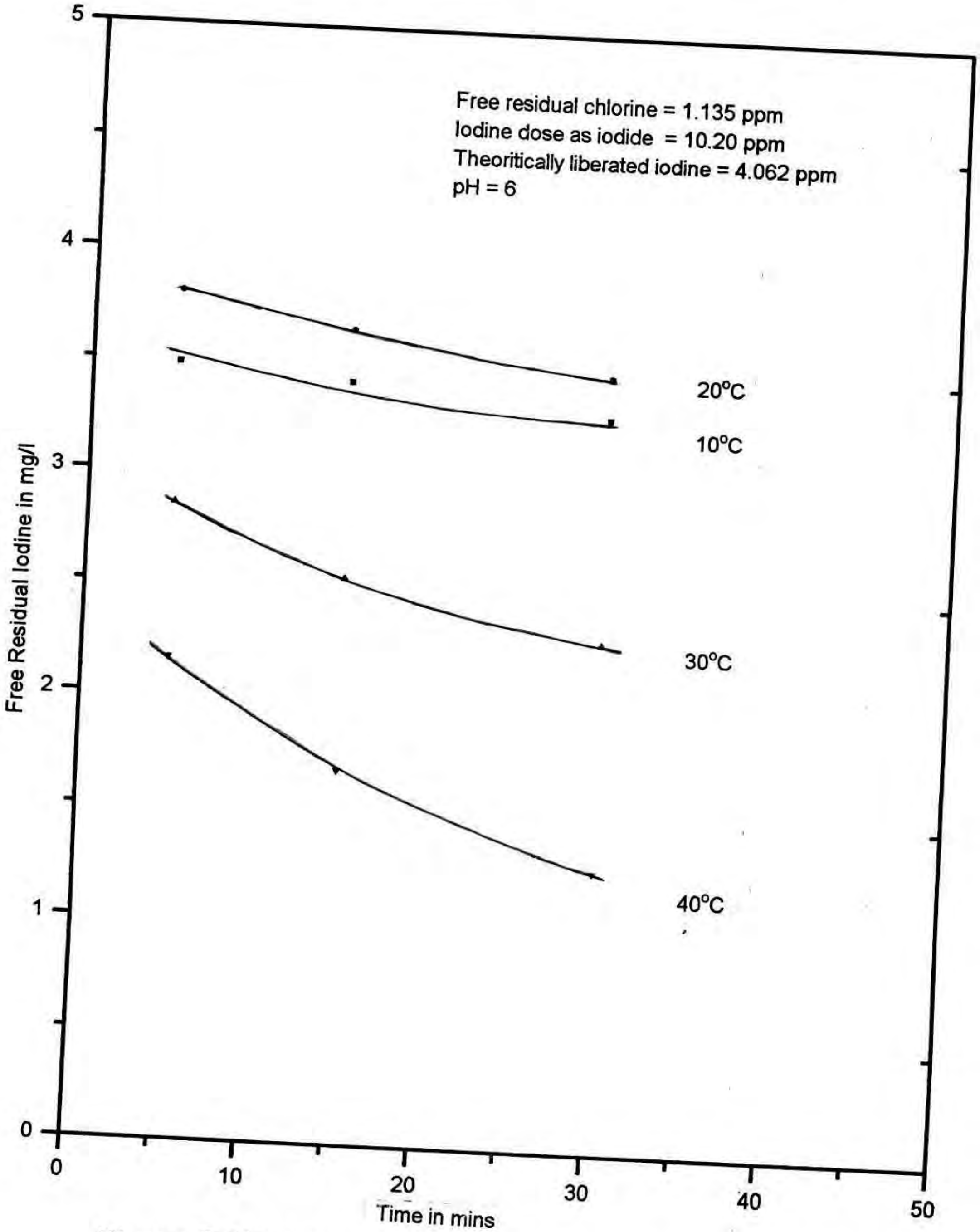


Figure 5.6(a): **Variation of Free Residual Iodine with Time at different Temperatures at pH 6**

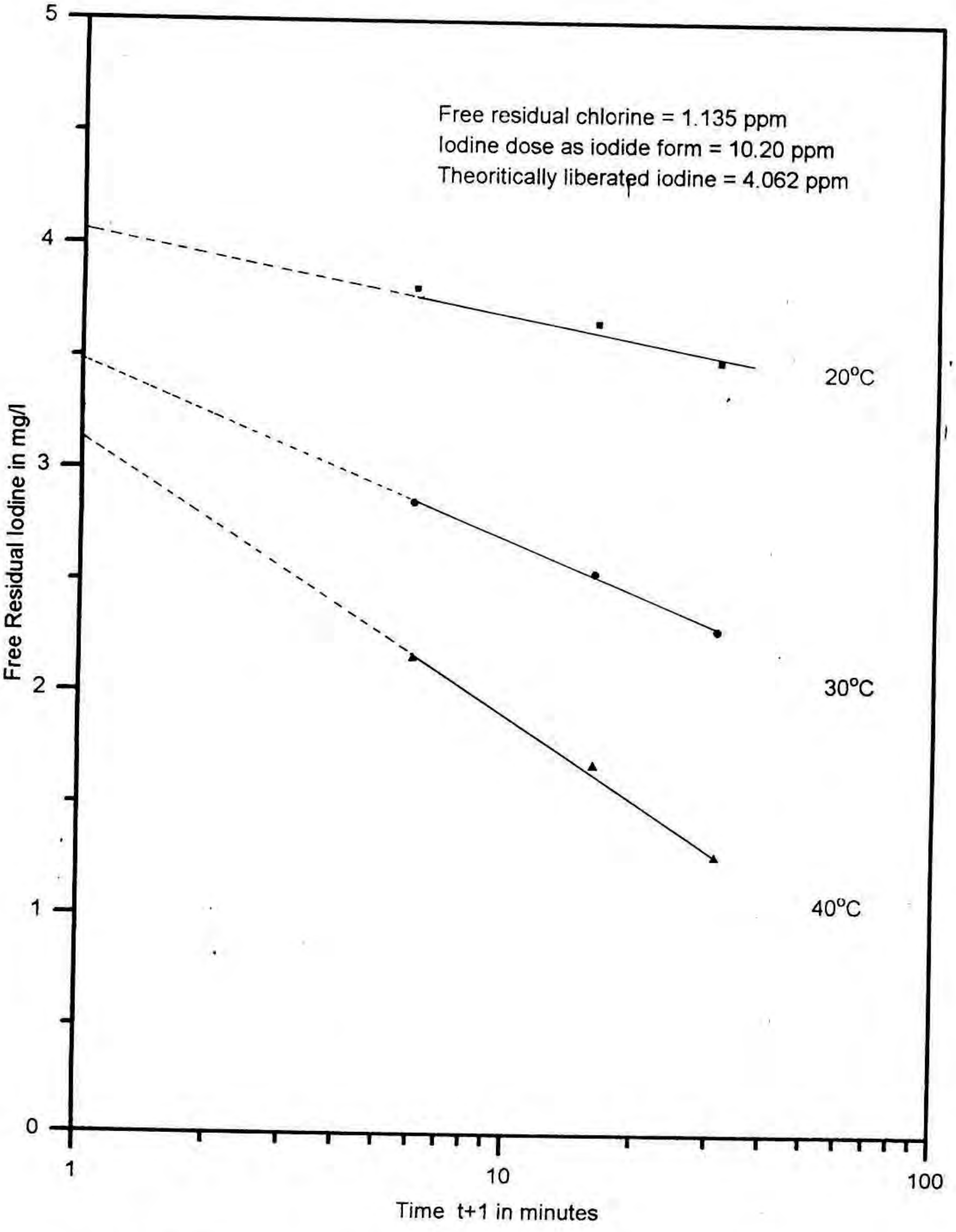


Figure 5.6(b): Variation of Free Residual Iodine with Time at Different Temperatures and pH 6

where, I_R = Free residual Iodine in ppm

C = Theoritical liberated iodine in ppm

t = elapsed time in the range 0 to 30 minutes

T = temperature in °C

Iodine in salt is added as a small proportion of sodium salt. The recommended value of potassium iodide in salt is only 0.02% *(Bernard, 1952). A*ccording to WHO the recommended value of chloride in drinking water is 250 mg/l and that for Bangladesh standard ranges from 250 to 600 mg/l (for coastal areas the value may be as high as 1500 mg/l) *(DOE,1991).* The concentration of chloride for a salty taste in cooking foods may vary from 1000 to 1500 mg/l. The residual iodide in water should be 0.0382, 0.091, 0.153 and 0.228 ppm if 0.02% potassium iodide is used in 250 ppm, 600 ppm, 1000 ppm and 1500 ppm chloride contained salts respectively. For those residual iodide ion in water, if water contains theoritically 0.011, 0.0262, 0.044 and 0.0657 ppm chlorine respectively, the liberated iodine may escape into air instantaneously at 30°C temperature. Because the instantaneous loss at 30°C is more than the theoritically liberated iodine in every case. At 40°C the instantaneous loss is more higher. At 20°C though the instantaneous loss is very low, the liberated iodine will evaporate with elapsed time within five minutes.

5.3.3At Different pH

In this section free residual iodine were measured at different pH and with elapsed time at a constant temperature. The results are shown in figure 5.8. From the figure it is observed that free residual iodine is about same at any pH for five minute contact time. This states that there is no effect of pH on evaporation of iodine for five minutes contact time. This is because a five minute contact time may not be sufficient for desorption of iodine molecules from liquid phase to gaseous phase to maintain the molecular equilibrium at gas-liquid phase for evaporation of iodine. But more

90715

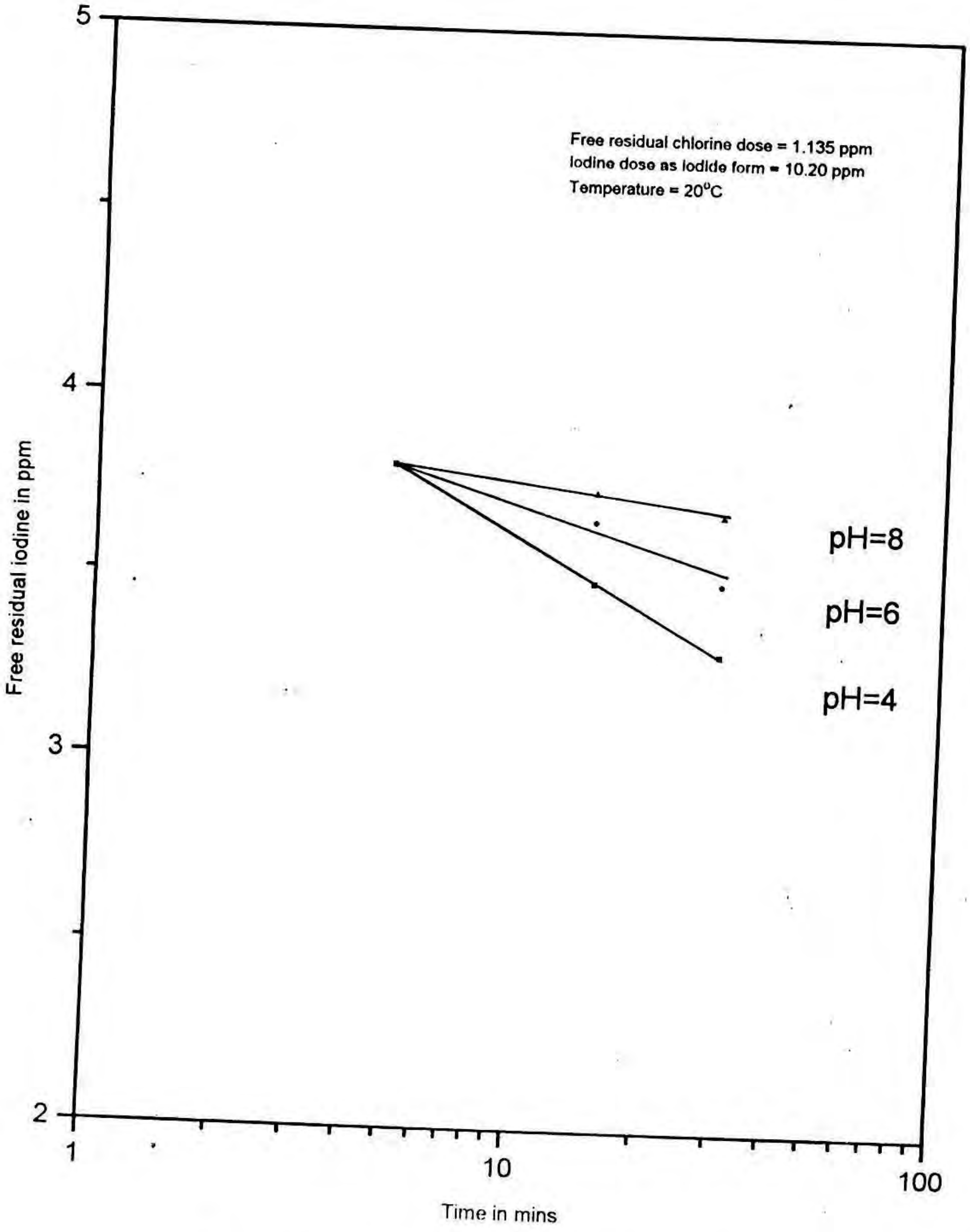


Figure 5.7: Variation of Free Residual Iodine With Time in ppm at different pH conditions.

detailed work is needed between 5 and 10 minutes contact time to know the fact. From the figure it is observed that free residual iodine decreases with elapsed time. The decreasing trend of free residual iodine increases with increasing pH. A low pH accelerates the evaporation of iodine.

Three linear relationships have been developed for free residual iodine with elapsed time at pH 4, pH 6 and pH 8. The relationships can be stated as follows:

$$I_R = 0.937\,C - 0.664\log_{10}(t/t_5) \quad \text{at } pH = 4$$
$$I_R = 0.937\,C - 0.364\log_{10}(t/t_5) \quad \text{at } pH = 6$$
$$I_R = 0.937\,C - 0.1365\log_{10}(t/t_5) \quad \text{at } pH = 8$$

where, I_R = Free residual Iodine in ppm
C = Concentration of theoritical liberated iodine in ppm for five minute contact time and constant 20°C temperature
t = time in min .
t_5 = 5 min.

5.3.4At different iodide concentration:

From this experiments it is observed that for variation of iodide ion concentration in chlorinated water within the range 7 to 15 ppm, there is no significant change in residual iodine in solution. A little variation in free residual iodine from 0.057 ppm to 0.063 was observed.

5.4 OBSERVATION OF FREE RESIDUAL IODINE IN IRON CONTENT WATER AT DIFFERENT CONDITIONS OF WATER

5.4.1In Different Ferric Iron Contaminated Waters

In this section free residual iodine was measured in different ferric iron contained waters using same as well as various concentrations of iodine as iodide form. The results have been tabulated in Table 5(c).

From tabulated results in Table 5(c) it is observed that the reaction of ferric iron with iodide salt is very slow but it depends on the concentration of ferric iron as well as iodide ion in solution. An increase in iodide concentration for a certain concentration of ferric iron in water expedites the reaction. A rapid reaction is found in 15 ppm ferric iron contaminated water for addition of 90 ppm iodine as iodide form. But in solution the theoritical iodine liberated from 15 ppm ferric iron should be 34.0 ppm. The pertinent reaction has been discussed in section 3.15 of Chapter-3. The difference between theoritical and observed iodine is 29.05 ppm respectively.This high difference in iodine may be due to precipitate form of ferric iron as ferric hydroxide in solution.

The precipitate form of ferric iron decelerates the reaction. Therefore no free residual iodine was found in water at low concentration of iron. Free residual iodine was not found in water contaminated by ferric iron ranging from 1 ppm to 15 ppm even after one day for addition of 30 ppm iodine as iodide form.

Table 5(c): **Free Residual Iodine (ppm) in different ferric iron contained waters using various concentrations of iodine as iodide form**

Iodine concentration as iodide form in ppm	**Concentrarion of Iron in ppm**				**Contact time to appear iodine**
	1 to 4	5	10	15	
3 to 30	Nil	Nil	Nil	Nil	After 1 day
40		1.015	2.538	4.062	After 22 hrs
50		Nil	Nil	5.076	After 15 hrs
60		Nil	2.79	4.188	After 30 hrs
70		Nil	2.538	4.569	After 25 min
80		Nil	2.289	3.68	After 20 min
90		Nil	3.425	4.95	Within five minutes.

5.4.2At Different Temperatures:

Free residual iodine was measured in 15 ppm ferric iron contained water using 80 ppm and 90 ppm iodine as iodide form separately. The results have been tabulated in table 5(d). From the tabulated results it is observed that the reaction of ferric iron with iodide salt is very slow. For addition of 80 ppm iodine as iodide form iodine appeared in solution after 20 minutes. About same amount of free residual iodine were found at different temperatures. This states the reaction of ferric iron with iodide ion is very slow and temperature does not accelerate the reaction.

For addition of 90 ppm iodine as iodide form, the free residual iodine appeared after 5 minute contact time which was indicated by starch. From table 5(d) it is shown that free residual iodine that liberates in solution decreases with increase in temperature. The decrease in free

Table 5(d) : Free Residual Iodine in ppm at different temperatures in different iron contained water

Iodine concentration in iodide form in ppm	Temperature in °C	Concentration of Iron in ppm			Contact time in minutes
		1 to 5	10	15	
80	15	Nil	2.285	4.188	20 minutes
	20	Nil	2.285	4.188	20 minuts
	30	Nil	2.285	4.1880	20 minutes
	40	Nil	2.285	4.188	
90	15	Nil	4.25	5.076	5 minutes
	20	Nil	4.44	5.140	5 minutes
	30	Nil	3.36	4.188	5 minutes
	40	Nil	2.538	3.538	5 minutes

residual iodine in this case may be due to evaporation of free iodine during handling and mixing for titration at those temperatures. The cause of more loss in free residual iodine at higher temperature has been described in section 5.3.1.

5.4.3With Elapsed Time at Constant Temperature

In this section free residual iodine, was determined in 15 ppm iron contained water adding 90 ppm iodine as iodide form. The results haave been tabulated in table 5(e).

Table 5(e): Free Residual Iodine with elapsed time in iron contained water

Iron concentration = 15 ppm
Iodide concentration = 90 ppm

Contact time in min	**5**	**10**	**15**	**30**
Free Residual Iodine in ppm	4.188	4.188	4.69	5.076

The table shows that free residual iodine increases with elapsed time and though free residual iodine appeared in solution in about five minutes, the reaction had not yet been completed.

The increase in free residual iodine with elapsed time is not very high. Because the iodine that liberates, evaporates due to volatile nature of iodine with temperature. The table states that the excess iodine that liberates after 10 minutes equals the loss due to evaporation of iodine for 10 minutes contact time. After 15 minutes and 30 minutes, the excess iodine that liberates are greater than the loss that occurs in 15 and 30 minute contact time respectively.

As the recommended value of iodine in table salt is very low, a trace amount of iodide ion exists in water. For this trace amount of iodine in table salts, the experiments reveals that there would have no significant effect of iron on iodide salt in water.

5.5 THE EXISTENCE OF IODINE IN IODIZED TABLE SALTS

In this section the existence of iodine in iodized table salts mostly available in the markets were observed. The tartaric acid and chlorine were used to identify the presence of iodine in iodized table salts as iodate and iodide form respectively. Starch was added as indicator of iodine . The results are shown in table 5(f).

Table 5(f) : The existence of iodine in iodized table salts of different salt crushing plants available in the markets of Bangladesh

Name of Iodized Salt	Bantex	Existence of Iodine as iodide/Iodate	Existence of Iodine as Iodate/iodide
Treepti Iodized table salt	Hiaat salt industries	Iodide	trace amount
Sohag Iodine Salt	Shama Salt Packaging Industries	Iodide	trace amount
Suruchi Iodized Salt	Suruchi Iodized salt industries	Iodate	trace amount (contains relatively high concentration of iodine as iodate)
Modhumita Iodized salt	Shim Salt Crushing Industries	Iodide	trace amount
Mollar Iodized Salt	Mollar Salt Industries	Iodate	trace amount
Modhumati Iodized Salt	Modhumati salt Industries	Iodate	trace amount

5.6 A FIELD SURVEY ON IODINE DEFICIENCY DISORDERS AND PEOPLE'S ARGUMENTS ABOUT IODIZED TABLE SALTS

A field survey on iodine deficiency disorders and people's ideas about iodized table salts has been carried out in different districts of Bangladesh based on the questionnaire attached in Appendix-A. The area includes Kutirpar Village of Rangpur, Khaturia and Jaldhaka Villages of Nilfamari, Farmehat and Pamuli Villages of Dinajpur, Chandangati and Shelbaria Villages of Sirajgonj, Murapara Village of Narayanganj, Basail Village of Tangail, Nizgram and Baliadanga Villages of Khulna, Baxiganj and Talukshuval Villages of Kurigram, Sundarpur Village of Gaibandha, slum area near BUET campus of Dhaka, some teachers' and staffs' quarters of BUET, Dhaka. The survey results are shown in table 5(g).

Unlike the southern zone (coastal areas), in the northern zone of Bangladesh, soil lack iodine and people can take little sea foods due to unavailability of those foods. For frequent flashing of land due to floods, soil in the northern zone lack iodine. Therefore, in the southern zone, iodine deficiency disorders is low and it increases towards the northern zone. In city or towns where water contain free chlorine, iodine deficiency disorders is low but people in those areas have enough seafoods and they are concious about iodine deficiency disorders. In villages only educated and affluent people buy iodized table salts but poor people take it as *medicine* of Ghagh.

A shopkeeper in the main market of sundarganj thana of Gaibandha district claimed that poor people who suffer from goitrous problems came back to him with accusations of fraud because their goitre could not be cured even after they had taken iodized table salts for several months. The shopkeeper and the village people added that they did not know whether the salt industries add iodine in table salts. But the test results on the existence of iodine in iodized table salts shown in table 5(f) state that salts contain iodine. The poor people in those areas now a days mostly use salts

Table 5 (g) : **A Survey on Iodine Deficiency Disorders (IDD) in different districts**

District	Thana	Village/ Town/City	No. of Families Surveyed	No. of population in persons	No. of People showing goitre visibly in persons	People suffering from visible goitre in %	No. of Cretin Children in persons	No. of people suffering from Iodine Deficiency Disorder in %
Rangpuc	Alamnagar	Kutirpara	20	119	31	26	1	55
Nilfamari	Dumar	Khaturia	25	161	47	29.2	6	60
Nilfamari	Golmunda	Juldhaka	13	112	20	17.8	2	-
Dinajpur	Debiganj	Farmehat & Pamuli	14	99	28	28.2	None	59
Sirajganj	Belkuchi	Chandan-gati and shell baria	35	262	41	15.6	1	52
Narayanganj	Rupganj	Murapara	30	190	18	9.5	None	53
Tangail	Mirzapur	Basai l	35	225	11	4.9	None	52
Khulna	Batighata	Nizgram/ Baliadanga	35	243	None	0	None	20
Khulna	Khulna	Sadar	35	255	-	0.4	None	10
Dhaka	Lalbagh	Slum area near BUET Campus BUET	16	97	1	1.03	None	10
Dhaka	Lalbagh	BUET Teachers Quarter	20	124	None	0	None	5
Dhaka	Lalbagh	BUET Staff Quarters	20	155	None	0	1	10
Kurigram	Ulipur	Baxiganj	28	212	55	25.94	2	60
Kurigram	Rajarhat	Talukshubal	27	201	51	25.4	1	60
Gaibandha	Sundarganj	Sundarpur	26	211	10	4.7	1	58
Rangpur	Saghata	Banuria	35	245	69	28.8	1	56

without iodine which is three taka less than iodized table salts per kilogram. All the surveyed villages were full of emaciated children and adults. There are stunted children, children with squints, children looking 'slow and simple', children with obvious protein energy, malnutrition as well as the hidden hunger of micronutrients like iodine.

A cretin child found in Belabou thana in Narashindi district and also an healthy girl having no iodine deficiency has been displayed in figure 5.8 and figure5.9 respectively which was published in "The Observer", 1995. Moreover a female and a male having visible goitre have been shown in figure 10 and figure 11 respectively. Though a few of the respondents made a vague link between iodized table salts and baseball goitre, not a single person in the areas knew the other consequences. But it was observed that water in the northern zone contain high concentration of iron. In Gaibandha district in the village areas water contain as high as 15 ppm or more iron. Iron incrustation was observed in rice and other cooking foods.

From the survey in the slum area near BUET campus, it was found that out of 27 families except one or two families all use iodized table salts. In this slum area only one female named Mazeda Begum shown in figure 12 was found suffering from goitre swelling a little. Her late mother was also affected by severe goitre. Mazeda Begum would take the costly injection to cure goitre from ICDDRB at Mohakhali, Dhaka. But her doctor has told her not to come to take injection any more.He advised her to take iodized table salts which contain enough iodine to meet health requirement of a human body and to cure goitre. She testified that her goitre could not be cured even after she had taken iodized salts regularly for several months. In reply of the question about the bleaching content in supply water she said that sometimes supply water contain tremendous odor of bleaching powder specifically during the

Figure 5.8 : Abdul is 8, but he is physically retarted and can neither walk nor speak . His mother was iodine deficient during her pregnancy. (*Source :* Yakub, *1995)*

Figure 5.9 : This healthy and happy girl is not iodine deficient and, therefore, likely to have a normal growth. (*Source :* (Yakub, *1995)*

Figure 5.10 : A Female Suffering From Visible Goitre. *(Source : Cover Page,* Yakub, *1995)*

Figure 5.11 : A Male Suffering From Visible Goitre. *(Source : Cover Page,* (Yakub, *1995)*

Figure 5.12 : **Mazeda Begum have a goitre swelling a little.**
(slum area near BUET campus)

cleansing of water. From survey it was found that iodine deficiency disorder is more higher in females than males. To eradicate iodine deficiency disorders the whole world is now fighting for mitigating iodine deficiency in human health providing people with iodine through iodized table salts. But they should aware of that whether this added iodine will be effective for human consumption when they use iodized salts in impure water for drinking or cooking purposes. Thinking over multidimensional health problems due to deficiency of iodine, more detailed investigations on how iodine in iodide or iodate form used in table salts reacts with impure water at different conditions of water is necessary for further studies. .

CHAPTER
SIX

CONCLUSIONS AND RECOMMENDATIONS FOR FURTHER STUDY

CHAPTER-6

CONCLUSIONS AND RECOMMENDATIONS FOR FURTHER STUDY

6.1 CONCLUSION

In this study an attempt has been taken to investigate the effects of different impurities on iodide salts. Several experiments were conducted in chlorine and iron contaminated water by adding potassium iodide salt at different conditions of water e.g. temperature, elapsed time, pH etc. Chlorinated and iron contained water samples were prepared from bleaching powder and ferric chloride stock solutions. Only a limited range of temperature was followed in this study due to unavailability of constant temperature bath in the laboratory. Moreover, a field study was carried out in different districts of Bangladesh to know the iodine deficiency disorders among people and their ideas about iodized table salts. The existence of iodine in iodized table salts were also observed. The major findings of the study can be summerised as follows

1. When iodide salt is used in water containing strong oxidizing agents such as chlorine, free iodine liberates. This liberated free iodine evaporates at different conditions of water. Therefore, the trace amount of iodide salt that is used in table salts for drinking, cooking and other purposes for human consumption will not be effective. But if iodine is used as iodate form, there will have no loss in iodine. So iodine in table salts should use as iodate form if water contains strong oxidizing agents like chlorine.

2. There is no significant effect of iron on iodine when iodide salt is used in ferric iron contaminated water at different conditions of water. The reaction of ferric iron with iodide salt is very slow. The rapid reaction depends both on ferric iron and iodide concentration in water but is independent of temperature. For use of low amount of

iodine in table salts as iodide form, the effect of iron on iodized table salts may be considered as insignificant.

3. The loss in free residual iodine increases with elapsed time at a constant temperature. At 20°C about 0.022 ppm iodine escapes into air instantaneously. The increasing trend of the rate of loss in free residual iodine increases with increasing temperature. At 30°C and 40°C temperature, the instantaneous loss in free iodine are about 13 times and 28 times the loss at 20°C respectively. This states that instantaneous loss increases at a higher rate as temperature increases. Therefore, the small quantity of iodide salt that is used in table salts will escape into the surrounding air instantaneously at higher temperature if water contains free chlorine.

4. At temperature below 20°C, the reaction of chlorine with iodide salt is slow. A complete reaction occurs at 20°C. A little loss in free residual iodine occurs at 10°C. As temperature increases, the loss in free iodine increases. At 30°C the loss starts to become significant. About 1.07 ppm free iodine evaporates into air at 30°C. At 65°C the loss is about 11.5 times that at 20°C. Therefore, though some iodine in table salts may enter into human consumption below 20°C, the use of iodine in table salts as iodide form in chlorine contaminated water will be totally ineffective at 20°C and above this temperature. Because at higher temperature due to complete reaction, all iodide ion will convert into free iodine and will escape into air due to volatile nature of iodine.

5. A low pH accelerates the loss in free residual iodine with contact time. No significant effect of pH is noticeable at 20°C for five minute contact time. Because five minute contact time may not be sufficient for desorption of iodine molecules to maintain molecular equilibrium between liquid and gaseous phase.

6. The evaporation rate of chlorine is more higher than that of iodine at same temperature and elapsed time. The evaporation rate of iodine is about 4.5 times that of chlorine. If water contains low amount of chlorine ranging from 0.015 ppm to 0.58 ppm, the iodide salts should use in water above the boiling temperature of water. In that situation iodine in iodide salt may be effective for human consumption due to evaporation of chlorine at that temperature.

7. The field survey reveals that in the northern zone of Bangladesh like Saghata in Rangpur, Boxiganj in Kurigram, Dumar in Nilfamari, people suffer from goitrous and other iodine deficiency disorders with a high rate. Because soil in those areas lack iodine and people can take little sea foods. On the otherhand, in the coastal zone of Bangladesh where soil contains iodine and people can take sea foods, these problems are low. Towards the northern zone from the southern zone, the rate of goitrous problem and other iodine deficiency disorders increases.

6.2 RECOMMENDATIONS FOR FURTHER STUDY

The following recommendations can be made to extend the scope of the present investigation:

1. The research can be extended for the investigations of the effect of other impurities having oxidizing behaviour such as sulphate, phosphate, carbonate, nitrate in potable water on iodide salts.

2. An investigation also can be carried out to observe the effect of different impurities having reducing behaviour such as iron in ferrous form on iodate salts.

3. The investigations can be extended for higher temperatures above 65°C and lower temperature below 10°C from which more reliable and accurate relationships of loss in free residual iodine for different factors can be established.

4. From the relationships an iodide concentration in table salts can be fixed up for a certain range of chlorine concentration in water so that some iodine may be useful for human body even after evaporation of iodine.

5. A combined relationship of the effect of an impurity on iodide salt for different conditions of water can be established.

6. A detailed survey on iodine deficiency disorders and people's ideas about iodized table salts can be carried out in different parts of Bangladesh.

REFERENCES

REFERENCES

Abrash, H. I. and Hardcastle, K.I. (1981), *Chemistry*, Glencoç publishing Co., California, 1st edition.

Ahmed, M.F., Hossain, M.D. and Khan, L .I. (1989), *Potable Water Supply in Iron Problem Rural areas of Bangladesh*, Final report, Deptartment of Civil Engineering, BUET, Dhaka, Bangladesh.

Ali, M.K. (1990), *Development of A Low Cost Iron Removal plant for Hand Tubewell*, M.Sc.engineering thesis, M-121, Department of Civil Engg., BUET,Dhaka, Bangladesh.

AWWA (19850 , *Standard Methods for Examination of Water and Wastewater*, American association, Washington, 16th edition.

AWWA(1990), *Water Quality & Treatment: a Handbook of Community Water Supplies*, Technical editor, Frederick W.P., Mc-Graw Hill Inc., 4th edition.

Aziz, M.A., (1986), *A Text Book of Water Supply Engineering*, Hafiz Book Centre, Dhaka, Bangladesh.

Bernard, J. (1952), *New World of Chemistry*, Silver burdett Co. Newyork, 3rd edition.

Black, A.P. and Whittle, G.P. (1967), *New Methods for Chlorimetric Determination of Halogen Residual*, Part-I, Iodine , Iodide and Iodate., AWWA, Washington, 59:471

Clark, J.W., Hammer M.J., and J.R, W.V., (1977), *Water Supply and Pollution Control,* Harper and Row publishers, 3rd edition.

Cotton, F.A. and Wilkinson, G. (1992), Basic Inorganic Chemistry, John & Sons Inc., 1st edition.

DOE (1991), *Environmental Quality Standards (EQS)* for Bangladesh, Dhaka, Bangladesh..

Dept. of ME, *Operation & Maintenance of Salt Iodation Plant,* Manual, BUET, Dhaka, Bangladesh.

Emeleus, H.J. and Anderson, J.S. (1962), *Modern Aspects of Inorganic Chemistry,* E.L.B.S., London, 1st edition.

Fair, G.M., Geyer. J.C., and Okun, D.A. (1968), *Water and Waste Water Engineering. Water purification and Waste Water Treatment & Disposal,* Vol 2, John Wiley & Sons, Inc., Newyork, London, Sydney, 1st edition.

Ferrao, N. (1990), *Health & Nutrition,* Lana publishing Co. Ltd., Esperanca, shahid Bhagat singh Road, Colaba, Bombay 400039, vol-2.

Garrett, A.B, Lippincott, W.T. & Vehoex, F. (1968),*Chemistry: A study of Matter,* Baisdell, Massachuse,1st edition.

Graham, R.P. & Cragg, L. H. (1969), *The essential of Chemistry,* Holt Rinehart and Winston, Newyork, 2nd edition.

Hicks, J. (1963), *Comprehensive Chemistry,* Macmillan, London, 1st edition.

Huda, M.K., (1995),*Groundwater Quality in Deep Aquifers of Bangladesh*, M.Sc. Engg. thesis in Civil Engg., BUET, Dhaka Bangladesh.

Hussain, S.K.(1978), *A Text Book of Water Supply and Sanitary Engineering*, Oxford & IBH publishing co., Newdelhi, 2nd edition.

Hutchinson, E. (1964), *Chemistry: The elements and their reactions*, W.B. Saunders, Philadelpphia, 2nd edition.

Jabber, A. and Haque M. (1972), *Practical Chemistry*, for degree courses, student's publications' Lalmatia Housing Estate, Dhaka, 2nd edition.

LGD, MLG, RD&C, UNCEF, UNDP, WBWSP (1994), *Bangladesh Situation Analysis: Water Supply and Sanitation*, Report, Department of Civil Engg., BUET, Dhaka Bangladesh.

Mahan, B.H. (1975), *University Chemistry*, Addition Wesley, Addision, 3rd edition.

Nebergall, W.H. and Schmidt, F.C. (1959), *General Chemistry*, D.G. Health & Comp., Boston, 1st edition.

Rethati, L.(1983), *Ground Water in Civil Engineering*, Elsevier scientific publishing Co., Neywork, 1st edition.

Seager, C.N., McCarty, P.L., and Parkin, G.F., (1994), *Environmental Chemistry*, Foresman, London, Scott., 4 th edition.

Vogel, I.(1961), *A Text Book of Quantitative Inorganic Analysis*, Logmans, Green and Co. LTD., London, U.S.A., 3rd edition.

Yakub, N. (1995), *Cover Story : Iodine Deficiency: Waking up to the Blight*, Observer Magazine, Friday, 17th November.

APPENDIX

APPENDIX

Table- A1: Free Residual Chlorine with elapsed time at constant temperature

Chlorine Dose = 1.135 ppm
Temperature = 20°C (Constant)
pH = 6

Time in mins	**5**	**10**	**15**	**20**
Free Residual Chlorine in ppm	1.082	1.028	0.975	0.922
Loss in Free Residual Chlorine in ppm	0.053	0.107	0.16	0.213
Percentage Loss in free residual chlorine	4.76	9.4	14.1	18.8

Table A2: Free Residual Iodine with elapsed time at different temperatures.

Temperature in °C	**Time in minutes**	**5**	**15**	**30**
10	Free Residual iodine in ppm	3.489	3.426	3.299
	Loss in free Residual Iodine in ppm	0.573	0.636	0.763
20	Time in mins	3	15	30
	Free residual iodine in ppm	3.807	3.66	3.55
	Loss in free residual iodine in ppm	0.255	0.402	0.572
30	Time in mins	5	15	30
	Free residual iodine in ppm	2.855	2.538	2.284
	Loss in free residual iodine in ppm	1.207	1.524	1.778
40	Time in mins	5	15	30
	Free residual iodine in ppm	2.157	1.65	1.269
	Loss in free residual iodine in ppm	1.905	2.412	2.793

Table-A3: Residual Iodide ion form in titrating solutions after determination of free residual iodine at different temperature

Free residual chlorine = 1.135 ppm
Iodine dose in iodide form = 10.20 ppm
Iodine required in iodide form for complete reaction = 4.062 ppm
Contact time = 5 mins
Test temperature = 20^{o}C

Temperature in ^{o}C	**10**	**15**	**20**	**30**	**35**	**40**	**50**	**55**	**60**	**65**
Residual Iodine as Iodide form in ppm	6.80	6.458	6.14	6.14	not tested	not tested	not tested	not tested	6.08	not tested
Unreacted Iodine in iodide form due to incomplete reaction in ppm	0.66	0.318	0	0	0	0	0	0	0	0
Loss in free residual Iodine in ppm	0.146	0.177	0.255	1.207	1.532	1.878	2.292	2.542	2.798	2.92
%Loss in free residual Iodine	3.64	4.36	6.3	29.2	37.7	46.2	56.4	62.6	68.6	71.5

Table A4: Free Residual Iodine at different pH and with elapsed time

Free Residual Chlorine = 1.135 ppm.
Theoritical Liberated Iodine = 4.062 ppm
Iodine dose in iodide form = 10.20 ppm.
Temperature = 20°C

pH	**Time in minutes**	**5**	**15**	**30**
4	Free Residual Iodine in ppm	3.807	3.489	3.299
	Loss in free Residual Iodine in ppm	0.255	0.573	0.763
6	Free residual iodine in ppm	3.807	3.66	3.49
	Loss in free residual iodine in ppm	0.255	0.402	0.572
8	Free residual iodine in ppm	3.807	3.74	3.68
	Loss in free residual iodine in ppm	0.255	0.322	0.382

Table A5: Free Residual Iodine at Different Iodide Concentration

Free Residual Chlorine = 1.135 ppm.
Theoretical liberated Iodine = 4.062 ppm
Temperature 20°C

Iodide concentration in ppm	7.25	9.0	11.0	14.5
Free Residual Iodine in ppm	3.745	3.745	3.807	3.807

Questionnaire of Survey on Iodine Deficiency Disorders and People's Arguments about Iodized Table Salts in Bangladesh

Name of the Village/Town/City: ______________________________

Thana: ______________________________

District: ______________________________

Name of the Head of the family: ______________________________

Status of the family: Rich/middle/poor/very poor.

Number of members in the family: ____________ persons

Do they eat sea foods: Yes/No

Is there anybody suffering from goiter in the family? Yes/No

If Yes --------- Person/Persons

Is there any cretin children in the family ? Yes/No

If yes, __________ person

Do they eat iodized table salts? Yes/No

If yes, any comment on iodized table salts ______________________

____

Are there other persons suffering from iodine deficiency ? Yes/No

If yes, ____________ persons

Does water contain iron? Yes/No

If yes, very high/high/moderate/low/very low

Does water contain free chlorine ? Yes/No

If yes, very high/high/moderate/low/very low. _