ASSESSMENT OF THE EFFICACY OF SOLAR RADIATION AS A DISINFECTION METHOD FOR WELL WATER IN A SLUM IN IBADAN

BY

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DEDICATION

TO LOVE...

Of my mother...a model, my father...the best there is, my brothers, my sisters, tunde, my kids, Tope, Segun, my friends Bisi, funlayo, tessie, buky, Ife, Titi, Sam, and my two brothers and friends (flinstone* and groucho*),

Bosses.....you loved me through it all

For all those times you stood by me

For all the truths you made me see

For all the wrong you made right

For all the joy you brought to my life

For all the love you gave to me

For being my strength when I was weak

Lifting me up when I couldn't reach

I thank you

ABSTRACT

Lack of safe drinking water is a serious problem in many urban centers in Nigeria. The limited water available for low income communities is contaminated with human wastes and is responsible for many water-borne diseases. This study is aimed at developing a cheap method of water disinfection using solar radiation in Koloko-Aiyekale communities in Ibadan North East Local Government. These communities are low income and live in unplanned, high-density areas. They are also characterised by narrow roads, open drains and shallow wells. The study is descriptive and analytical in nature. A random sampling method was used to select respondents for the study. All the houses in the area were surveyed and the PHC numbers used in random selection. Thus 324 households were selected and the senior woman was interviewed using a structured questionnaire. A guideline was developed and the items of information sought included demographic characteristics, source of water, water treatment practices, knowledge, attitude and practice of water use and related health risks, personal hygiene and sanitary features of wells. In addition 78 water samples were analyzed to determine physical, chemical and bacteriological quality.

Solar radiation disinfection, was standardized in the laboratory using various parameters such as type of container, cover, colour of container and cover, volume of water, turbidity and number of hours of exposure to sunlight. Furthermore, a solar radiation chamber was designed, fabricated and used to determine its efficacy in disinfecting water in polythene sachets.

The results showed that 96 (29.5%) interviewed had no formal education, 82 (25.3%) had primary education 52 (16.1) had secondary education, 15(1.5%) had tertiary education. Most of the women interviewed (91.1%) were married and belonged to the Muslim faith. The women had a mean monthly income of ₦1,253 and 13 (3.7%) were unemployed. 43 (13.6%) of the women also had vocational training in tailoring, hair dressing, cloth weaving and dyeing. Shallow well water was their main source of water with 78.9% of the households using it in rainy season and 92.4% in the dry season. They used the water for drinking and other domestic needs. About the sanitary features of the well 137 (42.3%) of the wells were unlined or poorly lined with many of them lacking parapet, apron, cover or a permanent bucket. About 199 (61.4%) had animal excreta around the wells. The depths of the wells ranged from 0.178m to 37.93m and the water depths ranged from 0.06m to 18.29m. About the treatment of water, 46 (8.29%) of the respondents said they chlorinate their wells, 211 (38%) boil, 257 (46.3%) treat using other methods like alum treatment and salt addition. About 41 (7.4%) gave no treatment. When asked whether they will like to use solar radiation as a method of water disinfection, 292 (93%) indicated their willingness.

Regarding the quality of well waters the following mean values were recorded during rainy season (mg/l): Total solids, 383.1; Suspended solids, 78.1; Total Alkalinity, 54.3 ; Total hardness, 86.3; Calcium, 28.7; Magnesium, 12.4 and Chlorides, 70.1; the mean coliform count was 2685 MPN/100ml. The dry season values recorded were (mg/l): Total solids, 443.6; Suspended solids, Not done; Total Alkalinity, 68.0 ; Total hardness, 67.6; Calcium, 15.6; Magnesium, 7.8 and Chlorides, 11.06; The mean coliform count was 833.7MPN / 100ml.

These results indicate that the well waters are polluted and needed effective disinfection.

Solar radiation experiments in the laboratory indicated that the disinfection process is effective when 5l samples were taken in a plastic bowl. The degree of disinfection is relatively higher when the colour of the container was white or black. Blue, green and brown showed relatively lower disinfection efficiencies. Similarly when the bowls were covered with plastic cover, white and black showed higher efficiency than other colours. The optimal exposure time was found to be 7 to 8 hours.

When the days were cloudy or rainy, the solar disinfection process was not significantly affected as long as the samples had 5 hours of sunshine. During the whether they will like to use solar radiation as a method of water disinfection, 292 (93%) indicated their willingness.

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When the days were cloudy or rainy, the solar disinfection process was not significantly affected as long as the samples had 5 hours of sunshine. During the solar radiation process the ambient temperature varied between 23°C and 46.5°C, and the water temperature ranged between 25°C and 45°C.

It was shown that solar radiation had a definite effect on the coliform reduction as compared to the heat effect. This study on regrowth of coliforms after storage of water indicated that when the water samples were properly disinfected, there were no regrowths after storage. Increasing turbidity beyond 40 mg/l had a slightly reducing effect on the disinfection efficiency. There was a negative correlation between the thickness of container and the efficacy of solar disinfection. The trials with selected community members also showed that solar disinfection process is satisfactory and viable.

A solar radiation chamber was designed and fabricated using plywood, plain glass and a mirror. This chamber was found to be efficient in disinfecting small quantities of water (500ml) which are commonly sold in the market as "pure water". The disinfected sachets did not show any regrowth even after storage for about a day. These results are significant in that the solar radiation disinfection method is economical as people can adopt this technology with minimal skills and little expenditure.

Based on these results, certain recommendations were made to the communities and policy makers to encourage the use of solar radiation technology as a water disinfection method.

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CERTIFICATION

We certify that this work was carried out by Boluwaji Enobor in the Deparment of Preventive and Social Medicine, , University of Ibadan.

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TABLE OF CONTENTS

LIST OF FIGURES

PAGE

LIST OF TABLES

Glossary and Definitions

Absorbance: The amount of Radiant Energy absorbed by a substance. Inversely and logarithmically related to transmittance.

Biochemical Oxygen Demand (BOD): Amount of dissolved oxygen in an aqueous solution, that is consumed by microorganisms during the breakdown of the present organic substances under standardized conditions (5 days, 20 °C)

Chromophores: Chemical group or substance that gives colour to a compound

Colifonns: Group of Bacteria related to Escherichia coli (one of the most abundant components of the intestinal flora)

Deoxy-ribonucleic acid (DNA): Substances found in the chromosomes responsible for the transmission of genetic characteristics of a living organism.

Dissolved oxygen: Amount of oxygen found an aqueous solution usually expressed in milligrams per litre (mg/l)

Exposure Time: or Residence time is the amount of time (minutes) that a quantity of water is exposed to sunlight in a flow through system

Gennicidal Action: Inactivation or killing effect exerted by a chemical of physical factor on pathogens

Indicator Bacteria: Group of bacteria used for assessing the quality of a water body

Intensity: Amount of Incident radiation expressed in W/cm^2, W/m^2

Irradiation: Exposure to a radiation source

Most Probable Number (MPN): Expression and Technique for estimating the bacterial density of a sample.

Pathogens: Disease causing organisms usually bacteria, viruses and larger parasites

PTWI:	Provisional Tolerable Weekly Intake
Solar Energy:	All kinds of radiation from the sun that reaches the earth, usually after being scattered and filtered through the atmosphere. Divided into invisible (ultraviolet and infra red) and visible ranges
Solar Irradiation:	Emission or exposure to Solar Radiation
(P)	Used for contaminants for which there is some evidence of a potential hazard where available information on health effects is limited
TDI:	Total Daily Intake
ADI:	Average Daily Intake

CHAPTER ONE

INTRODUCTION

1.1 General Introduction

Potable water is a scarce commodity in developing countries. According to an editorial in Water International (1991) referring to water and sanitation, one in three people lack this basic requirement for health and dignity. In spite of projects like the Water And Sanitation Decade (1980-1990), which had the goal of providing universal access to water, at the end of the decade only an estimated 60% of the world's developing countries had access to a water supply adequate and safe by International standards (WHO, 1991).

One reason espoused by various authorities for the inability of the water decade to achieve its aim, was the use of expensive technology that was not fully utilised. Reasons for non-utilisation include lack of trained personnel; funds or socio-cultural unacceptability, resulting in abandoned wells, broken down hand pumps and unused communal wells. In 1980, 80% of the water and sanitation delivery for developing countries by the UNICEF was spent on high cost technology, (Salisbury 1978; UNDP 1990; UNICEF 1991).

In response to the lessons learnt during the decade there was a shift to an appropriate technology and community based approach for water and sanitation delivery. Appropriate technology refers to low-cost systems that can be built with locally available materials and skills and also be maintained by the community (UNDP 1990; Kalbermattan 1990; Warner 1991; Chrismas, 1991).

Benefits of appropriate technology include reduction in cost. Examples are shallow drum lined wells for guineaworm eradication as shown in Nigeria, savings in time and energy like the use of pousse-pousse in Burkina-Faso. (A wheelbarrow used by the women to carry water) Other examples of low-cost technology for water and sanitation are the popular Mark III VLOM pumps, Gravity reticulated systems and nylon filters for guineaworm eradication. Other direct and indirect benefits include environmental protection and improved potential for economic and social development. (UNDP, 1990; Ayotamuno et al. 1992; Bulajich, 1992).

Despite the shift to low cost technology and the additional provision of safe and adequate water to 302 million people in 1992, by 1994, 1.3 billion people in the developing world lacked safe water and 1.9 billion had no sanitation facilities. (Bulajich, 1992; UNICEF, 1994).

A reason for the continuing dismal picture in water and sanitation delivery to developing countries is the explosive population growth particularly in the urban population, which is estimated to double in about eighteen years based on a growth rate of 3% (WHO, 1991). A concomitant of this rapid urban growth in the developing world is the increased phenomenon of urban slums, characterised by inadequacy of infrastructure necessary for the support of environmental health such as water and sanitation, housing, food and storage. According to Nakajima (1996), the health of 600 million people is threatened by the inadequacy of facilities in urban slums.

The lack of access to an adequate supply of safe drinking water and sanitation thus remains the most widespread and important environmental hazard, causing about 80% of diseases in the tropics e.g. cholera, typhoid, diarrhoea, dysentery, infectious hepatitis (Caldwell, 1988; WHO 1995). Diarrhoeal diseases remain one of the world's leading causes of morbidity claiming 3 million deaths among children every year, with diarrhoea ranking as second cause of under five mortality rate in Central and West Africa, with Nigeria not being left out (Dee Rooy, 1995).

Improvements in water supply result in the reduced incidence and prevalence of waterborne and associated diseases, an example is the eradication of guineaworm in Nepal, brought about by en integrated water management program embarked upon by the Nepalese government (UNICEF, 1994).

The poor are mostly affected by the non-access to potable water, with two thirds of the world's poor belonging to this category (Bulajich, 1992). The urban poor, resident in slums are particularly exposed to water related diseases because in the absence of piped water, they rely on polluted alternative water sources, such as shallow wells, streams and commercial vendors but lack the finances and knowledge to improve the quality of this waters.

Ibadan in Nigeria is an example of a city that possesses urban slums, Such as

Agbowo, Agugu and Odinjo. Although the entire city of Ibadan lacks a steady supply of piped water, the urban slum residents bear the brunt of the unavailability of water. As a result they suffer from infections and epidemics. For example, the areas of the highest incidence during the cholera epidemic of the seventies occurred in these areas of Ibadan (Egunjobi, unpublished). This is because while the residents of high income, low-density areas like Bodija and Jericho can afford to sink deep wells, the urban slum residents use polluted wells, streams and water from commercial vendors. Some of the people of Agugu, one of the urban slums in Ibadan claim to use alum and salt, and also chlorination as water treatment methods for their well water. These methods do not, however, improve the well water quality because although alum clarifies the water, the bacteriological quality is not affected. Chlorination is ineffective because the users cannot afford to buy the chlorine, as it is available in 50Kg drums only. Another reason for the ineffectiveness of chlorination when used by the poor is that they lack the knowledge to apply the chlorine in correct doses and also because they use the chlorine in inadequate quantities, in order to make the chlorine last longer. There is a need for a low cost method of water treatment for the alternative sources which urban slum residents depend on, which is simple to use and can be maintained by the intended users at their present socio-economic status. Some work carried out in developing countries revealed that solar disinfection might be a cheaper and efficient option in tropical countries (Sommer et al 1997).

1.2 Problem Statement

High-density areas in Ibadan such as Agugu, lack treated piped water and have to rely on alternative sources, which are not potable. Examples are polluted shallow wells and streams. The residents lack both the knowledge and finances to improve the quality of these water sources thereby predisposing them to water related diseases.

1.3 Broad Objective of the Study

To assess the efficacy of Solar Radiation as a method of providing potable water for resource poor communities in a high-density area of Ibadan, practices of the women in the community concerning water sources.

1.3.1. Specific Objectives:

1. To obtain baseline information on demographic characteristics of the communities and the knowledge, attitude and practices (KAP) of the women concerning water sources, use, sanitary features of the sources, health related risks perceived, personal hygiene and information on methods of water treatment practiced by them.
2. To assess chemical and bacteriological quality of well waters used by the community.
3. To carry out investigation in the laboratory on optimization of solar radiation technique using the coliform index, and
4. To transfer the laboratory findings on the solar disinfection method to the selected

community and test its large scale efficacy and acceptability.

1.4. Significance of the Study

This study will be a significant step towards providing a cheap means of water disinfection, which is effective and acceptable to the community, bearing in mind the socio-economic status of the people and the cheap nature of the technology being used.

This study is also one that employs the use of current trends in the water and sanitation sector of women participation in projects. The data obtained will be useful for other communities in similar situations.

1.5. Limitations of the Study

The study was carried out during the rainy season, and thus the solar radiation was not as high as can be obtained during the dry season, this might have implications for the minimum exposure time necessary for adequate disinfection.

There is also a need to carry out further studies during the dry season.

CHAPTER TWO

LITERATURE REVIEW

This chapter is a review of literature available in Nigeria, Africa and other parts of the world. It deals with water distribution, water importance, water sanitation and health, water pollution, drinking water quality, water treatment methods, solar disinfection technique and community participation in water and sanitation delivery.

2.1 Water Distribution:

Water permeates the earth in three domains, atmosphere, hydrosphere and the lithosphere in the three states, liquid, gaseous and solid. It moves through three phases, atmospheric, surface and sub-surface water in a cycle known as the hydrological or water cycle (Fig 1). The total volume of water on the earth is about 1.4 million Km^3.

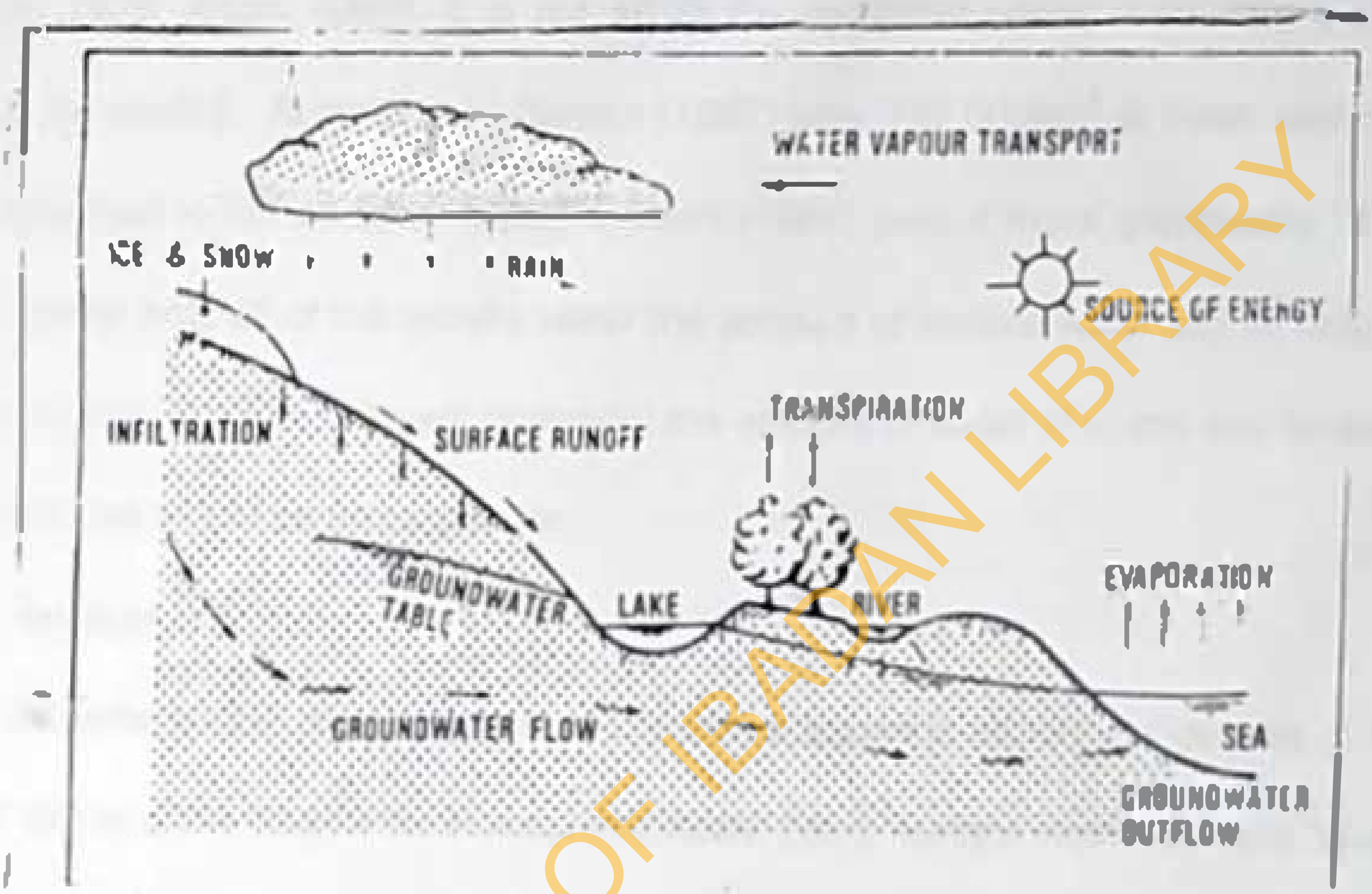

Fig.1 Hydrological Cycle
Source Hofkes 1981

The oceans cover more than 70% of the earth surface and contains 1,350,000 km ^{3} of water, whilst 770,000,000 km^3 is localised within the lithosphere in the form of water and hydration and 28,000,000km^3 is held in the ice-caps and glaciers (Chow, 1979; Anon, 1990). It is not all of the available water resources that are usable or wanted. According to Barrow (1987) only 137,000km^3 is fresh water, the type essential to life on land. Catley-Carson (1988) puts it more graphically "if half gallon bottle held all of the world's water the amount of usable water will fill only 1/2 of a teaspoon, a single drop will represent the amount of water in rivers and streams, whilst the rest would be ground water.

2.2 Sources of Water

All water that is available to man comes as aqueous vapour condensed in the form of rain or snow, and forms atmospheric water (rain), surface water (oceans, lakes, streams) or sub surface water (wells, springs) through distribution by the water cycle. Though according to Chapman (1991), each of the principal types has distinct hydro-dynamic properties, one water type can change to another e.g rain can become surface water, which in turn can become ground water. The contaminants each water type comes into contact with will determine its properties and also its use.

2.2.1 Rain water

Rainwater has always been used as a source of water in developing countries and has found increasing use in rural areas of the developed countries as rainwater catchment systems (Mayo, 1991).

Rain water is dissolved water i.e. water that has been vaporized and condensed leaving all volatile substances behind and therefore theoretically closer to chemical purity than any other kind of water. Various factors however affect the expected chemical purity of rainwater. An example is the quality of precipitation i.e. what kind of gases it has come into contact with during its passage through the atmosphere. For example where it passes through mists of sulphur and nitrogen it is precipitated as acid rain. This is unsuitable for use as drinking water and other domestic purposes, because it causes corrosion and is unaesthetically unacceptable to the consumer. Another factor that determines the chemical purity of rainwater is the catchment surface area. This is because the collected rainwater will contain all the substances on the catchment surface. These substances include particulate matter from automotive gas emissions and industrial manufacture and corrosion of galvanised roofs. Gumbs (1987), noted that rain water in a cisterns supplying single family dwellings, contain lead and calcium in amounts that exceed the US Public Health Standards. Dissolution of sediments also reduces the chemical purity of rainwater for domestic purposes, as heavy metals due to their particulate nature settle to the bottom of the cistern and accumulates as sediments, which are released into the water when disturbed.

The biological quality of rain water has always been a source of concern in its use for domestic purposes, because apart from micro-organisms which may be washed into it from the catchment area, man can also contaminate otherwise pure rain water in his bid to use it. Oluwande (1983), devised a tap for a rain water catchment system to eliminate the need for dipping containers into the cisterns. He stressed that in order to protect the microbiological quality of rainwater, thatched roofs should never be used as a catchment surface for rain water.

2.2.2 Surface Waters

Surface waters include rivers, lakes, creeks, streams, ponds and impounding reservoirs which are used for purposes which include transportation of goods and people, power generation e.g. The Kainji lake and dam in Nigeria. 2/3 of all the water used for agriculture is taken from surface water (Johansson, 1993). Natural or man-made lakes also serve as vital sources of domestic water supply to surrounding towns and cities.

The characteristics of surface water include dissolved solids from the ground water overflows, surface run-off, turbidity, organic matter as well as pathogenic organisms because surface water originates partly from either outflows or rainwater which would have flowed over the ground. The natural self-cleaning mechanisms can be overcome, such that lakes are eutrophicated and rivers become sewers, and cannot be used for domestic purposes without extensive treatment (Nest, 1991; Zaid, 1991).

Ayoade (1994) reported that none of the rivers in Ibadan metropolis is potable by WHO standards. Oluwande et al (1983) examined river Ogun in the southwestern region of Nigeria, which received brewery effluents, and observed that it had no dissolved oxygen at some sampling points. He further noted that levels of some other parameters like coliform count and suspended solids showed that the river would require full scale conventional treatment before it could be used for domestic purposes.

2.2.3 Ground Water

Groundwater refers to all the water occupying the voids, pores or fissures within geological formations, which originated from some form of atmospheric precipitation either directly by rainfall infiltration or indirectly from rivers, lakes or canals. Sand and gravel, sand stone, limestone formations are the usual sources of groundwater supply though some may be drawn from impervious rocks such as granite when they have an over burden of sand or gravel.

Groundwater can be hydrochemically classified as meteoric when it comes from rainfall which has passed through the normal hydrological cycle. Connate which is saline ground water from marine sediments and juvenile i.e. groundwater which arose from igneous process within the earth and has not been in the circulating system of the hydrological cycle.

Groundwater is a valued fresh water resource and contributes almost 2/3 of the fresh water reserves of the world (Chilton, 1992). It is used for agricultural, individual and domestic purposes. It accounts for about 50% of livestock and irrigation use and just under 40% of water supplies, whilst in rural areas, 98% of domestic water use is from groundwater (Todd, 1980). There is a high dependence on ground water for community use in developing countries, and Nigeria is no exception to this due to the usual non-functioning of government provided piped water systems.

Advantages of groundwater include its relatively low capital cost of development, which make it popular for community use in the rural, peri-urban and urban areas of developing and developed worlds (Park, 1991; Chilton, 1992).

This is due to the fact that unlike surface waters, groundwater has excellent natural qualities which means that it requires little or no treatment before use. The proximity of ground water to where it will be used also makes it cheap to develop. Another advantage of ground water is that the source, when properly developed is likely to be continuous in all seasons.

Groundwater has some disadvantages, which might increase the cost of developing it for community use. One of such disadvantages is that it often requires pumping or some arrangement to lift the water. Another disadvantage which might increase cost of development, is that ground water is often high in mineral content such as magnesium and calcium salts, iron and manganese depending on the chemical composition of the stratum through which the rock flows (Todd, 1980; Hofkes ,1981). Hofkes (1981) further noted that though iron and manganese can be precipitated by aeration it is usually more cost-effective to develop another ground water source.

Although groundwater has good natural qualities due to the attenuation processes that occur during its passage through the earth, once polluted, some groundwater types can remain so for decades or hundreds of years due to the slow pace of its natural flushing processes.

There are various types of groundwater which range from water holes which, as their name implies are holes dug in the ground with a stick till water gathers in the hole to boreholes which are developed to several hundred of meters deep with sophisticated equipment. Oluwande (1983) identified four types of waterholes that demand full conventional treatment before use. He identified water holes as the oldest means of obtaining sub-surface water, although Aggawarata (1993) reported that the oldest form of sub surface water used by communities is the quanats, which are underground galleries connecting a series of wells, using a technique perfected by Iranians 2,000 years ago.

A spring is a concentrated discharge of ground water appearing at the ground surface as a current of flowing water (Todd, 1980). It is distinct from seepage areas, which are a slower movement of groundwater to the surface. Springs can be classified according to their cause, rock structure, temperature, variability and discharge. Examples are depression springs, thermals springs, which apart from their domestic use are also believed to have medicinal properties e.g. the Ikogosi warm springs.

Wells are holes in the ground that intersect the water table as water bearing rocks flowing as aquifers. Park and Park (1991) classified wells as shallow or deep depending on the location of the impervious strata from which the water is obtained. A shallow well refers to that in which water is obtained from the first impervious layer whilst one which taps water lying beneath the impervious layer is known as a deep well. Shallow wells are generally less than 15m in depth (Hofkes, 1981). Shallow and deep wells exhibit differences in bacteriological quality and yield, with deep wells being purer and more constant in water supply.

Hand dug wells are wells which may be little more than an irregular hole in the ground, intersecting the water table (Todd, 1980). They are prone to pollution from air borne materials, run-off from the surface, though their sanitary status may be improved by inclusion of features such as lining, a cover, parapet, apron and drain.
However the ability to do this is largely determined by the socio-economic status of the well owner. A properly constructed well can yield 2,500 to 7,500m^3 per day, although most domestic dug wells yield less than 500m^3/day (Todd, 1980).

Tube wells also known as driven wells consist of a series of pipes, usually made up of galvanized iron, sunk or driven into the ground by repeated impact on the water bearing stratum, it is fitted with a strainer at the bottom and a hand pump at the top. They are suitable for small capacity water supplies, due to their small yields of 100-250m^3/day (Todd, 1980). They are however limited to only unconsolidated ground due to the possibility of damage of the drivel point by gravel or rocks.

Boreholes are drilled wells with depths of over 300m and small diameters of 15-20cm or a maximum of 60cm. They serve large communities due to their very high yield, but they have the limitation of being expensive.

Well maintenance and rehabilitation are very important because if wells are not properly maintained, problems such as well screen clogging and corrosion, concrete casing cracks and insufficient well depths arise resulting in a reduction of the life span of pumps and wells. Hydrochloric and sulphuric acids might be used to dissolve the precipitates, whilst regular chlorination, physical agitation and a combination of polyphosphates and hypochlorite may be used to disperse screen deposits.

The method of withdrawing water from a well is an important consideration as it has a proven effect on water quality. Goecler (1995) demonstrated that wells that were lined with rope pumps had a 62% reduction in the geometric mean of fecal coliforms, with or without a cover. Methods of withdrawal include the use of fixed buckets to which a rope is tied, windlass method consisting of a windlass wheel and axle and continuous flow device made up of belt, small buckets and pumps.

Pumps are devices used to lift water from a well and can be classified according to the mechanical principles involved (Table I). Hand pumps are being introduced in Nigeria in recent years and are used for shallow wells of small diameter. Mark I-V are VLOM pumps which have been continuously improved for use in Nigeria. Water pumping technology developed parallel to the sources of power available at the time. An example of power sources is human power that is important in developing countries because the requirements can be met within the user group at a low cost. Other power sources are animal power, wind, diesel and electric engines.

Table 1. Types of pumps commonly used by population

Type of Pump	Usual depth range	Characteristics and Applicability
1. RECIPROCATING (plunger) a. Suction (shallow well b. Lift (deep well)	Up to 7 m	low speed of operation; hand, wind or motor powered; efficiency low (range 25 - 60%) capacity range 10-50 l/min;
2. ROTARY (positive displacement)		low speed of operation; hand, animal, wind powered;
a. Chain and bucket pump	Up to 10m	capacity range: 5-30 l/min. discharge constant under variable heads
b. Helical rotor	25 to 150m Usually submerged	hand, wind or motor powered good efficiency; suited to low capacity-high lift pumping.
3. AXIAL - FLOW	5 to 10 m.	high capacity - low lift pumping; can pump silted or sandy water
4. CENTRIFUGAL		high speed of operation - smooth, even discharge; efficiency (range 50-85%)
a. Single - stage	20 to 35 m	requires skilled maintenance; not suitable for hand operation. power: engine/ electric motor
b. Multi-stage Shaft-driven	25 to 50 m.	as for single stage, motor accessible, above ground; alignment and lubrication of shaft critical; capacity range 25 -10,000 l/min.
c. Multi-stage Submersible	30 to 120m	as for multi stage shaft driven; smoother operation; maintenance difficult; affected by sandy water
5. AIR LIFT	15 to 50 m	high capacity at low lift; efficiency reduced with increase in lift. Well casing straightness not critical.

Source: Hofkes (1981)

2.3.0 Importance of Water

Water is an essential need of the human body. Almost all forms of life are dependent on water. The UNDP (1990) refers to it as the source of life. It is the principal constituent of living things and the human body is made up of about 65% water by weight. The human being can survive for a longer period without food than it can without water. Hofkes (1981) noted that the human body needs about 3-10 litres of water per day for normal physiological functioning. Water forms the backbone of the world's economy, as it is critical in all spheres of man's activities. It is used for production as in power generation, irrigation and flood plain farming, it is vital to transportation of goods such crude as oils and timber and it is also used for recreation in water sports and holiday resorts, which contribute significantly to some economies. Water is also used for a wide range of domestic purposes; laundry, drinking, food preparation and the maintenance of personal and environmental hygiene. (De mare, 1977); Catley-Carson, 1988; Nest, 1991).

Water is vital to development as it plays a vital role in the pattern of human settlement in ancient civilizations like Egypt and the Nile, Rome and the Mediterranean. Barrow (1987) observed that groundwater is the key to development. It can also serve as an index of the level of development of a community by using parameters such as per capita water consumption. The water consumption increases with the level of development from 400l/day to as high as 1,500l in metropolitan areas (Naca, 1975;

Chow, 1979).

Although half the UNO recommended amount of 200l/day is enough to meet the needs of an individual and his household, in rural Nigeria, even this meager amount is not available (Uma, 1988; Sridhar, 1985).

2.3.1. Water, Sanitation and Health

Inadequate water supply and sanitation are still the world's leading cause of human illness. About 80% of tropical diseases are said to be water related e.g cholera, typhoid, diarrhoea, dysentery and infectious hepatitis. They can be attributed to poor or non existent sanitation, which leads to water contamination by human wastes (Mcjunkin, 1983; Caldwell 1988). Whist some water experts insist that the overall incidence of infant and child mortality can be reduced by half through water and sanitation improvement, others say there is difficulty in measuring improvement empirically. There is, however a consensus that easy access to water helps to build a relatively healthy and aesthetically clean population (Sebura, 1980; Christmas, 1991).

Sridhar and Omishakin (1985) carried out a study which showed that the incidence of documented disease in ten major states in Nigeria is correlated with water supply and sanitation. Availability of ample supplies of high quality water characterizes a community's hygiene status by preventing the spread of water-borne diseases and improving the communities' living standards (Krasovsky, 1986). Sages over time have recognized the importance of water in relation to health. Water is related to disease in various ways. It serves as a route of transmission e.g cholera; a breeding site of a stage of the life cycle of the infective agent e.g malaria; a harbour for the carrier of the infective agent e.g. Schistosomiasis; Its presence or absence in inadequate quantities can also cause disease e.g. trachoma.

Water associated microbiological diseases are transmitted through the ingestion of a sufficient number of the causative organisms in water. They might be as few as 10-100 as in Shigella, or as many as 1-10 million in cholera (Chandra, 1986).

Classical waterborne diseases include:

(i) Amoebiasis or amoebic dysentery caused by the protozoan, Entamoeba histolytica, which infects 500 million people annually in developing countries

(ii) Cholera which is caused by Vibrio cholerae infecting 300,000 people annually in developing countries

(iii) Gastro enteritis which annually infects 100 million people in developing countries;

(iv) Giardiasis caused by Giardia lamblia which infects 250 million people annually in developing countries (Table 2).

(v) Hepatitis, a viral infection which causes 14,000 deaths annually in developing countries and

(vi) Typhoid caused by Salmonella typhi, which affects 70 million people in developing countries annually (Warner, 1991; Series m, 1992).

Table 2 Diseases related to deficiencies in water supply and/or sanitation and their median infective doses.

Group	Diseases	Pathogen	Median infective Doses (ID50)
These are diseases transmitted by water (Water-borne diseases) in which water acts only as a passive vehicle for the infective agent. All these diseases also depend on poor sanitation	Cholera Typhoid Bacillary dysentery (shigellosis) Infectious hepatitis Leptospirosis Giardiasis Gastroenteritis	Vibrio cholerae Salmonella typhi Shigella sp Hepatitis A virus Leptospira sp Giardia lamblia Rotavirus Aeromonas Pathogenic Escherichia coli Campylobacter jejuni Balantidium coli Cryptosporidium parvum Yersinia enterocolitica	H H M L ? L L H ? L ? H M? L L H?
Diseases due to lack of water. (Water-washed diseases) lack of adequate quantity of water and poor personal hygiene create conditions favourable for their spread. The intestinal infections in this group also depend on lack of proper human waste disposal.	Bacillary dysentery Amoebic dysentery Enterovirus diarrhoea Ascariasis Whipworm (Trichuriasis) Hookworm (Anchylostoma) Leprosy Lice and typhus Scabies, skin sepsis and ulcers Trachoma Yaws Conjunctivitis	Shigella sp Entamoeba histolytica Ascaris lumbricoides Trichuris trichiura	M L L L

Key: L = Low ($< 10^2$), M=Medium ($\approx 10^4$), H= High ($> 10^6$), ?Uncertain
Source: (Hofkes, 1981; Feachem, WHO 1995)

Table 2 (Contd.)

Group	Diseases	Pathogen\vector	Infective Dose
Diseases caused by infective agents spread by contact with or ingestion of water (water based diseases)	Schistosomiasis (Urinary and Rectal) Dracunculiasis (Guinea worm) Thread worm	S haematobium D medinensis Strongyloides stercoralis	L L L
Diseases transmitted by insects which live close to the water (water-related vectors)	Yellow fever Dengue and dengue Haemorragic fever West Nile and rift valley fever Encephalitides Bancroftiasis Filariasis Malaria* Onchocerciasis * Sleeping sickness*	mosquito mosquito mosquito mosquito mosquito mosquito mosquito mosquito mosquito Simulium fly Tse tse fly	
(Fecal disposal diseases) Diseases caused by infective agents mostly contacted by eating uncooked fish and other food	Clonorchiasis Diphyllobothriasis Fasciolasis Paragonimiasis	Clonorchis sinensis Diphyllobothrium latum Fasciola hepatica Paragonimus westermani	L L L L

Key: L= Low (<10^{2}), M= Medium (10^{4}), H= High (>10^{6}), ? Uncertain

Source:- (Hofkes, 1981; Feachem,1983; WHO 1995)

Interventions include breaking the faeco-oral transmission route by improving water supply and sanitation. Masters et al (1990) in a study to access the impact of improved water sources on childhood diarrhoea in Sri Lanka, observed that children in households which drew their drinking water from hand pump equipped wells suffer fewer diarrhoea episodes than children using unprotected water. Whist children in households using protected traditional wells suffer 35% fewer episodes than children in families using unprotected traditional sources. Other interventions include hygiene education without which the benefits of improved water supply and sanitation will be limited (Gawatarisa, 1991).

Water vector habitat diseases are also water related, they are diseases in which a stage of their life cycle depends on water or proximity to it. Examples are Onchocarciasis, which infects 118 million people, occurs in 27 countries in Africa with 1 of 3 cases in the world being a Nigerian (WHO, 1987; FMOHHS, 1995). Another example is guineaworm, which is transmitted by ingestion of infected cyclops. Nigeria contains nearly 60% of all the reported guineaworm cases in the world, with Ondo, Anambra, Imo and Kwara states being most affected (UNICEF, 1995). Provision of developed water supply, environmental sanitation and use of chemicals and nylon filter for guineaworm are possible interventions. Other examples of water related diseases are water contact diseases transmitted by contact with the pathogens in water e.g schistosomiasis or bilharziasis.

interventions include reducing man-vector contact, environmental sanitation and use of chemicals.

Water hygiene diseases are those whose incidence and impact can be reduced by provision of ample quantities of water to improve personal and domestic hygiene (Population report, 1992). Examples are trachoma, tinea and scabies.

Non-classical water diseases which are chemically related, such as methaemoglobinemia are on the rise due to the production of new types of wastes by new technology, increased use of agrochemicals and the dependence on water sources (including groundwater) which are vulnerable to pollution (Zaid, 1988, Johansson, 1993). Interventions include more stringent rules about efficient treatment and protection of water sources.

2.4 Water Pollution

Water is said to be polluted when its quality is degraded as a result of man's activities such that it becomes less suitable for its intended use (Kumar, 1979, Chapman, 1992). The substances that impair or degrade the water quality are referred to as pollutants and they are foreign substances that may be of organic, inorganic, radiological, biological or physical origin. The deleterious effects of pollutants include harm to human health, hindrance to aquatic activities and the inability of the water to support agricultural, industrial and other economic activities. Chapman (1992) observed that types of pollution problems and the periods they are encountered in a country can be related to its level of socio-economic development (Fig 2).

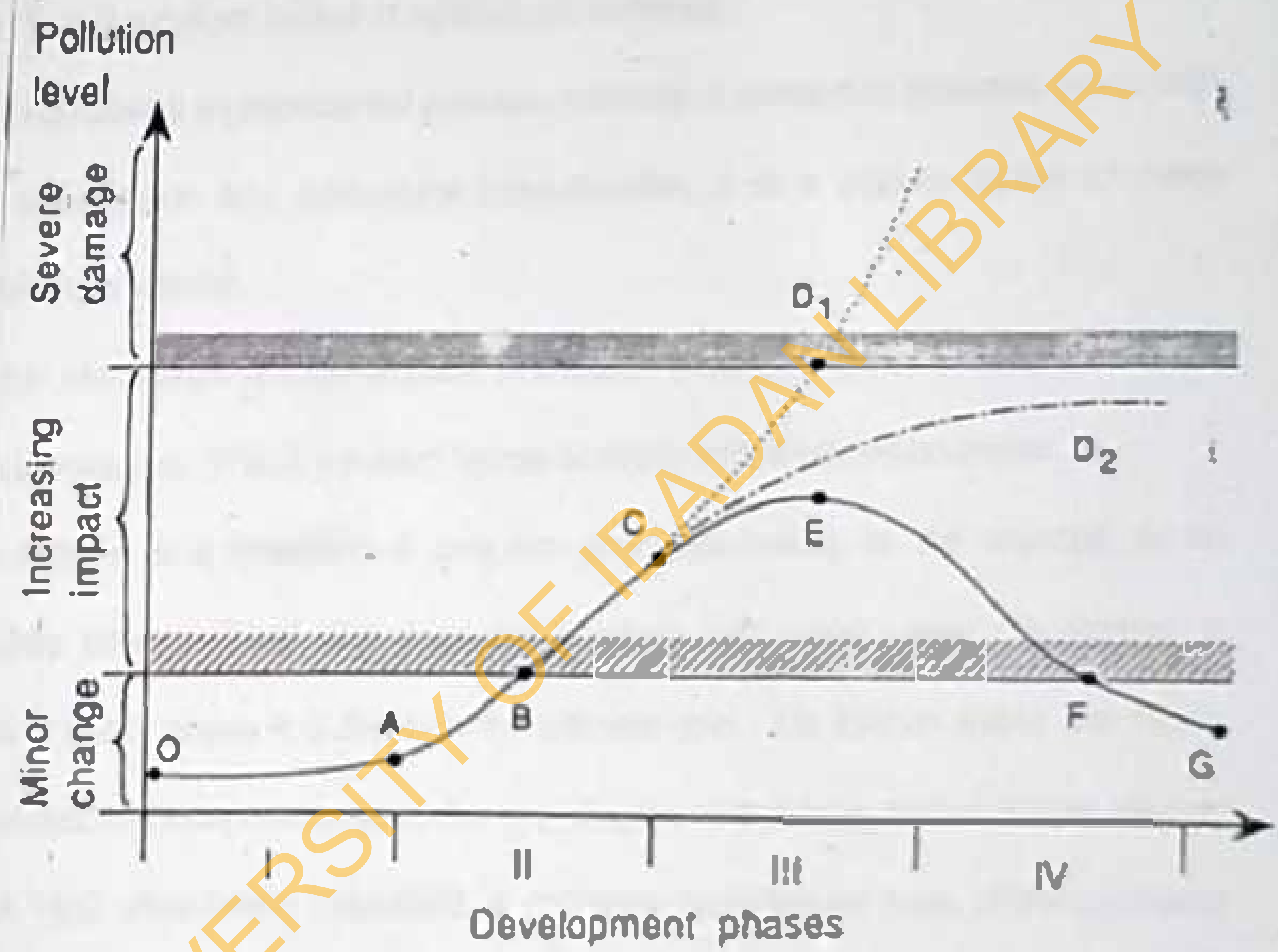

Fig 2 Phases of Pollution
(Source: Chapman 1992)

Chapman (1992) identified four phases of environmental pollution development namely:

Phase 1, which represents linear increase in low level pollution in relation to population number. This is a pattern typical of agricultural societies.

Phase 2 represents an exponential pollution increase in relation to industrial production, energy consumption and agricultural intensification. It is a pattern typical of newly industrializing countries.

Phase 3 in which there is a containment of pollution problems due to the implementation of control strategies. This is a pattern typical of highly industrialized countries.

Phase 4 there is a reduction of pollution problems mainly at the sources, to an ecologically tolerable level that does not interfere with water uses. According to Chapman (1992), phase 4 is the thus the ultimate goal. He further stated that highly industrialized countries encountered the four phases over a long period of time starting at about 1850 while newly industrialized countries experienced most of the problems from the 1950s to more recent times. Developing countries, which have predominantly agricultural economies, have not yet experienced most of the water pollution problems except those due to organic and fecal pollution. Furthermore, in developing countries, the different phases of pollution problems occur more closely in time than in developed nations, which results in a situation where problems such as chemical pollution appears before much control has been achieved over traditional types of pollution problems.

Nigeria is an example of a developing country where changing technologies and new agricultural practices due to population growth have contributed to water pollution (Oganga, 1985). Pollutants can be released into the water bodies either from point or diffuse sources. A point source of pollution is one that can be related to a single outlet, while a diffuse source of pollution may result from several point sources. Untreated or inadequately treated sewage and industrial effluents are major point source pollutants. Diffuse pollution sources may be atmospheric or non-atmospheric with the atmosphere being one of the most extensive sources of water pollution, due to volatilization from agriculture waste disposal regions, particles or solutes from fuels and acid rain. Examples of non-atmospheric diffuse sources include agricultural run-off, urban run off, waste disposal sites and wastes from navigation, harbour and marina sediments.

2.4.1 Groundwater pollution

Groundwater pollution is the artificially induced degradation of natural groundwater quality (Todd, 1980). Ifeadi (1980) however noted that natural occurrences such as the geological nature of the underground aquifer can cause pollution of groundwater, or where saline water intrudes into fresh water aquifers. Artificially induced groundwater pollution could be due to municipal, industrial or agricultural activities of man.

A major municipal pollution source is unsewered sanitation such as VIP latrines and septic tanks which have been noted to be possible sources of pollution in ground water supplies, causing an increase in BOD, COD, nitrates, inorganic chemicals and pathogens and leading to disease outbreaks in many areas of S. America, Africa, and India. (Lewis et al, 1980; Chapman 1992). In places where the water table is high in Nigeria, like Shasha community in Ibadan, fecal matter from pit toilets is seen as contributory factor for high coliform count in the spring (Sridhar, Unpublished). The high potential for ground water pollution in countries like Nigeria, where most parts of the country lack conventional water borne sewerage can best be appreciated if considered in the light of the fact that even in countries with sewerage, large quantities of partially treated sewage are released on to the ground. In the United States for example, 2.5 billion gallons of partially treated sewage is released onto the ground everyday from homes alone (Todd, 1980).

Sewers that are not water tight, perhaps due to poor workmanship may also cause leakage of heavy metals into groundwater, though pollution from this source may be less than expected because suspended solids clog minor sewer openings.

Solid waste disposal on land is an important municipal source of ground water pollution in developed countries. In the USA for example, only 10% of the 10,000 landfills are sanitary, others being mostly refuse dumps. In Nigeria, a developing country, uncontrolled tipping is the most common method of solid waste disposal. Leachate flows into surrounding soils, thus polluting underlying groundwater. (Todd 1980;

Sridhar, 1983; Chapman, 1992).

Industrial wastes and effluent disposal methods may serve as pollution pathways to underlying aquifers by introducing viruses, heavy metals, other chemicals such as DDT and dyes which are toxic to man and aquatic life. Some of such methods include the use of lagoon and oxidation ponds, deep soakaways, abandoned wells, and deep injection wells favoured by the oil industry. Other industrial waste disposal methods, which have the potential of polluting groundwater are the discharge of effluents onto land, stream and sanitation sewers that raise health related concerns especially where treated waste water is chlorinated and recharged for potable use.

Tank and pipeline leakage is also a pathway of groundwater pollution, the leakage may be due to corrosion, rupture, sabotage or human error. The fuels and chemicals being stored move underground through permeable soils, until they reach the water table. Examples are crude oil and liquid radioactive wastes. An estimated 400m^3 of gasoline was discovered floating as deep as 0.75m on the water table (Todd, 1980). A significant oil spill occurred in Nigeria in 1980, spreading as far as 100km along the coast and 30km inland along the delta, polluting the drinking water (STAN, 1982).

Mining activities also cause groundwater pollution. Examples of these activities are acid mine drainage, when mineralized water is pumped out to expend the mined region, there is an intermingling with the groundwater producing ferrous sulphate or sulphuric acid in solution. This pollutes the groundwater by reducing the pH and increasing the iron and sulphate ground water content. Other mining activities that pollute ground water is the leaching of old mine tailings.

Oil and gas production is often accompanied by substantial discharges of wastewater called brine, which is disposed of using methods such as abandoned pits, evaporation ponds and streams. These methods have the potential of polluting aquifers with brine, leading to an increase in sodium, calcium, ammonia, boron, chlorides, sulfates, trace metals and substantial amounts of total solids.

Agricultural sources of pollution include irrigation, which although widely practiced in Nigeria, its environmental impact from Irrigation return flow is not assessed (Ogedengbe, 1980; Nest, 1991). The possible effect on the ground water include an increase in ground water salinity, due to inadequate drainage and direct evapo-transpiration of irrigation return-flow from soils whose salinity has been increased by salts from fertilizers (Todd, 1980; Chapman 1992).

Animal wastes particularly from feedlots, where animals are confined for purposes of beef and milk production, may carry through storm run-offs, significant amounts of nitrates, salts, organic loads and bacteria to surface and sub-surface water.

Agrochemicals also pollute ground water. Their impact became fully apparent in industrialized countries in the 1970s and is becoming increasingly significant in developing countries due to the increased food demand of the explosively growing populations. Nitrate based fertilizers are a significant contributor to ground water pollution. This is because nitrogen in solution is not fully utilized by plants or absorbed by the soils. The use of pesticides or biocides closely follows the trend of fertilizer use in Nigeria. Examples of pesticides used in Nigeria include gamalin-20, paraquat-atrazine and glycophosphates (Sridhar, 1986). The persistence and ubiquitous nature of these chemicals has raised concern about the potential for pollution of surface and ground water, by aerial transport, surface run-off and accidental discharge, which prompted the US EPA to set limits for pesticides in drinking water. Osibanjo (1990) reported that chlorine pesticides PCBs have been found in sediments from IITA lake, Awba dam (UI) and the Agodi fish pond.

Stock piles of solid materials from construction sites, individual plants and other industries are potential groundwater pollutants when precipitation falls on these piles causing a leaching of heavy metals, salts and other organic and inorganic constituents.

Groundwater is vulnerable to acid deposition i.e. the transfer of acidic substances from the atmosphere to vegetation, land or water surface. The susceptibility of groundwater to the transfer is due to the fact that the water potentially available for abstraction is mainly from rain water, which has infiltrated through the soil to underlying aquifers (Chapman, 1992). Acid deposition has been well documented in North America and Europe. Not much research, has been carried out in Nigeria, although there have been indications of acid rain in the oil producing region of the country.

Interchange through wells which are improperly constructed, or not sealed after being abandoned, means they can serve as avenues for ground water pollution because of their highly permeable vertical connections.

Miscellaneous sources of groundwater pollution include uncontrolled liquid discharge from improper control of storm run-off and wastewater. Boiler losses and indiscriminate emptying of spent engine oil on the ground, also serve as sources of groundwater pollution. Although no figures exist for Nigeria, Todd (1980) estimates that millions of gallons of automobile waste oils are discharged onto the ground annually.

2.4.2 Surface Water Pollution

Sources of surface water pollution are similar to those of ground water pollution, and invariably end up as groundwater pollutants. They include industrial, agricultural and domestic wastes. Major pathways of surface water pollution include surface run off which carries pollutants into streams, rivers and lakes. Rivers in tropical areas have high amounts of suspended solids and humidity especially flood conditions, which is subject to seasonal variation.

The use of surface waters as receiving bodies for industrial and domestic wastes, which have undergone different stages of treatment is another major pathway of surface water pollution. The level of pollution has overcome the natural processes of self purification of these wastes, such as aeration in moving waters, sedimentation in lakes and rivers and bio-chemical processes which cause a substantial reduction in the microbiological level of these wastes.

This results in the gross pollution of most surface waters with many lakes being silted and eutrophicated, while rivers particularly those flowing through urban and industrial centres have become open sewers. These waters are rendered unsuitable for human consumption and are unable to maintain aquatic life at natural levels (Oluwande, 1983, Zaid 1991).

2.5 Drinking Water Quality

Water quality refers to the concentrations, specifications, and physical values of inorganic and organic substances contained in water including its biota (Zoldbakova, 1980; Chapman, 1992). The quality of water is usually determined in relation to its intended use. For instance water intended for pharmaceutical preparations must have lower levels of certain minerals than drinking water (Solt, 1983).

The first water-quality standards for drinking were set in 1914 (Hammer, 1986), whilst WHO published the first international standards of drinking water in 1958 (Table 3)

Table 3. Drinking Water Standards and Public Health and Other Significance of Physico-chemical Parameters

Parameter	Guideline Value	Public Health and other Significance
Total Dissolved Solids	No health based value	No deleterious effect, may confer protective health benefit, certain components, i.e. chlorides, sulphates, magnesium, Calcium and carbonates affect corrosion and encrustation in water distribution systems, affects taste in extremely low concentrations: flat insipid taste; above 1200mg/l becomes increasingly unpalatable.
Turbidity	5NTU (not health based)	Unaesthetically unacceptable, forms complexes with heavy metals, promotes microbial growth, and protects microbes from disinfection. Implicated in Trihalomethane formation
Colour	15TCU	Same as above
pH	6.5-8	Many water treatment processes are correlated with pH e.g. chlorination, coagulation and flocculation. Growth of iron bacteria and hydrogen sulphide is pH dependent.
Total Hardness	500mg/l	High hardness: Scale deposition, scum formation. Low hardness: possible corrosion
Chloride	250mg/l	High levels imparts undesirable taste to water and beverages depending on the associated cation

Table 3 Contd.

Parameter	Guideline Value	Public Health and other Significance
Sulfate	No health based	Contributes to corrosion of metals especially in waters with low alkalinity
Lead	0.01mg/l	cumulative poison causes lassitude, abdominal discomfort, anemia and behavioral changes in children
Fluoride	1.5mg/l	high level-Skeletal fluorosis, teeth mottling, low level- dental caries
Aluminum	0.2mg/l (not health based)	Anesthetically pleasing sediments, discoloration of water, neurological disorders like Alzheimer's diseases and dialysis dementia
Copper	2.0mg/l (p)	unpleasant color and astringent, stains laundry and plumbing fixtures
Nitrate Nitrite	50mg/l 3mg/l	methaemoglobinaemia, formation of nitrosamines which are suspected carcinogens
Manganese	0.5 mg/l (p)	Undesirable taste in beverage stains plumbing fixtures and laundry precipitates form incrustation, encourages bacterial growth which gives taste, odor and turbidity problems to distributed water
Arsenic	0.01mg/l (p)	Acute poisoning involves Central nervous system leading to coma and possibly death. Chronic poisoning leads to general muscle weakness, appetite loss, nausea, mucous membrane inflammation, skin cancers

Table 3 Contd.

Parameter	Guideline Value	Public Health and other Significance
Cadmium	0.003mg/l	Partial inhibition of Gastrointestinal tract absorption of iron, renal effects like proteinuria, glucosoria and aminociduria
Chromium	0.05mg/l (p)	Hexavalent chromium causes necrosis, nephritis and death in man
Cyanide	0.07mg/l	Possible death
Mercury (total)	0.001mg/l	Neurological and renal disturbances
Boron	0.3mg/l	Mild gastro intestinal irritation
Zinc	3mg/l (not health based)	imparts undesirable astringent taste to water, may confer greasy film on boiling
Organic constituents		
Carbon Tetrachloride	2ug/l	destroys cell membranes, proven carcinogenic in mice
Dichloromethane	20ug/l	Possibly carcinogenic
Vinyl Chloride	5ug/l	Causes angiosarcoma, possible carcinogen
1,2 dichloroethene	50ug/l	possible genotoxic activity

Table 3 Contd.

Parameter	Guideline Value	Public Health and other Significance
Benzene	10ug/l	Carcinogenic-leukemia
Toluene	700ug/l	May affect taste at levels below guideline values, impairment of CNS and irritation of mucous membranes
Xylene	500mg/l	Produces detectable odor and taste
Styrene	20ug/l	Imparts sweet odor to water, possible carcinogen
PAH (benzo[a] pyrene)	0.7ug/l	Closely associated with suspended solids, some e.g. benzo[a] pyrene proven carcinogenic
Acrylamide	0.5ug/l	Neurotoxic, genotoxic carcinogen
Nitroloacetic acid	200ug/l	Produces tumors after long exposure
Pesticides		
Aldrin and Dieldrin	0.03ug/l	Health effects on central nervous system and liver
Carbofuran	5ug/l	Chemical manifestations similar to organophosphorus intoxication
Chlordane	0.2ug/l	Possible carcinogen
DDT	2ug/l	Impairs reproduction
2,4 -dichlorophenoxyacetic acid	30ug/l	Limited data available to include on its carcinogenity

The aim of drinking water quality standards is:

a. To ensure that water intended for human consumption is free of organisms and from concentrations of chemical substances that may be hazardous to human health (WHO, 1971).

b. To ensure that water is aesthetically acceptable to consumers

c. To serve as an indicator of the reliability of water supply systems, making them economically useful.

Drinking water quality standards can be grouped according to physical, chemical and microbial quality.

2.5.1 Microbial Quality

Safe guarding the microbial quality of drinking water is believed by experts to be the most important objective, even ahead of its physical and chemical quality, because water represents an obvious mode of transmission of enteric diseases (Bland, 1980; Skinner, 1971). According to the WHO (1971), the greatest danger associated with drinking water is contamination by sewage, human or animal excreta.

Microbial quality is determined using various methods of bacterial examination. Percy Frankland in London, started the first routine examination of water using gelatine plate counts. In 1891 he enunciated the concept of using organisms usually abundant in human and animal excrement, as evidence of contamination and the possible presence of other potentially dangerous micro-organisms (WHO, 1984). These organisms are known as indicator organisms.

The use of indicator organisms for determination of the microbial quality of water saves the time, labour and expense involved in attempting to test for all pathogens that a water sample might possibly contain. For an organism to be ideal for use as an indicator, it must meet the following criteria

a) The methods of isolation, identification and enumeration should be simple and unambiguous.

b) It should be resistant to chlorine and have a higher survival rate in water than pathogens.

c) They should be more neutral than all pathogens in the environment.

The significance that can be attached to the presence or absence of a particular fecal indicator varies with each organism and with the degree to which that organism can be specifically associated with faeces. (WHO, 1984).

Houston recognized the 3 main groups of indicator used today i.e. the coliforms, fecal streptococci and gas forming clostridia. The Coliform or total coliform group include all the aerobic and facultative anaerobic, gram negative, non-spore forming rod shaped bacteria that ferment lactose in 24 hours at 35°C (EPA, 1978) e.g. *Escherichia coli*, *Citrobacter*,

Citrobacter, enterobacter and klebsiella.

The coliform group includes a sub-group known as fecal coliforms, which ferment lactose in 24±2 hours at 45±0.2°C with the production of gas in a multiple tube procedure (EPA, 1978).

E.coli is specifically of fecal origin, and its absence can generally infer that disease producing organisms are also absent (WHO, 1971).

The ease of detection and enumeration of coliforms, have made them widely used in assessment of drinking water quality, however some doubts have been raised as to their suitability as indicator organisms. These include:

a) Their proliferation in nutrient enriched waters that might not be due to fecal contamination. e.g waters enriched by effluents from a paper mill (Dutska, 1979; WHO 1984).

b) Their use as an indicator for health hazards of which they cannot be true determinants. e.g in swimming associated diseases like skin and naso-pharyngeal infection (James, 1979).

c) The greater resistance to disinfection of some cysts like Giardia lambiia and amoebae, raises doubts on the inference that the absence of coliforms from recently disinfected water means that pathogens are absent (WHO, 1984).

d) The validity of 100ml coliform counts has also been queried where coliforms are homogeneously dispersed. Gale (1996) notes the public health significance of this lapse especially in diseases where a single pathogen like rotavirus has been known to infect 27% of adults.

e) Dutska (1979) reports that the temperature at which coliform are incubated is inhibitory to the growth of enterobacleriacidae and thus wonders if the enumeration of cultures is representative of the natural water samples.

The awareness of the limitations of coliform groups stimulated research in the use of other organisms as indicators.

Fecal streptococci are those normally present in the faeces of man and animals e.g S.faecalis, S.faecium, S.duralis and S.avium, as well as strains with properties intermediate between them (WHO, 1984). The advantages of fecal streptococci over coliforms include their non-multiplication in water and their higher survival rates which means that they can be used to indicate pollution distant from the source. Fecal streptococci also show a degree of host specificity permitting characterization of the pollution source. The high ratio of fecal coliforms to fecal streptococci may be useful in locating the origin of fecal pollution in heavily contaminated raw water.

Fecal streptococci have the limitation of being less abundant than E.coli in faeces and may grow on vegetation and insects. Their persistence in water with moderate salt concentrations also limits their use as indicator for drinking water.

Clostridia are spore forming organisms, which are characterized by their ability to reduce sulfites to sulphates and their formation of spores. Examples are C. perfringens

(WHO, 1984). They have some advantages over the coliform group due to their ability to survive longer and greater resistance to disinfection than the coliform group. The presence of C. perfringes in a natural water and the absence of coliforms suggests that the contamination took place a longtime ago. Their presence in disinfected water indicates that there is a deficiency in the water treatment system. Their high survival rates means that they can give false alarms and should therefore not be used for routine examinations.

Pseudomonas aeruginosa is a gram negative non spore forming, rod-shaped bacterium that grows at 42^{0}C, it is oxidase and catalase positive, reduces nitrates, nitrites, ammonia and oxidizes glucose (WHO, 1984). It occurs in lower numbers than coliforms in the faeces of man. P. aeruginosa is of value in preparation of pharmaceuticals, baby foods, and rehydration mixtures, rather than for routine examination of drinking water.

The desire for an indicator system which unequivocally denotes the presence of fecal matter and potential health hazards has stimulated research along bacteriological and biochemical lines. One such organisms is Bifidobacter a major component of human and animal species. Bifidobacter has the advantage of being anaerobic and unable to multiply in natural water. They may provide a specific assay by which lower animal and human fecal pollution may be separated Dutska (1979). Coprostanol (5^{a}-Cholestan-3^{a}-o^{1}) is an example of a biochemical indicator, which has the advantages of being stable and non-pathogenic. It can be detected even in the presence of other lipid like compounds in the water. Unlike biological indicators Coprostanol is not affected by disinfectants or toxic waste discharge, and is therefore ideal for use in chlorinated effluents and industrial wastes to indicate fecal contamination or health hazards due to non-inactivated viruses. Coprostanol has limitations that include the laborious procedure required for each sample and the lack of knowledge about the relationship between pathogens, indicators and Coprostanol.

Microbiological standards for rural and small community water supplies can be less stringent than those for urban areas, because of the non-attainability of urban standards in small communities, where water sources are wells, boreholes and springs not piped water. There is therefore a greater likelihood of contamination during transportation or storage (WHO, 1971; WHO 1984; Morgan, 1989). The WHO (1975) recommended standard for such water supplies is an MPN count of <10/100ml for total coliforms and 2.5/100ml for E.coli. The WHO (1995) recommends that due to the widespread faecal contamination in developing countries, the national surveillance agency should set medium-term targets for the progressive improvement of water supplies.

2.5.2 Physico-Chemical quality

The term physico-chemical quality is used in reference to the characteristics of water which may affect its acceptability due to aesthetic considerations such as colour and taste; produce toxicity reactions, unexpected physiological responses of laxative effect and objectionable effects during normal use such as curdy precipitates (Charlett, 1979)

Taste ad Odour

Taste and odour depend on the stimulation of the human receptor cells, which are located in the taste-buds for taste and nasal cavity for odour (Emslie-Smith, 1988; WHO, 1984). Taste and odour are complimentary, e.g when tasting water, both the olfactory and gustatory nerves are active. In all taste tests it is actually flavour that is being measured. Flavour refers to the combination of taste, odour, temperature and feel. The close association between taste and odour may be illustrated by the lack of flavour of many food substances, when the sense of smell is lost during a head cold (Emslie-Smith, 1988; APHA 1996)

Taste and odour problems account for the largest single class of consumer complaints in drinking water supplies, due to the water source, the treatment method, distribution system or a combination of all three (WHO, 1984). Taste in drinking water is measured by taste tests such as the threshold test or taste rating tests. While odour tests are carried out for odour in drinking water (Table 4) (See standard methods, for details). The sense of smell is more sensitive than the best analytical method, for example the guideline for cyanide in drinking water would be 1/100th of the present limit if based on the odour threshold of 0.001mg/l (WHO, 1984).

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Taste ad Odour

Taste and odour depend on the stimulation of the human receptor cells, which are located in the taste buds for taste and nasal cavity for odour. (Emslie-Smith, 1988; WHO, 1984). Taste and odour are complimentary, e.g when tasting water, both the olfactory and gustatory nerves are active. In all taste tests it is actually flavour that is being measured. Flavour refers to the combination of taste, odour, temperature and feel. The close association between taste and odour may be illustrated by the lack of flavour of many food substances, when the sense of smell is lost during a head cold (Emslie-Smith, 1988; APHA,1996)

Taste and odour problems account for the largest single class of consumer complaints in drinking water supplies, due to the water source, the treatment method, distribution system or a combination of all three (WHO, 1984). Taste in drinking water is measured by taste tests such as the threshold test or taste rating tests. While odour tests are carried out for odour in drinking water. (Table 4) (See standard methods for details). The sense of smell is more sensitive than the best analytical method, for example the guideline for cyanide in drinking water would be 1/100th of the present limit if based on the odour threshold of 0.001mg/l (WHO, 1984).

Factors that affect taste and odour include:

i. **Temperature**

The growth rate of micro-organisms, some of which produce bad tasting metabolites is positively correlated with temperature. The odour of substance is also temperature influenced because of the relationship between odour and vapour pressure, therefore odour measurements usually specify temperature.

ii. **pH** influences the taste and odour of a substance significantly, especially when it controls the equilibrium concentration of the neutral and ionized forms of a substance in solution. The average threshold increases from 0.075mg/l to .450 mg/l as pH increases from 5.0 to 9.0 (WHO 1984).

iii. **Residual Chlorine**

A balance is sought such that the level of residual chlorine is high enough for microbial safety without leaving an objectionable taste in drinking water.

Table 4 Taste threshold for major cations

ELEMENTS	TASTE THRESHOLD mg/l
Calcium	100
Magnesium	30
Sodium	100
Potassium	300
Iron II	0.4 in distilled water
Iron III	0.12 in distilled water
Zinc	4.3 in distilled water
	6.8 in mineralized water

Source: (WHO, 1984)

Health implications of taste and odour in water is related to the fact that consumers seek alternative sources that have more acceptable tastes to them, even though the alternatives may not be of as high a microbial quality as the rejected water. Short term changes in taste and odour of water may be indicative of changes in the raw water quality, deficiencies in the treatment process. These changes may also be indicative of chemical corrosion and biological growth in the distribution system. All of which may have negative health implications (WHO, 1984). Organisms responsible for taste and odour in water include actinomycetes, algae, iron bacteria, and free living worms.

Total Dissolved Solids

Total Dissolved solids comprise organic matter and inorganic salts which may originate from sources such as sewage, effluent discharge, urban run-off or from natural bicarbonates, chlorides, sulphate, nitrates, sodium, potassium, calcium and magnesium. The major determinant of the TDS level in water is the geochemical characteristics of the ground it comes in contact with e.g. granite and siliceous sands, and well leached soils have TDS less than 360mg/l. TDS levels are mainly determined by gravimetric methods. According to WHO (1984) the palatability of drinking water according to its TDS level has been rated by Bruvold with levels less than 500mg/l being rated as excellent and levels greater than 1700mg/l unacceptable (Table 6).

Total Dissolved solids is related to other water quality parameters like hardness which occurs if the high TDS content is due to the presence of carbonates. A low total dissolved solids level also affects the taste of water and might be perceived by the consumer as flat and thus unacceptable. Furthermore TDS levels due to chloride, causes corrosion, whilst that due to carbonate and calcium salts might result in encrustation.

Turbidity

Turbidity is an expression of certain light scattering and light absorbing properties of the water sample caused by the presence of clay, silt, suspended matter, colloidal particles plankton and other micro-organisms (WHO, 1984). Examples of micro-organisms that cause turbidity are the summer blooms of the blue-green algae in surface water and algal detritus formed by iron bacteria. Turbidity can be measured by various methods, two of which are currently used; turbidimetry and nephelometry. The nephelometric method is more current and measures the intensity of light scattered at 90^0 to the path of incident light. Turbidity of water affects other water quality parameters such as colour, when it is imparted by colloidal particles. Therefore when measuring color, the colour is that from which turbidity has been removed. The taste and odour of raw and treated water varies with high levels of turbidity. Turbidity also negatively affects the microbiological quality of water by promoting microbial proliferation and protecting bacteria and viruses from disinfecting agents. Turbidity also affects the chemical quality of drinking water through the formation of complexes between the turbidity causing humic matter and heavy metals. The absorption of organic molecules like herbicides onto a clay-humic acid surface also affects water quality.

Colour

Colour in drinking water is caused by the presence of coloured organic substances, usually humic, which originate from the decay of vegetation in surface water. Iron and manganese also give water a red and blue colour respectively by the action of bacteria, which oxidize them to their ferric and manganic oxides respectively. The solubilisation of copper from copper pipes may also give a blue tinge to water. Colour can be measured by visual comparison of the sample with platinum cobalt standards where one unit of colour is that produced by 1mg/l platinum of chloraplatinate ion (EPA, 1983). The WHO (1984) recommends limit of 15TCU for drinking water.

Table 6 Consumer ratings according to total dissolved solid levels of drinking water

RATINGS	TOTAL DISSOLVED SOLID LEVEL (mg/l)
Excellent	<300
Good	300-600
Poor	600-900
Unacceptable	>1700

Source (WHO 1984)

Table 7 Classification of hardness in equivalent of calcium Carbonate concentration

Classification	Quantity (mg/l)
Soft	0-60
Medium hard	60-120
Hard	120-180
Very hard	>180

Source (WHO, 1984)

pH

The pH of a solution is the negative common logarithm of the hydrogen ion activity, aH^+, and it is measured electrochemically using a glass electrode. Most raw water sources have a pH range of 6.5-8.5 (WHO, 1984). pH is temperature dependent, and a decrease of about 0.45 occurs with a temperature increase 25^0, though this can be modified by the buffering effect of bicarbonates. Water treatment processes such as chlorination lowers the pH, while softening with excess lime/soda raises the pH.

Dissolved Oxygen

The level of Dissolved oxygen in water is used as an indication of pollution and potability, it thus forms a key test in water pollution control activities and waste treatment process control. Dissolved oxygen is measured using either the Winkler method, its modification or the iodometric method, depending on the accuracy desired, convenience, and interference present (APHA, 1996). The recommended guideline value for drinking water is a level not below 6mg/l (WHO, 1984). Lower levels indicate microbial contamination or corrosion. It is however possible for large amounts of iron corrosion to occur without the oxygen level falling perceptibly.

Hardness

Hardness of a water is the traditional measure of the capacity of water to react with soap. Hard water thus requires a considerable amount of soap to produce lather. The principal ions causing hardness are calcium and magnesium, and when the anion is carbonate it is referred to as temporary, because this type of hardness can be removed by boiling, unlike when the anions are sulfates, chlorides and nitrates. Natural sources of hardness include sewage and run-off from soils particularly limestone formations, while main industrial sources are mining, the building industry where calcium oxide is used and the use of magnesium in textile tanning and paper industries. Groundwater is often harder than surface water and may have levels up to several thousand mg/l because of its high solubilizing potential, particularly for rocks that contain gypsum, calcite and dolomite. Hardness may be estimated by titrimetric determination of individual concentrations of the components of hardness, their terms being expressed in terms of an equivalent quantity of calcium carbonate (Table 7).

Alkalinity

Alkalinity is an index of the buffering capacity of water, produced by anions of weak acids, usually hydroxides, bicarbonates and carbonates. It is measured by titrimetric methods, where an increase in alkalinity causes a loss of colour, which is directly proportional to the alkalinity of the sample. Alkalinity of a water sample is usually close to its hardness value.

Chloride

Chloride occurs in nature in the form of sodium, potassium and calcium chloride salts from the oceans. It occurs in ground water as a result of saline intrusion, brine in oil well operations, sewage discharge, irrigation drainage, contamination from refuse leachate and in temperate countries, from the use of salts to de-ice roads. Chloride in drinking water is measured by titrating an acidified sample with mercuric nitrate in the presence of mixed diphenyl mercuric carbazone blue indicator with the formation of the blue solid, mercury diphenyl carbazone complex as end point (EPA, 1983). Although the taste threshold of chloride in drinking water depends on the associated cation, it is usually in the range of 200-300mg of chloride/litre. The WHO (1984) recommends a guideline value of 250mg/l. A higher value than 1000mg/l in water is an indication of pollution.

2.5.3 Toxic Chemicals

Chemical contaminants of drinking water supplies occur along with contaminants of other inorganic and organic constituents. Therefore since guideline values for these chemicals are calculated separately, without consideration of possible synergistic effects, on the occasion when contaminants with similar toxicological effect occur at levels near their respective guideline values, appropriate action should be taken with the assumption that the toxic effects of these compounds are additive.

Nitrates and Nitrites

Nitrates and Nitrites are considered together because conversion from one form to the other occurs in the environment and the health effects of nitrates are generally as a consequence of its ready conversion to nitrites in the body. Nitrate levels in polluted water are usually higher than nitrite levels. Nitrates are formed as by products of incomplete oxidation of organic nitrogen by bacteria present in soil. Sources of nitrate pollution are feedlots, domestic effluents, industrial effluents, refuse dump leachates, and excessive fertilizer use and land disposal of sludge. The WHO (1984) guideline for nitrates in drinking water are typically below 50mg of nitrate-N per litre, levels exceeding these are indicative of pollution. Nitrite levels can be reduced during water treatment by the oxidizing effects of chlorine.

Lead

Lead is a natural constituent of the earth crust at an average concentration of about 16m/kg. It exists in the environment almost entirely in the inorganic form, although small amounts of organic lead occur from the use of leaded gasoline and from natural alkylation processes that produce methyl lead compounds. Lead is used for a wide range of purposes such as the manufacture of motor batteries, alkyl lead compounds for gasoline, solder pigment, cable sheathing, roofing and piping materials, which are all potential pathways of pollution of drinking water. Lead levels in drinking water are relatively low, because conventional water treatment procedures remove a significant amount of lead, levels may be higher where lead plumbing or lead storage tanks are used. Low pH and softness increases lead content of water by promoting corrosion. The maximum intake of lead from food, air and water is 3mg/week (0.05mg/kg of body weight) for adults (WHO, 1984).

Iron

Iron is the most abundant element by weight in the earth crust, it occurs in water in its ferric and ferrous states, particularly in well aerated conditions. Rock and mineral dissolution, acid mine drainage, land fill leachates, sewage or iron related industries are causes of high iron levels in groundwater, lakes and reservoirs, particularly where reducing conditions are present (Okun, 1983).

Ammonia

Ammonia refers to the non-ionized (NH_3) and ionized (NH_4^+) forms. Its occurrence in the environment is from metabolic, agricultural, industrial processes and from disinfection with chloramine. No guideline value is fixed for ammonia in drinking water, due to the fact that it is not of immediate public health significance.

Arsenic

Arsenic is another inorganic constituent of drinking water that is widely distributed throughout the earth. The sources of introduction into drinking water include dissolution of minerals and ores, industrial effluents and atmospheric deposition. Concentrations in groundwater may be elevated as a result of erosion from natural sources. A provisional guideline value of 0.01mg/l is established, with a view to reducing its concentration in drinking water.

Asbestos

Asbestos is introduced into water by the dissolution of asbestos containing minerals and ores as well as from industrial effluents, atmospheric pollution and asbestos cement pipes in the distribution system (WHO, 1995). The amount of asbestos exfoliated from water pipes depends on the aggressiveness of the water supply. There is no health based guideline value for asbestos in drinking water.

Barium

Barium occurs as various compounds in the earth's crust, and it is used in a wide variety of industrial applications. Its presence in water is from natural sources. The guideline value is 0.7mg/l (WHO, 1995).

Boron

Boron is released into water from industrial and domestic effluents from its use in detergents and industrial processes. Elemental boron is also used in composite structural materials. Boron is present in drinking water at concentrations below 1mg/l. Though higher levels have been found which are attributable to natural occurrence of boron. A 0.3mg/l (rounded figure) guideline value based on a 10% TDI from drinking water has been established by the WHO (WHO, 1995).

Cadmium

Cadmium is a metal used in the steel industry and in plastics. Its compounds are widely used in batteries. Environmental sources of cadmium include wastewater discharge, fertilizers and air sources. Drinking water contamination occurs from impurities in the zinc used in galvanized pipes, solders and some metal fittings. Levels in drinking water are usually less than 1ug/l. A guideline value of 0.003mg/l is established with an allocation of 10% of the PTWI to drinking water.

Chromium

Chromium occurs widely in the earth crust in +2 to +6 valences. Total chromium concentrations in drinking water are usually equal to or less than 5ug/l, although concentrations as high as 20ug/l have been reported. A provisional guideline value of 0.05 mg/l has been retained from considerations that it is unlikely to give rise to significant risks to health (WHO, 1995).

Copper

Copper plumbing can greatly increasa concentrations of copper in drinking water from its usual low level of a few micrograms per litre to several milligrams per litre, usually following a period of stagnation in pipes. The presence of copper in a water supply system may interfere with the intended domestic use of the water, due to an increase in the corrosion of galvanized iron and steel fittings, which causes staining of laundry and sanitary wares at concentrations above 1 mg/l. At levels higher than 5 mg/l, a colour and an undesirable taste is imparted to the water.

Aluminum

Aluminum is a widespread and abundant element comprising some 8% of the earth's surface. A frequent reason for the presence of aluminum in drinking water is deficiency in control and operation of the treatment process. When present in concentrations above 0.2 mg/l deposits of aluminum hydroxide floc occur causing an increase in the discoloration of water leading to consumer complaints.

Fluoride

Fluoride accounts for about 0.3 g/kg of the earth's crust. Sources of exposure include the use of inorganic fluorine compounds in the production of fluoride, the release of fluoride during the manufacture and use of phosphate based fertilizers. Exposure from drinking water depends greatly on natural circumstances. Raw water levels are normally below 1.5 mg/l though ground water may contain about 10 mg/l in areas rich in minerals containing fluorides. A guideline value of 1.5 mg/l exists for fluorides (WHO, 1995)

Mercury

Mercury usually occurs in the inorganic form in surface and ground water at concentrations less than 0.5 mg/l. The guideline value for total mercury is 0.001 mg/l (rounded figure).

Organic contaminants

Organic contaminants of drinking water include chlorinated alkanes, chlorinated ethenes, aromatic hydrocarbons and chlorinated benzenes.

Chlorinated Alkanes

Carbon Tetrachloride is used principally in the production of chlorofluorocarbon refrigerants. Sources of environmental exposure include release into air and water during manufacturing and use. Concentrations in drinking water are usually less than 5 ug/l. A guideline value of 0.2 ug/l was derived based on a TDI of 0.714 ug/kg of body weight (WHO, 1995).

1, 1- dichloroethane is used as a chemical intermediate and solvent, limited data show that it can occur in concentrations up to 10 ug/l in drinking water. According to the WHO (1995), its occurrence in ground water may increase due to its widespread use and disposal in ground water. No guideline value has been proposed, because of the limited database on its toxicity and carcinogenicity.

Chlorinated Ethenes

Vinyl Chloride is used primarily for the production of polyvinyl chloride. Sources of environmental exposure include the constant presence in air, which in Western Europe is estimated to range from 0.1 to 0.5 ug/m^3 (WHO 1995). Vinyl chloride can be formed in water from trichloroethene and tetrachloroethene. It has been found in drinking water at levels up to a few micrograms per litre, and on occasion, higher levels occur in ground water.

Aromatic hydrocarbons

Benzene is used principally in the production of other organic chemicals. Routes of environmental exposure include petrol and vehicular emissions. It may be introduced into water by industrial effluents and atmospheric pollution. Concentrations in drinking water are generally less than 5 ug/l. A guideline value of 10 ug/l, for a 10^{-5} excess cover risk is therefore retained (WHO, 1995).

Styrene is another aromatic hydrocarbon, used primarily for the production of plastics and resins. It is found in trace amounts in surface water, drinking water and food. Levels in air can be up to a few hundred micrograms/day in industrial areas. A guideline value of 20ug/l, with 10% of TDI allocated to drinking water has been established by the WHO (1995).

Polyaromatic Hydrocarbons

Polyaromatic hydrocarbons (PAH) from a variety of contamination and pyrolysis sources have been identified in the environment as minor sources of drinking water contamination. A guideline value for benzo[a]pyrene in drinking water of 0.7ug/l has been established. According to the WHO (1995) there is insufficient data available for the derivation of values for other PAH.

Chlorinated benzenes

Monochlorobenzene (MCB), is released to the environment from volatisation associated with its use as solvent in pesticide formulation, a degreasing agent and from other industrial applications. Although the lowest reported taste and odour threshold for MCB in water is 10-20ug/l, guideline values of 300ug/l are based on an allocation of 10% of the TDI to drinking water.

Di(2-ethylhexyl) adipate (DEHA)

DEHA is used mainly as a plasticizer for synthetic resins like polyvinyl chloride (PVC). DEHA have been infrequently identified in drinking water at levels of a few micrograms/litre. The guideline value is 8ug/l litre (rounded figure) based on an allocation of 1% of the TDI to drinking water.

Di (2-ethyhexyl) phtalate is another organic contaminant used primarily as a plasticizer. It occurs on the surface of groundwater, and concentrations of hundreds of micrograms/litre have been reported in polluted sources. It occurs in drinking water in concentrations of a few micrograms per litre. A guideline value of 8ug/litre (rounded figure) with an allocation of 1% of the TDI to drinking water has been established.

Organic chemicals

Nitrilotriacetic acid (NTA) is used primarily in laundry detergents as a replacement for phosphates and to treat boiler water, so as to prevent scale accumulation. A guideline value of 200ug/l has been established (WHO, 1995).

Edetic acid ((Ethylene diamine tetracetic acid; EDTA) and its salts are used in many industrial processes, as food additives in domestic products, as drugs in chelation therapy, all of which allow substantial release into the aquatic environment. Levels in natural water of 0.9mg/l have been recorded though levels less than 0.1mg/l are more usual. A guideline value of 200ug/l has been established (WHO, 1995).

Acrylamide in the form of residual acrylamide monomer occurs in poly acrylamide coagulants used in the treatment of drinking water. Other sources of exposure from water include its use as grouting agents in the construction of drinking water reservoirs and wells. A guideline value of 0.05ug/l has been established.

Biocides

Biocides in drinking water are increasing becoming a problem, due to degradation of these compounds.

Guideline values have however not taken into consideration toxicities attached to the degraded products due to lack of data.

Aldrin and Dieldrin

They are chlorinated pesticides used against soil dwelling pests, for wood protection. Dieldrin is also used against insects of public health significance. The compounds have similar toxicology and mode of action, with Aldrin being converted to Dieldrin under moist environmental conditions. Dieldrin is highly persistent with low mobility in soil and atmospheric losses. It is occasionally found in drinking water through agricultural run-off into surface waters and eventual percolation into ground water. A guideline value of 0.03ug/litre has been established based on an allocation of 1% of the ADI to drinking water. (WHO, 1995).

Bentazone is a broad-spectrum herbicides used for a variety of crops, though it photodegrades in soil and water, it has a high soil mobility and moderate persistence in the environment.

It has been found in ground water, and has a high affinity for the water component. A guideline value of 30ug/l based on 1% allocation of the ADI to drinking water was established (WHO, 1995).

DDT

Although DDT has been banned or prohibited in some countries, it still enjoys extensive usage. It is a persistent insecticide, soluble under most environmental conditions. A guideline value of 2ug/l has been established for DDT and its metabolites. Although this exceeds the water solubility of DDT, which is 1ug/l, some DDT may be absorbed into the small amounts of particulate matter present in drinking water, so that even the guideline value of 2ug/l can be reached under certain conditions.

2.6 Water Treatment for Small Community Water Supply Systems

Small Community water supply systems refer to technologies used in water distribution including treatment methods that are integrated with community involvement. Homer (1986) points out that it is not a scaled down version of urban installations, but one in which the peculiarities of the community in terms of organization, management, skill, economics and social practices are taken into consideration. This is necessary in order to choose the technology appropriate for water provision in the selected community.

Water treatment is the process of converting raw water from surface or sub-surface sources into a drinking water suitable for domestic uses (Hofkes, 1981). Although authorities agree that the aim of water treatment is the removal of pathogenic organisms and toxic substances, they note that water treatment should not make drinking water pure or sterile in the analytical sense. In this regard salts are sometimes added to improve the taste. (Hofkes, 1981; Solt, 1984; Oluwande, 1983, APHA, 1996)

The various methods by which water is rendered potable are referred to as unit operations and they are namely Aeration, Coagulation and Flocculation, Sedimentation, Filtration, and different means of Disinfection, which make use of physical, biological and chemical processes to achieve their objectives.

There are other purification methods, which though not unit operations are used for small community water supplies.

Storage

This is a purification method used in many low socio-economic communities. Water can be made safe to drink if stored for 2 days during which the harmful organisms die and sink to the bottom. DD (1987) advocates the three pots method, whereby two pots are used for fetching water on alternate days and one for storing which allows the household to have water which has been stored for at least 2 days before contamination. Pots should be covered to prevent contamination, limit evaporation and prevent algal growth. Earthenware pots should not be used because they encourage bacterial growth.

Boiling

Boiling is a safe and effective way of pathogen extinction if carried out properly, e.g. making sure that water boils for recommended period of five minutes. However recent studies reveal that most micro-organisms are killed far below the boiling temperature

+ 90^{0}C (SODIS, 1997).

Boiling water might be tedious in terms of time needed to prepare fire and to cool boiled water.

2.6.1 Aeration

Aeration is the treatment process, whereby water is brought into intimate contact with air in order to increase their oxygen content to facilitate precipitation and results in the removal of iron and manganese in their ferric and manganese forms, and organic compounds such as methane and hydrogen sulphide. Aeration decreases the carbon dioxide content of water and thus reduces the solubilizing tendencies of water, which cause corrosion and leaching of plumbing materials into water. Groundwater high in iron and manganese benefit from aeration.

2.6.2 Coagulation and Flocculation

Coagulation and flocculation is the process by which finely divided suspended and colloidal matter in the water is made to aggregate and form flocs with the aim of removing substances that cause turbidity and color in water. Coagulants are often salts of multivalent elements, the most common of which are aluminum and ferric salts e.g. aluminum sulphate (alum) and ferric chloride. Coagulation encourages sedimentation, thus reducing the load in filters, thereby reducing costs through the extension of the life of the filter.

2.6.3 Sedimentation

Sedimentation, also known as clarification refers to the unit process where particles heavier than the liquid they are in, are removed by gravitational settling. Apart from the obvious significance of clarification, sedimentation also affects the chemical quality of water, through the settling of complexes formed between heavy metals and flocs.

2.6.4 Filtration

Filtration is the process whereby water is purified and made attractive by passing it through a porous material or medium. Hofkes, 1981; Oluwande, 1983). When sand is used as a medium, filtration has an effect on the physical and microbiological quality of the water, the extent of which depends on the method of filtration employed, i.e. slow or rapid sand filtration. Treated water comes into the filter with about 2 JTU and leaves with a turbidity of 0.2 JTU. Bacterial removal is 98-99% or more. (WHO, 1995). Rapid sand filtered water, needs to be chlorinated due to the filtration rate, which is an amount fifty times that of the slow sand filter, and allows little time for biodegradation. Slow sand filters are more suitable for small communities in the developing countries due to factors such as reduction of costs arising from the elimination of the need for chemical purchase and the elimination of mechanical devices to encourage coagulation and flocculation. Costs are also reduced for the reasons related to the cleaning intervals, which is thirty times that of rapid filters. Though the filters require extensive bed areas and have a throughput rate of one thirtieth of that of rapid filters, slow sand filters are more ideal for developing countries (Chanlett, 1979).

2.6.5 Disinfection

Disinfection is a major unit operation in water processing. Its objective is to obtain microbiologically clean water processing which contains no pathogenic organisms and is free from biological forms that may be harmful to human health or aesthetically objectionable (Koolapep, 1980). While other unit operations affect more than one aspect of water quality, disinfection affects the biological quality only. The efficacy of disinfection is influenced by factors such as the nature and number of organisms in the raw water, the type and concentration of disinfectant, water temperature, contact time, nature of water to be disinfected and pH. Disinfection can either be physical or chemical.

Chemical disinfectants employ the use of chemicals known as disinfectants as the disinfecting agents. Some examples include chlorine, ozone, potassium permanganate and chlorine dioxide, whose popularity varies with factors related to acceptability due to taste, odour and cost. These factors would also determine its suitability for small community use.

Hofkes (1981) notes that for a chemical to be suitable for use as a disinfectant, it should satisfy the following parameters

I). Be quick and effective in killing pathogens present in water.

ii) Be readily soluble in the water concentrations required for disinfection.

iii) It should leave a residual

iv) It should impart no taste, odour or colour to the disinfected water.

v). It should be easy to detect and measure in water

vi). It should be readily available at moderate cost.

Chlorine was first used for water disinfection early in the 20th century, it is by far the most widely used chemical disinfectant for reasons, which include its low cost, and efficacy against enteric diseases, that are water related (Hofkes, 1981; DD, 1987; Reiff, 1992). Chlorine can be used in various forms for water treatment (Table 8).

The following reactions take place when chlorine is added to water.

(1) $Cl_2 + H_2O \Leftrightarrow HOCl + Cl + H^+$

(2) $Ca(OCl)_2 + H_2O \Leftrightarrow Ca^{++} + 2OCl^- + H^+{}_2O$

The first equation represents chlorine, whilst the second represents what occurs when $Ca(OCl)_2$ is used. The hypochlorous acid and the hypochlorite ions are referred to as free available chlorine, it is more powerful than combined chlorine which refers to monochloramines, dichloramines, and nitrogen tetrachloride formed when water containing organic nitrogen and ammonia is chlorinated (Chanlett, 1979).

Table 8 Chlorine compounds

Type	Formula	Formula	% Available Chlorine	Containers	Feeding
Calcium hypochlorite	$Ca(OCl)_2 \cdot 4H_2O$	Powder	60-70	Cans or Drums	1-3% Solution
Bleaching powder (chlorinated lime)	$CaO \cdot 2CaOCl_2 \cdot 3H_2O$	Powder	25 - 35	Drums	1 - 2% Solution
Sodium hypochlorite	$NaOCl$	Solution	10 - 15	Glass or plastic	1 - 3% Solution
Chlorine	Cl_2	Liquefied gas	99	Steel Cylinders	Gas or solution

APPROPRIATE TECHNOLOGY FOR WATER TREATMENT

Technology for small and rural water supplies is limited to that which the community's resources in terms of financial and manpower can operate and maintain e.g. chlorine gas is not suitable for small community supplies due to high skill requirement.

Pot Chlorination

This refers to the disinfection of well water by placing a vessel containing a mixture of chlorine powder and sand in the well (Hofkes, 1981). 1.5kg of chlorine will provide satisfactory disinfection for one week. Pot chlorination might be either single or double pot where the single pot is found to give too high a chlorine content to the water. The double pot is effective for 2 weeks, in a well with a 4500l capacity drawn at a rate of 400-450l/day.

Chlorine may also be introduced into the well by means of a Jerry can placed on the parapet and allowing it to drip from an extended outlet tube into the water. Chlorine tablets and bleach solution may also be used to disinfect small quantities of well water. DD (1987), recommends 3 drops of 1% solution to 0.95l of water with a standing time of 20-30 minutes (Hofkes, 1981; DD, 1987). Trade names include Hadex, ~~Hydrochlozone~~ and Halozone.

Iodine is another chemical disinfectant that DD (1987) lauded as excellent but other experts believe it possesses limitations, which outweigh its advantages (Oluwande 1983; Holkes 1981). Some of its limitations are the high doses necessary to achieve satisfactory disinfection and its ineffectiveness in colored or turbid water, though Diarrhoeal diseases (1987) notes that the dosage should be doubled if water is polluted. Other limitations include its medicinal aftertaste end its volatility that limits its use to emergencies. Iodine is available in tablet form as tetraglycic potassium triiodite. It is highly effective against amoebic cysts, some viruses and bacteria (Oluwande, 1983).

Potassium permanganate is another chemical disinfectant that is a powerful oxidizing agent and is effective against Vibrio cholerae but not for other pathogens. It stains containers limiting its acceptability in the community.

A method of physical disinfection which is gaining increasing use is UV disinfection, which makes use of the ultraviolet band of the electromagnetic spectrum, situated in the wave length range of 10 B400nm, between X-rays and visible light. (Fig 3). The UV band brings about germicidal action in water by inactivating pathogens through damage done to the pyrimidine, thymine, and cytosine and uracil DNA bases of the microbes. (Anghem, 1984).

A basic disinfection unit requires an irradiating chamber, and a radiation source of between 240-270nm in wavelenght (Fig 4). The radiation source is usually a low-pressure mercury quartz lamp, which emits radiation when stimulated by an electric current. Althaus carried out one of several studies in Germany between 1982 and

1983 on a UV unit with 2 irradiating chambers, each with a 36 UV lamp as its radiation source. The raw water from river Ruhr with an initial bacterial count between 10^3-10^4 per ml and coliform count of $5x10^2$-$5x10^3$ per 100ml was reduced to zero on both counts after UV disinfection.

UV disinfection has limitations that include the fact that it does not leave a residual to combat recontamination and the possibility of regrowth of inactivated microbes. Anghem (1984) however reports that regrowth is not possible because conditions which enable bacteria carry out repair processes do not occur in nature except where water is improperly irradiated, in which case regrowth by as much as a hundred present is possible (Anghem, 1984; Baldi, 1980).

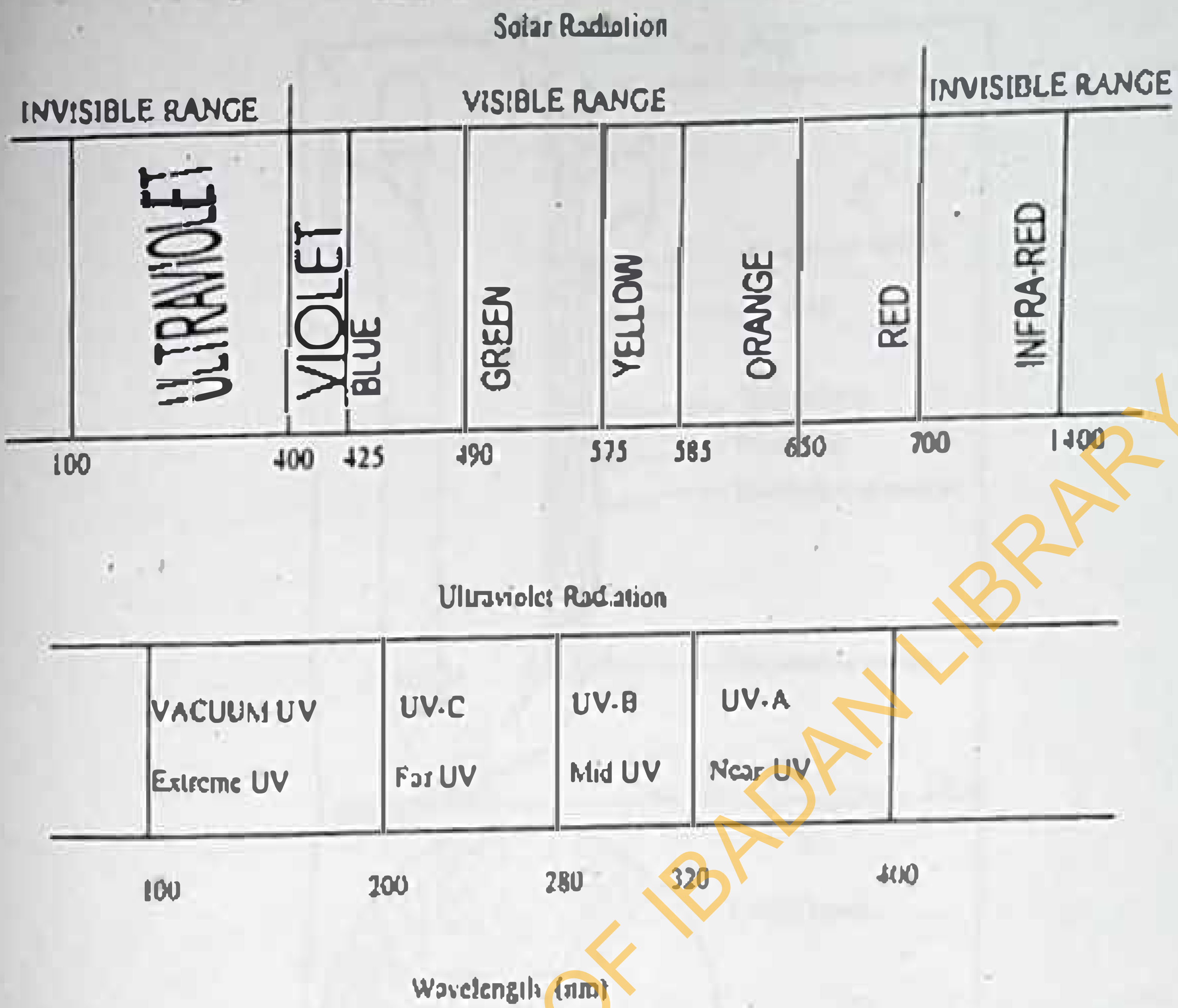

Fig 3 Electromagnetic Spectrum
(Source; Acra, 1990)

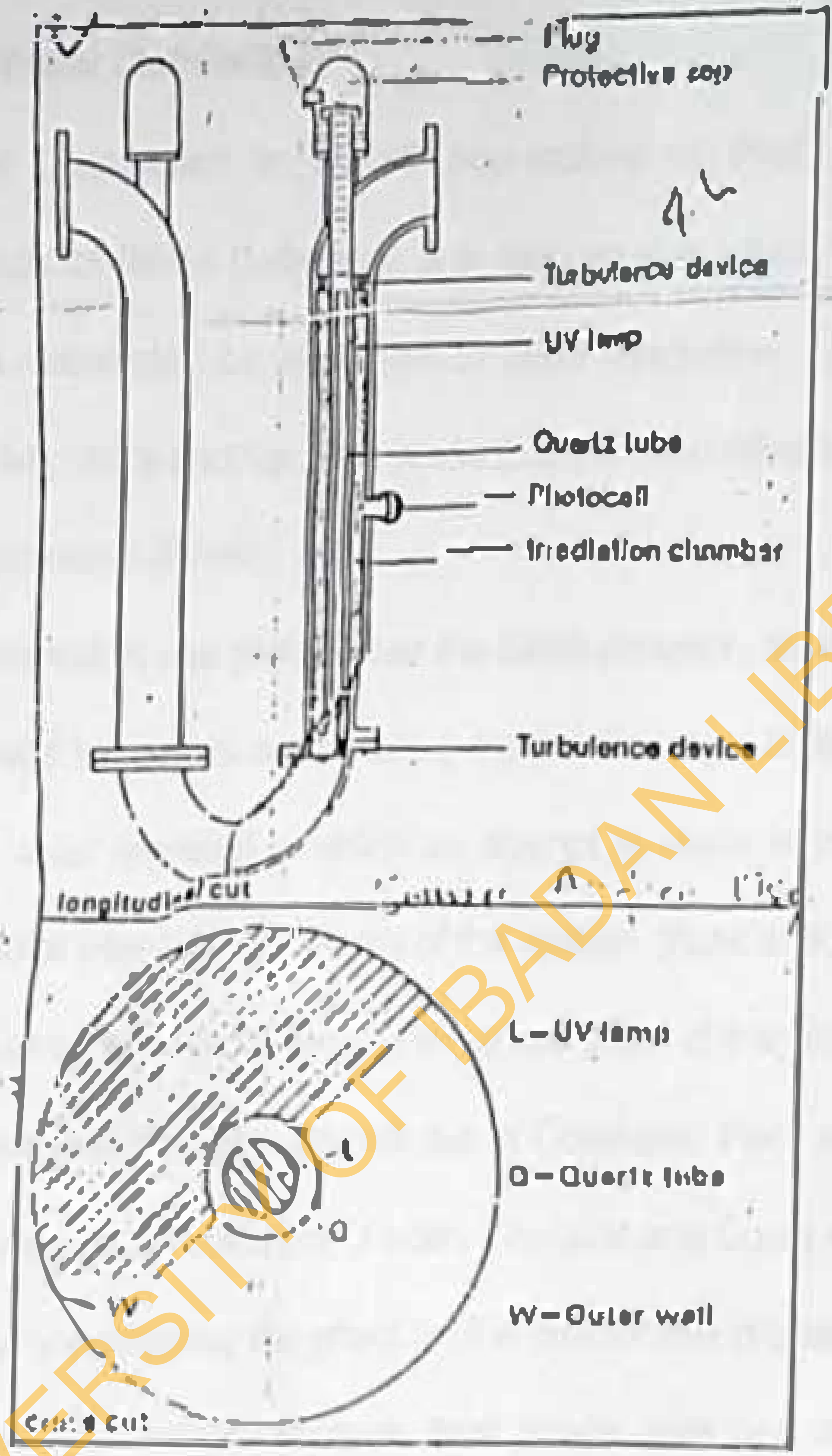

Fig 4 A basic disinfection unit showing various components and their layout
(Source; Anghem, 1984)

2.6.5.1 Solar Water Disinfection

Solar Water Disinfection or SODIS popularised by Prof. Aftim Acra of the American University of Beirut (Lebanon) is a technique in which small quantities of drinking water is disinfected by exposure to Solar Radiation. (Acra et al ,1990; Wegelin et al, 1994). Acra and his team noted that the most effective spectral band is the ultraviolet optimum of 357nm.

The technique makes use of the either the batch process , in which discrete units of water are exposed in various containers (e.g plastic bags, bottles) or continuous flow systems (e.g. solar reactors) in which an attempt is made to maintain a uniform flow of water and solar intensity at all points of the system (Acra et al, 1990).

Several studies have been carried out in various parts of the world based on Aftim Accra's work. These studies were carried out in Columbia, Peru and Nigeria in the eighties and more recently in Columbia, Jordan, Thailand and Costa Rica. The studies had the objective of investigating tho effect on the disinfection process of factors such as minimum number of hours of exposure, type shape, size and color of container, turbidity, type of pathogen end density, water temperature, water volume and cloudiness. Investigations were also carried out on the possibility of regrowth in irradiated water.

Acra (1980) observed that with a 95 minute exposure to sunlight (between 0900 hours and 1400 hours) in Beirut, a 99.9% reduction of the faecal coliforms was achieved with 300 minutes being required for 99.9% inactivation of the total bacteria. The minimum exposure time appears to vary with location for reasons related to solar intensity which in turn varies with latitude, geographical location, season, cloud coverage, atmospheric pollution, solar altitude and elevation above sea level (Acra, 1990). Odeyemi (1980) noted that a minimum of 5 hours exposure was required for adequate solar disinfection of water in Nigeria. Studies carried out in Columbia, Jordan, Thailand and Costa Rica observed varying exposure times with different percent age reduction of the micro organism load (Table 9).

Table 9 Inactivation rates of faecal coliforms and *Vibrio cholerae* (where indicated) and test conditions, container: quartz test tube (Volume 30ml)

Site/year	Test organism	Constant (°C)	Turbidity NTU	SS or TS* mg/l	Initial MPN	Final conc. MPN CFU/100ml	Exposure Min	UV-A W/m²	Total (%)	Aver… (%)
[illegible]dia 93	5 5b 6b	30 30 30	56 120 24	N/A N/A	2.10 2.00 3.30	3.07 1.53 [illegible]	300 360 240	86 82 31	98.54 99.24 87.27	4.9[illegible] 4.13 [illegible]
[illegible]bia 93	1A 1B 2B 3 1/Vch 3/Vch	30 30 30 30 30 30	17 17 13 78 17 28	17 17 13 32 17 32	3.19 1.19 1.06 2.80 1.30 7.00	1.90 7x1 1x1 1 3x1 1	300 300 300 45 150 21	82 82 99 13 57 5	84.34 94.12 99.91 99.96 80.00 99.99	4.20 4.71 5.00 33.33 8.00 65.21
[illegible]na 93	22 22	30 30	400 0.3	307 9	1.60 1.60	1.20 3x1	140 40	58 15	99.25 99.99	10.63 37.50
Thailand 93	21 21 22 22A	30 30 30 30	140 21 108 102	270 40 N/A 140	4.67 1.28 1.30 2x1	2x1 0.1 3.30 3.80	300 300 120 120	85 85 28 25	100.00 99.99 100.00 99.98	5.00 5.00 12.50 12.50
Costa Rica 96	A1 A2 B1 B2	30 30 30 30	20 20 30 30	70 70 203 202	900 1.10 1.30 120	1.30 1x1 3 0	300 300 60 120	129 129 28 55	98.56 99.09 99.77 100.00	4.91 4.93 24.94 12.50

* Experiments in Costa Rica and Thailand

+ N/A not available (Source: Sommer, 1997)

According to Wegelin et al (1994), a 5 hour exposure of water to mid latitude summer sunshine that corresponds to a dose of 555 W/m^2 will result in a 3 log reduction of E. coli.

Suitability of the materials, for the SODIS technique is a function of the type and thickness of the material, the angle of incidence and the specific wavelength band of radiation as these factors will determine the maximum transmittance of solar radiation. Clear glass, polystyrene and polythene transmit UV radiation fairly well. With ordinary glass of the soda lime silica type transmitting more than 90% of the incident radiation in the UV-A with certain provision. Ordinary glass is opaque to radiation in the UV-B band and attains highest transmission level at 340nm and above. Quartz has higher transmission properties than Pyrex (Acra, 1980; Odeyemi, 1980 Acra, 1984; Acra, 1990). Transparent plastic materials such as Lucite and plexi glass are good transmitters, end more efficient due to their low transmission losses ≤10% (Acra, 1990; Sommer, 1997). Investigations on the effect of colour revealed that the most effective colour is the white, black, light green and light blue, whilst Arafa and Cotis(1980) observed a decreasing germicidal effect in the order of white, blue green and brown. Presently SANDEC designed and is testing a 5 litre plastic bag with the upper part transparent and the lower part black to allow absorption, transmittance and containment of heat (SODIS, 1997).

Regarding container shape, although Cotis (1980) observed that container shape has little effect on the disinfection process, it is one of the variables that determine the amount of solar radiation tapped, with round or cylindrical being most efficient (Mathur and Khandpal, 1980; Acra, 1984).

Whilst investigating the effect of water volume on the disinfection process, Cotis (1980) observed that 500ml samples had a higher disinfection rate than 100ml samples, but those results cannot be generalized due to the smaller than usual volumes involved. Authorities caution that the treatment method should be applied on small quantities of drinking water only. This is because of the rapid decrease in UV-A intensity with increasing water depth and turbidities due to attenuation from its reflection and absorption. (Acra, 1990; Sommers, 1997.)

Studies carried out to investigate the effect of turbidity on the disinfection process, revealed that water within a turbidity range of 1-10 NTU did not show any clear trend of variation. Highly turbid waters and those with high bacterial load were not satisfactorily disinfected by solar radiation (Odeyemi, 1980; Baldi 1980; Kootapep, 1980). SODIS (1997) advocates storage of water for 3-5 hours before exposure to reduce the turbidity of the raw water.

Investigations on the effect of the microbiological content of the raw water on the disinfection process, revealed that mixed cultures have a longer inactivation time, as shown by results of experiments by Acra (1970) which involved using pure E.coli culture and sewage contaminated by coliforms and Str. faecalis as a source of water

(Wegelin, 1994). Relatedly E.coli strains are slightly more resistant to solar disinfection than other bacteria such as P.aeruginosa, S. flexneri, S. typhi, S.enteritidis, while Str. faecalis was slightly more resistant to solar disinfection when compared with E.coli and other coliforms. High bacterial loads also showed a lower sensitivity to solar radiation, when compared with those of low or moderate density (Wegelin, 1994). Solar disinfection is effective with other pathogens such as Vibrio cholerae, although the rate of inactivation will be correlated with whether they exist in their vegetative or spore forms. With tested viruses bacterial spores and amoebic cysts requiring 3-4 times, 9 times, and 15 times higher doses respectively to achieve the same effect (Odeyemi, 1980; Sommer,1997; Wegelin, 1994).

The role of temperature in the solar disinfection process was for some years under debate with some authorities believing temperature plays no significant role in the solar water disinfection process, since the temperature rise in the irradiated water is only about 5^{0}C (Odeyemi, 1980; Acra, 1980). This appears to be true only within a certain temperature range, according to Sommers (1997), a variation in temperature between 12^{0}C and 40^{0}C does not lead to significant bacterial inactivation. Above this upper limit, from about 42.8^{0}C or 50^{0}C, the pasteurization effect of temperature could occur with bacterial inactivation rates increasing (Baldi, 1980; Kootapep, 1980; Sommers, 1996).

Various devices have been developed to make use of the synergistic effect of high temperature and solar radiation in water disinfection. A solar still or radiation chamber is one of such designs with the objective of concentrating the sun's rays by the use of reflecting surfaces like mirrors, and raising temperature using aluminium, black colour etc. Kootapep (1980) carried out a study to evaluate some models of solar radiation chambers, viz. a rise in temperature model and a UV disinfection model. He noted that the model which combined temperature and the UV component was more efficient at disinfection (at temperatures above 60^{0}C) than the UV disinfection model.

Continuous flow systems such as SODIS and SOPAS (solar pasteurization) reactors were assessed in Costa Rica in 1996, the SODIS plant consists of a 1.8m long retention container, with the upper side made up of a solar glass panel sealed with silicone to a copper basin (Manno, 1995) (Fig. 5). It uses both the thermal and the radiation effect for pathogen inactivation. The unit consists of raw water tank, from which a continuous flow is maintained by valves, it then passes though a heat exchanger where the temperature is built up to 50^{0}C, before passing into the solar plant for UV disinfection. It then goes back to the heat exchanger where it is cooled down before going to the tank for potable water (Fig 6). The SOPAS reactor however makes use of only temperatures of at least 70^{0}C for inactivation of the micro-organisms. Percentage reduction of faecal coliforms and *Vibrio cholerae* concentrations using the SODIS and SOPAS varies with flow rate and temperature. In the SODIS plant, given clear skies, faecal coliforms were almost completely inactivated in the solar collectors through out the experiments at a flow rate of 54-56 l/h. No inactivation occurred in the irradiation reaction at lower flow rates, suggesting that an increase in flow rate optimizes the operations (Sommers, 1997). The results obtained from the SOPAS plant show that it is difficult to maintain the 70°C minimum temperature throughout the entire experiment, leading to possible incomplete inactivation of faecal coliforms even at maximum flow rates of 75l/hr.

The reactors were used to assess the impact of cloudiness on disinfection process. Results revealed that more clouds mean less sunshine and thus a decrease in temperature, with percentage coliform reductions which indicate that there was about three times more energy available for heating and irradiation on a day with a clear sky than on a completely overcast day, thus reducing the efficiency of SODIS and SOPAS plants. (Sommers ,1997). No regrowth of faecal coliforms occurred within 24 hours at normal temperature (30°C) either after inactivation in the batch process or in the continuous flow process (Sommers, 1997).

The advantages of solar disinfection include its non-employment of chemicals, and thus the non-formation of undesirable products such as THMs, associated with chlorination of water. It also carries no risk of overdose (Angthem, 1984). The mineral composition of the water e.g. the $NAHCO_3$ remains unaffected (Acra, 1984). It also has the advantage of using a free natural energy source, and requiring few high technology skills with the implication of affordability for use by the millions of people still lacking water in developing countries (Sommers, 1997).

2.6.5.2 Halosol Water Disinfection

This is a method developed at the American University in Beirut (1979-1982), through which water is treated with large doses of Sodium hypochlorite or iodine solutions and subsequently exposed to solar irradiation. It was intended to be an efficacious disinfection method for small volumes of heavily polluted water with the resultant removal of excess halogen by solar radiation. During experiments carried out using this method on the batch process, 5l of halogenated water containing chlorine or iodine residuals were exposed to sunlight in containers made of colourless or blue tinted glass or plastic, showed efficient halogen removal. According to Acra (1990), the T_{50} and T_{90} values for dechlorination where T is the exposure time were 11 and 72 minutes (32 and 215 minutes for deiodination), respectively. He further observed that in contrast, the decay reaction occurring under normal room illumination was slower, and that complete darkness (or the use of dark brown containers) retarded it. Commenting on the significance of this method, Acra (1990) noted that viruses, spores, ova and protozoa are less efficiently destroyed by halogens (chlorine, iodine and some of their derivatives) than waterborne pathogenic bacteria, Whilst sunlight has proven to have similar bactericidal properties but unclear effect on viruses, ova, protozoa and spores. He further comments that the combined effects of the two forms of disinfection (halosol process) could destroy highly resistant microorganisms and their latent stages. He based this view on the known germicidal effects of solar radiation and free chlorine

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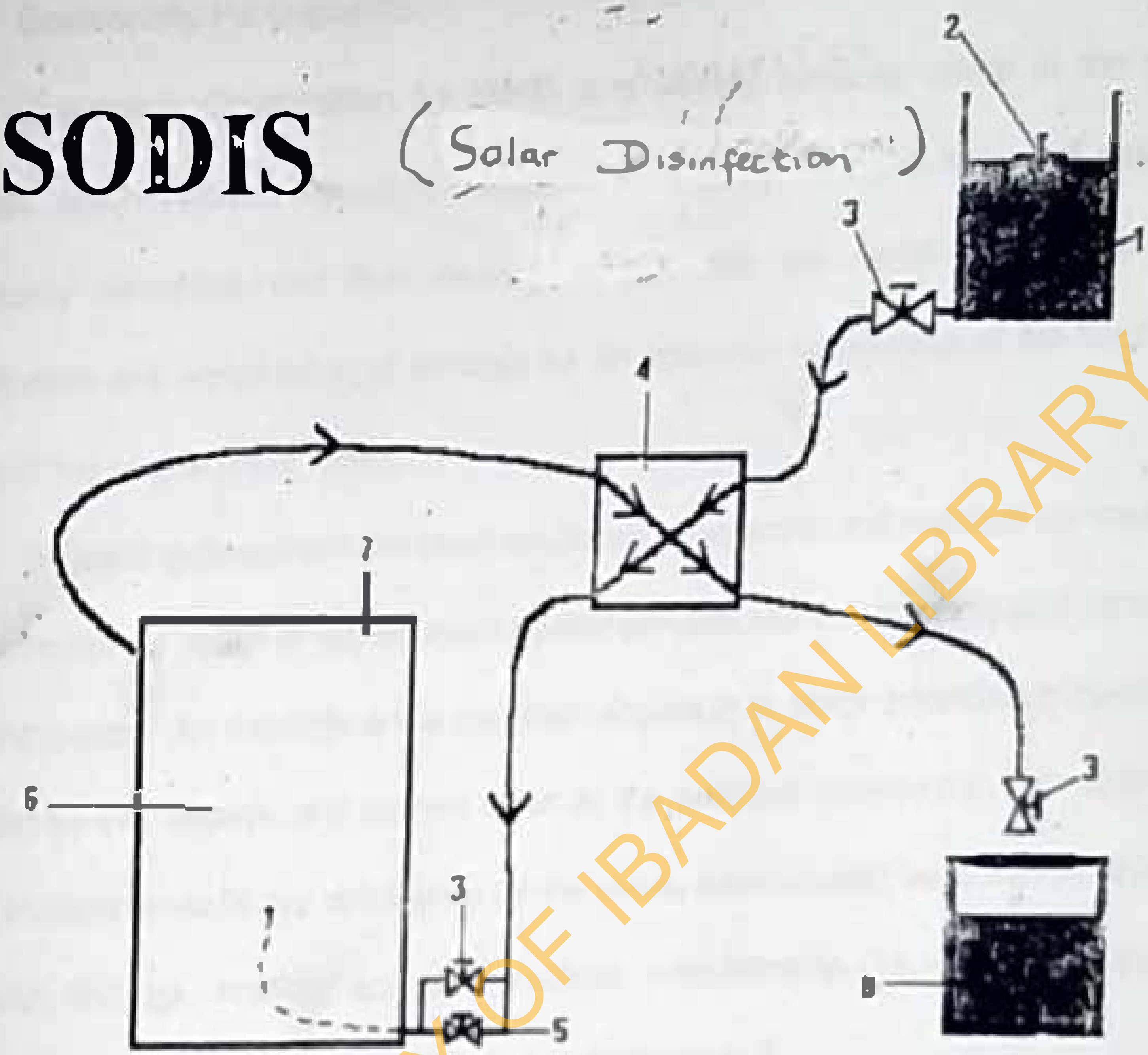
Fig 5: A photograph of the SODIS Reactor
(Source: Reichslner, 1997)

SODIS (Solar Disinfection)



1-Tanque de agua cruda (contaminada) — Raw Water
2-Controlador de flujo — Control flow
3-Llaves de paso — valves (in and out water control)
4-Intercambiador de calor Thermal exchange
5-Válvula térmica con sensor Thermal valve
6-Reactor Reactor
7-Desairador Pressure guage
8-Tanque de agua potable Tank for potable water

Fig 8 SODIS Reactor Plan
(Source; Valiente, 1997)

2.7. Community Participation

Community Organization for health and welfare services refers to the social process, which involves the measurement of community needs in terms of available community resources, and from these measurements; the development, extension, modification and organization of services for an adequate satisfaction of the continued needs of the people (Fion, 1990).

Different approaches have been employed to organize and mobilize communities in a bid to deliver health or development related services like water supply and sanitation to communities. An example is the top-down approach in which priorities or needs are decided by the 'experts' and passed down to the selected community. This approach often involves professional dominance as the needs have usually been defined through research findings. Another approach involves indoctrination, in which the targeted community is told what to do, when to do it and how to do it.

The self -help approach is one in which the targeted community provides the labour for the intended project such as the construction of a pit latrine. Although this approach due to its high level of community involvement has at times been mistaken for true community participation, it is still far from ideal. This is because the people often have not been asked for their views or felt needs before the relevant organization or government body embarks on the project and involves them in labour supply (Olaseha, lecture notes).

From past experience all the above mentioned forms of community organization or mobilization have proven to be ineffective approaches in delivery of water and sanitation, due to their unresponsiveness to local situations, beliefs and practices, and because they are non-self sustaining. There are numerous examples of abandoned wells, unused communal pipe wells and broken down hand pumps due to reasons, which vary from cultural unacceptability to non availability of man power. (UNDP, 1990; Salisbury, 1978).

According to United Nations Conference on Environment and Development (1994), services and technologies need to be tailored to the demand and condition of the targeted environment in order to make them efficient, viable and sustainable. This is particularly important in peri-urban areas where people settle before any formal development takes place, often exceeding the assimilative capacity of the environment. For these areas a demand oriented response to water & sanitation delivery would be more effective than one in which the authorities decide the needs. Past experience in the water supply and sanitation sector has indicated that for a water and sanitation project to be effective, it is necessary to develop a sense of ownership in the users, towards the delivery infrastructure. This is so that they perceive themselves not just as beneficiaries but as owners and operators of the scheme. It also became increasingly evident that in order to achieve this, the approach employed should move beyond persuasion or indoctrination to one in which the communities take the leading role. An enabling environment must also be provided to allow the people make informed decisions about proposed technologies. (De Rooy, 1986; Head, 1988; Hubbley; 1990; UNDP, 1990). An approach that incorporates all these is known as community participation.

Community participation can be defined as the active involvement of the local population in the decision making concerning development projects or in their implementation (White, 1981). Certain features distinguish community participation from community involvement.

- In community participation the people are involved in decision making even from the first stage of conceptualization, through later stages of project planning, implementation, maintenance and evaluation (White, 1981; Head, 1988).
- The community is involved as an organized entity and not just a few individuals as is the case with community involvement. White (1981) agrees with the view that true community participation is achieved only when the community is in full control of the process but cautions that in the delivery of water and sanitation, this should be considered a special form of participation. This is because of the difficulty in operating the ideal concept of community participation by a governmental sectoral agency like the Water Corporation.

In order to create a sense of ownership, which is vital to a true participatory approach in water and sanitation projects, it is necessary to understand thoroughly the selected community, in terms of its physical and social environment. These include water sources, local resources, local religious beliefs, practices and taboos, communication network, leadership structure, community felt needs and other features which may affect the success of the water project. This can be done through a community diagnosis (Olaseha, Lecture notes).

It is also necessary, in an attempt to create a sense of ownership to establish a community water committee. The committee is made up of a representative sample of the community such as traditional leaders, representatives of various societies (market, religious, social, co-operatives), members of village health committees and women chosen by the community. This committee will serve as a 2 way channel between the project coordinator and the users in order to make decision making, evaluation, implementation and the resolution of any problems that may arise in the course of the project. It is also necessary to involve the community in selection of installation sites of water points, provision of locally obtainable construction materials such as sand, gravel, stone and labour supply during drilling and test pumping.

Apart from the benefits of sustainability and improved effectiveness achieved by the community participatory approach, the sense of ownership thus created will provide a means to establish a village level project maintenance system. An example is as occurs in the VLOM hand pumps, where local artisans are part of a three tier maintenance system made up of village level, sub regional and regional technicians.

The resultant effect is a greater sense of responsibility amongst users and a substantial reduction in the maintenance costs (De Rooy, (1995).

Community participation can also provide a basis for modest cost recovery, which is a key problem to the sustainability of water supply and sanitation systems. According to De Rooy (1995) the challenge to the sector is movement towards communities paying the full cost of operation and maintenance of services provided for them. Strong mobilization and education is needed for this to be achieved.

Education is an integral part of community participation in the delivery of water supply and sanitation because the success of a project depends on its adoption usage end maintenance by the people with accompanying hygiene practices. Morgan (1992) gives the example of UNICEF who in coordination with the Nepal government provided many improve water supplies over the last twenty years without significant health benefits, because of the non inclusion of a sanitation education component in the delivery of these services. Education is necessary because often barriers exist to changing even clearly high risk behaviour. De Rooy (1995) gives the example of a review of sanitation in Central and West Africa which revealed that although the quality of water was known to be bad, only half of the one thousand women surveyed took any form of precautions. Boiling was resisted because of the accompanying change in taste and difficulty in re-cooling the water in the hot regions. These barriers to behavioural change can only be removed if the knowledge, attitude and practices of the target population are understood.

According to experts, for behavioural modification to occur, a participatory approach must involve a partnership between the different agents concerned, the population and the use of a systematic association of the relevant method of health and hygiene education in the water project (UNCED, 1994; De Rooy, 1995).

Honduras is an example of a city that has employed the community participatory approach in water and sanitation delivery. In this project, thousands of economically disadvantaged people, took loans which were used to drill wells and buy community water tanks. This proved cheaper than their former practice of buying water from private vendors. According to UNICEF (1994), In 1985, in India within 2 years of calamities such as drought, erosion, a failed monsoon and food riots, safe water had reached 98% of hamlets, aquifer was recharged, irrigated land doubled and productivity increased. By 1990, guineaworm had been eradicated. This was made possible by an integrated water management programme with strong community participation.

2.7.1 Women in Community Participation

The role of women in water and sanitation projects continues to increase, in recognition of their roles as agents of behavioural change and prime beneficiaries of water and sanitation projects. They are primary beneficiaries because water provision is a woman's responsibility and she bears all the costs incurred in the course of water collection (Hoffman, 1991).

Benefits of improved water supply to women, which would make them active participants in water projects include savings in time and energy, which can be otherwise spent in productive activity such as self development, income generation and improved child care (UNICEF,1994, UNICEF,1995). Lindth (1980) noted that in Sudan, a young Nkobo girl spends a total of eight hours a day fetching water for her family. According to De Rooy (1995), the girls and women in 15 million households in West and Central Africa, living without access to readily available water would gain 45 million hours/day, if water supply services improved. Other benefits include a reduction in water related diseases as their contact with polluted water reduces (Bulajich, 1992; UNICEF, 1995).

The success of women in areas which were traditionally regarded as bastions of men have led to the water sector regarding women not just as mere targets of water projects, but active agents with contributions to make to the sector. They can contribute to policy, mobilise labour, provide resources and disseminate and implement innovations leading to more efficient achievement of the ultimate goal, which is more and safer water resulting in better health (Hoffman, 1992; Bulajich, 1992).

An example of the effectiveness of women in water and sanitation projects is the Mukuni women of Zambia. These women mustered energy and enthusiasm for a new initiative to supply safe and more convenient water for their families with 60 new bore holes being sunk and equipped with mark 1 hand pumps through the assistance of OPS and UNDP (Kinsley, 1991).

CHAPTER THREE

METHODOLOGY

3.1 Study design

This study is descriptive. It serves to gather baseline data on Knowledge, Attitude and Practices of women in an urban slum towards water use, water sources, water and health; water quality through laboratory analysis of well water samples; assessment of efficacy of solar disinfection and a field trial of the water treatment method in the community.

3.2 Description of study area

The study area is Koloko - Aiyekale in the Ibadan North East Local Government area (fig 7). The people are predominantly Yoruba. They practice subsistence farming and belong to the lower educational and socio-economic class. They are mainly of the Christian and Muslim faith, with a few practicing traditional African religion.

Koloko-Aiyekale is part of Agugu which has a total population of 20, 938 people and occupies an area of 0.97km^2. The study area Koloko -Aiyekale consists of 471 households with a mean population of seven people per household although some houses have as many as 36 people per household. It is divided into 8 zones namely Koloko, Aiyekale zone A, Aiyekale zone B, Aiyekale Zone C, Aiyekale Zone D, Ogele, Orepaju and Idigba. It is an urban slum with the houses-built in unplanned clusters with little environmental infrastructure such as pipe borne water.

Koloko-Aiyekale originated in 1960 when Alhaja Mopelola bought the land, it was then called Oko-Mope (Mope's bush) after the owner. In December, 1966, the present Baale Chief Osuolale Akanji bought land in Oko-Mope and settled there. Development began in 1971, when Chief Akanji and honourable Fagbemi decided to make a road to Oko-Mope after which, they felt the name Oko-Mope (Mopes's bush) was not befitting of the community. The name was then changed to Aiyekale (The world has come to stay) and it was registered with the council in 1977.

The leadership structure of Aiyekale, consists of the head of the community, the Baale, Chief Osuolale Akanji, who is also the present president of the customary court, he settles disputes with the help of the representatives in each zone. They are namely Bola Tijani - Zone A, Tafa Akintayo -Zone B, Mr Ibitoye - Zone C, Mr Ogunbiyi -Zone D. These representatives have a weekly meeting every Wednesday.

The people of Koloko-Aiyekale have no predominant occupation and some of them sell wood at Bodija, are involved in petty trading, transporters, traditional healers, civil servants, pepper millers. Those who farm practice subsistence farming and not large scale farming. There are many societies in Aiyekale but the prominent ones are:

a. The Landlord society whose objective is development of Aiyekale

b. Egbe Aiyekale trading society, a cooperative society whose objective is to lend members money for trading and

c. The Al-mujahidu fil Islamic society, a religious society, whose objective is to win followers to the Muslim faith.

3.3 Data collection

Data was collected using:

1. Interviewer administered questionnaires to obtain baseline information on demographic characteristics; water use pattern; water treatment; sanitary features of wells; knowledge, attitude and practices of women and water related health risks and personal hygiene. (Appendix 1)

2. Analysis of well waters for the Physico-chemical and bacteriological qualityand

3. Laboratory and field assessment of the efficacy of solar disinfection.

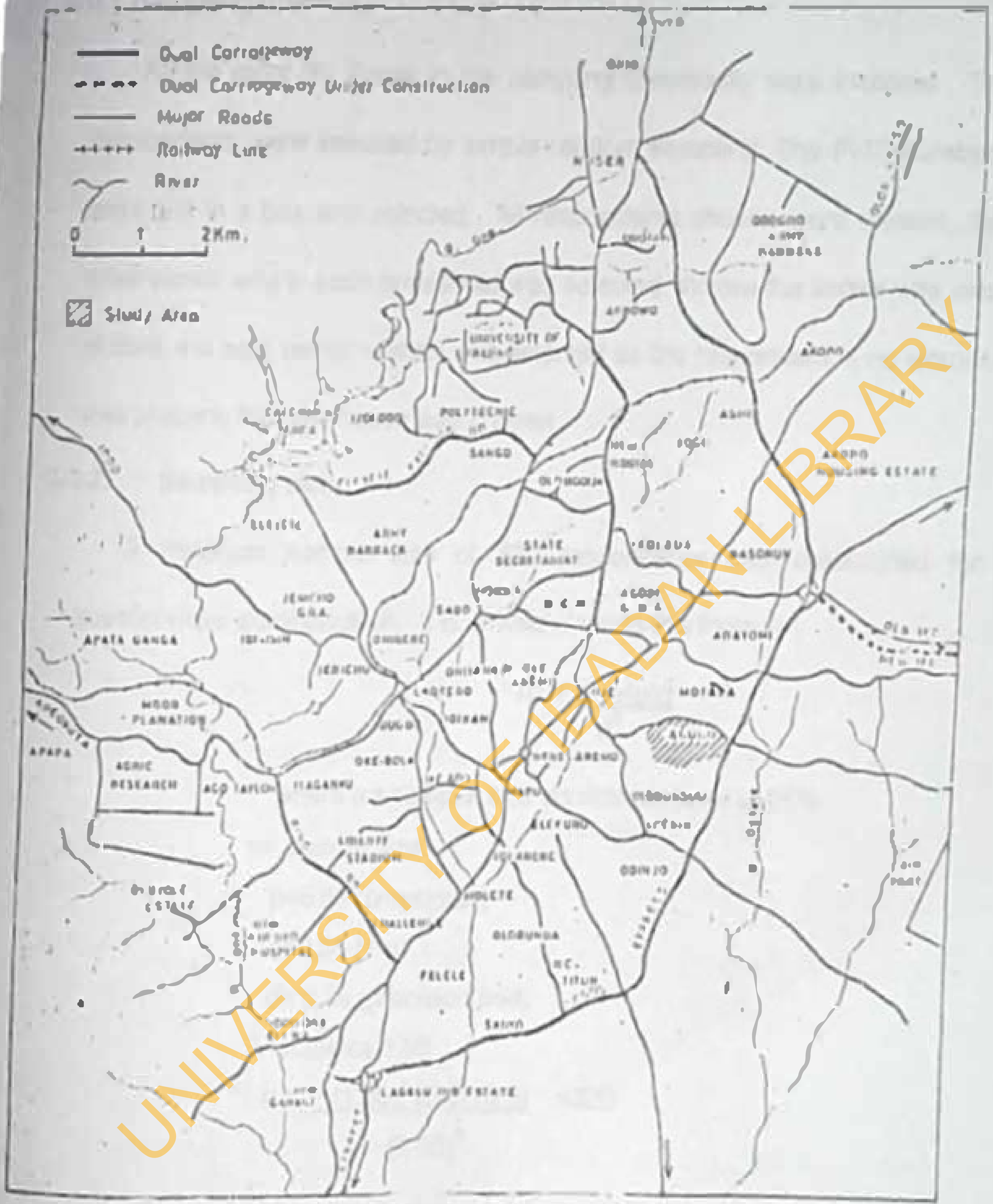


Fig 7 Map of Ibadan showing Study Area

3.3.1 Sampling method

All the eight (8) Zones in the sampling community were involved. The respondents were selected by simple random sampling. The PHC numbers were put in a box and selected. All respondents chosen were women, the most senior wife in each household was selected. Where the senior wife was absent, the next senior woman was selected as the respondent, if no woman was present, the next house was chosen.

3.3.2 Sampling size

A minimum sample size of 320 respondents was determined for questionnaire administration. It is arrived at using this formula :

$$n = \frac{Z^2 \alpha(p)q}{d^2}$$

where α= sample size confidence level at 95%

n= sample size

p=0.65 (proportion)

q=0.35 (1-p)

d= 0.05 (precision limit)

Z=statistics 1.96

$$n = \frac{(1.96)^2 (0.5)(0.5)}{(0.05)^2} = 320$$

A sample of 324 questionnaires was drawn from the eight zones.

3.4.0 Materials

3.4.1 Well water samples

A Total of 78 ground water samples were collected from shallow wells in the eight (8) zones of the community. The samples were collected in 1 litre plastic bottles in the mornings and taken to the laboratory for immediate analysis. Some of the water samples from those wells were used in the laboratory standardization of the solar water disinfection process.

3.4.2 Chemicals

Chemicals used in the study include: Kaolin for suspended solids; Sulphuric acid and Bromocresol indicator for alkalinity; Ethylene diamine tetracetic acid, buffer solution of ammonium chloride dissolved in ammonium hydroxide with mg EDTA, Sodium hydroxide and murexide indicator for calcium; Silver nitrate, potassium chromate as indicator for chloride; phenol disulphonic acid, sodium hydroxide, potassium nitrate for nitrates; McConkey broth was used for the coliform count. Distilled water was used in all reagent preparations. The chemicals were of analytical grade.

3.4.3 Other materials

Materials used for the standardization of solar water disinfection process include:

i. White cylindrical bowl with a surface area of $3187cm^2$, a thickness of 3mm and a capacity of 7 litres

ii. Plastic round bowl with a surface area of 3956cm, with a thickness of 1.3mm, and a capacity of 7 litres.

iii. White plastic bottle shaped container with a capacity of 1.15 litres were used.

iv. Transparent polythene bags, Polythene sheets of white, blue, green brown and black were used in some experiments as specified.

All temperature readings were taken with a standard mercury thermometer and expressed as ^{0}C.

A solar radiation chamber was designed, and built with wood, glass and a mirror. It is handy and potable like a brief case, which could be opened and closed. The chamber had the following dimensions 61cm long x 40cm wide. A mirror was 37cm wide and 57cm long was fixed in the inner lid of the chamber, to reflect the solar rays at various periods of the day. A pane of plain glass was placed on the bottom part and could be removed depending on the test. The angle of tilt of the top lid containing the mirror was adjustable, so that the sun's rays could be continuously trapped, regardless of the sun's position (Fig 8).

3.5 Methods

3.5.1 Administration Of Questionnaire

The questionnaire consisted of 71 questions and were pretested in Ogbere, a low income similar community in the same Ibadan North East Local Government. Before the questionnaires were administered, 10 research assistants were recruited with an educational background of at least O' level were trained and abilities checked. All respondents were checked and rectifications were made where necessary before the questionnaires were produced for the study.

Fig 8: Photograph of the solar radiation chamber designed in this study

3.5.2 Physico-Chemical Methods Of Analysis

pH

The pH of water was determined by probe method, using a standard calibrated pH meter, model Kent EIL 7055.

The Total Solids

The Total solids, which refer to the sum of homogenous, suspended and dissolved matter in the well water samples was determined by gravimetric methods. An empty porcelain dish was dried and weighed after cooling. 100ml of water sample was evaporated at 105^{0}C in the pre-weighed porcelain dish in an oven. The porcelain dish was weighed after evaporation, cooling and desiccation.

Calculation:

$$\text{Total solid mg/L} = \frac{(A-B) \times 1{,}000}{\text{ml of sample}}$$

where A = weight of sample + dish

B = weight of dish

Suspended Solids

The suspended solids content in well water samples was determined spectrophotometrically. In the preparation of standard suspended solids suitable proportions of pure kaolin were taken, and suspended in distilled water and read at 475nm. Calibration curve is shown in fig 9 and a factor, (f) = 50 was obtained from the curve which was used in calculating the mg per litre equivalent.

Fig 9 Calibration curve for Suspended Solids

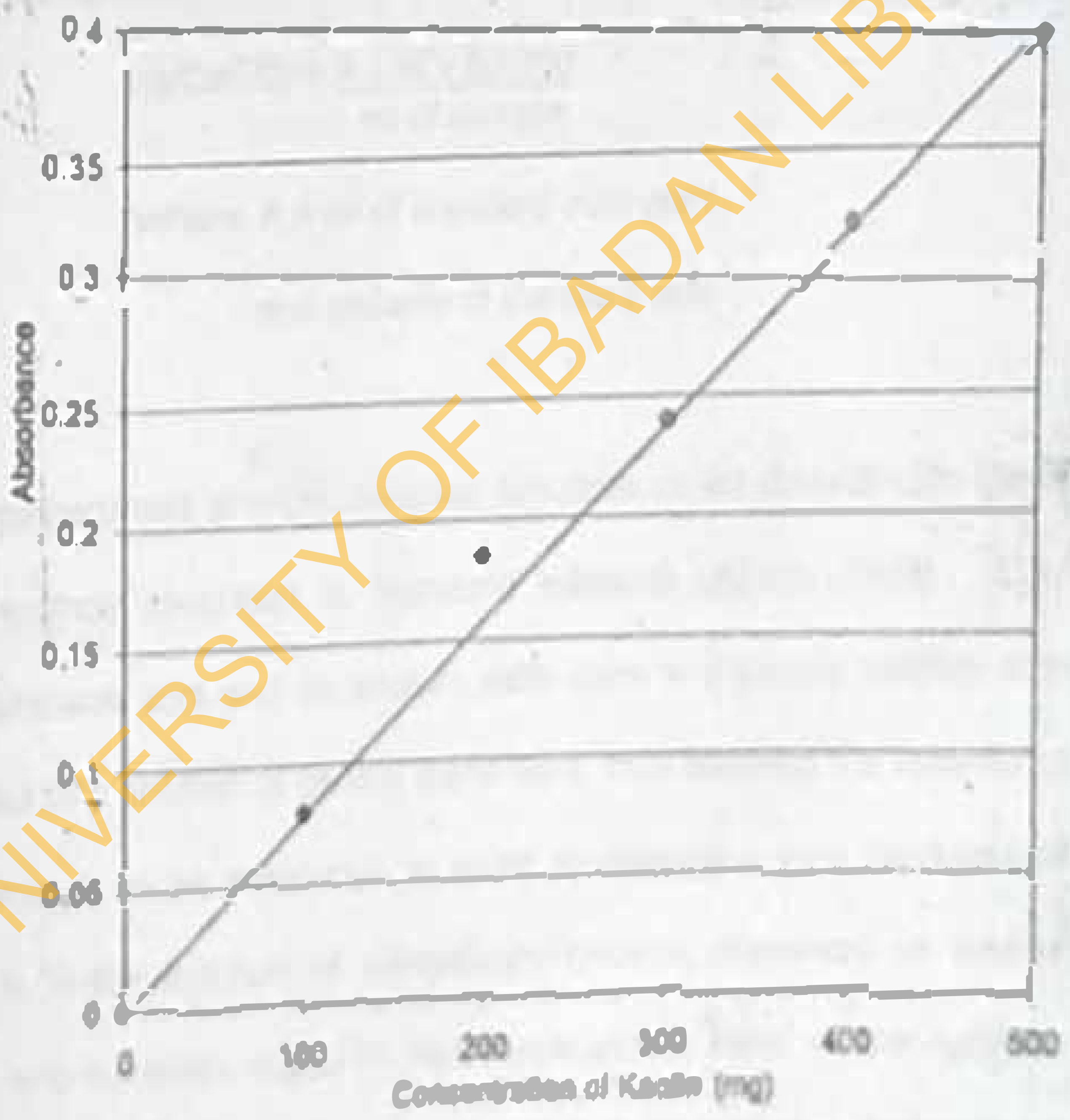


Fig 9 Calibration curve for suspended solids

Alkalinity

The alkalinity of water is a quantitative capacity to neutralize a strong acid to its designated pH. It was determined according to standard methods (APHA, 1989). 50ml of sample was titrated against 0.02m H_2SO_4 using mixed Bromocresol green-methyl red indicator. The end point of titration was signified by a change of colour from pale green to pink.

Calculation:

$$mg/CaCO_3 = \frac{A \times M \times 50{,}000}{ml\ of\ sample}$$

Where A = ml of standard acid used

m = molarity of standard acid

Hardness

The total hardness of water samples was determined according to the EDTA titrimetric method described in Standard methods (APHA 1989). Ethylene diamine tetracetic acid and its sodium salts form a chelated soluble complex when added to a solution of certain metal ions, thus allowing the quantity of the particular metals to be measured. In order to determine total hardness of the samples, a buffer solution of ammonium chloride dissolved in ammonium hydroxide and to which mgEDTA has been added. 50ml of the sample was titrated against EDTA, using Eriochrome Black T as indicator. The end point of titration was signified by a colour change from pale red to blue.