ASSESSMENT OF QUALITY PARAMETERS OF POTABLE PACKAGED WATER IN MINNA, NIGER STATE.

BY

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DECLARATION

I hereby declare that this project work is a record of a research work that was undertaken and written by me. It has not been presented before for any degree or diploma or certificate at any university or institution. Information derived from personal communications, published and unpublished work were duly referenced in the text.

Musa, Isah Hassan

7/12/2010

Date

CERTIFICATION

This is to certify that the project entitled "Assessment of Quality Parameters of Potable Packaged Water in Minna, Niger State" by Musa, Isah Hassan meets the regulations governing the award of the degree of Bachelor of Engineering (B. ENG.) of the Federal University of Technology, Minna, and it is approved for its contribution to scientific knowledge and literary presentation.

12/01/11 ________________________ 12 - 01 - 11 ________________________

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DEDICATION

This research project is dedicated to the almighty Allah who in His infinite mercies has been my guiding light. Also my parents, brother, sisters and friends whose unflinching supports and inspiration has enabled me complete my project work successfully.

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CHAPTER ONE

1.0 INTRODUCTION

1.1 BACKGROUND TO THE STUDY

The most important uses for water are at our homes. Water generally gets to our homes in one of two ways, by a city/county water department or maybe by a private company or people supply their own water, normally from a well. Water delivered to homes is called "public supplied" and water that people supply themselves is called "self supplied." People who supply their own water almost always use ground. Quite a few of the residents of Minna gets their water delivered from a public-supply system (Gleick, 1996).

The lack of safe drinking water and adequate sanitation measures lead to a number of diseases, such as cholera, dysentery, salmonellosis and typhoid, and every year millions of lives are claimed in developing countries. Diarrhea is the major cause for the death of more than 2 million people per year world-wide, mostly children under the age of five. It is a symptom of infection or the result of a combination of a variety of enteric pathogens (ANON, 2000).

Water-borne pathogens infect around 250 million people each year resulting in 10 to 20 million deaths world-wide. In Nigeria alone more than 47 million people do not have access to potable water supply and nearly 42 million (about 54% of the population) lack basic sanitation. This highlights the potential of infection due to water - borne pathogens (Ajayi, 1996).

The evaluation of potable water supplies for coliform bacteria is important in determining the sanitary quality of drinking water. High levels of coliform counts indicate a contaminated source, inadequate treatment or post-treatment deficiencies (Mathew et al., 1998). Many developing regions suffer from either chronic shortages of freshwater or the readily accessible water resources are heavily polluted (Lehloesa and Muyima, 2000). Microbiological health risks remain associated with many aspects of water use, including drinking water in developing countries (Craun, 1996), irrigation reuse of treated wastewater and recreational water contact (Grabow, 1991). It has been reported that drinking water supplies have a long history of association with a wide spectrum of microbial infections (Grabow et al., 2000).

POTABLE WATER.

Potable water is the water that is safe and acceptable for drinking and it must have the following basic characteristics or requirements;

1. it must be attractive to people i.e. colourless, odourless and tasteless. Majority of people are used to water without excessive organic and in organic substances which give smell, taste and odour.

2. The water must be germs free and chemically safe

3. It must not contain disease carrying organisms. These include;

i. Bacteria e.g. cholera and typhoid

ii. Virus e.g. infective hypatis

iii. Protozoa e.g. amoebic dysentery

iv. Worms e.g. guinea worms

v. Fungus e.g. ring worm of the foot

All of the following except (v) can affect man through drinking water. Ring worm of the foot affect man through contact with contaminated water e.g. swimming in a badly managed swimming pool (Adeniran, 2000).

A certification by a licensed professional engineer specialized in the field is no longer sufficient. The public health aspects are of such importance and complexity that the health authority having jurisdiction in the community now reviews, inspects, samples, monitors and evaluates on a continuing basis the water supplied to the community, using constantly updated drinking water standards. Such public health control helps to guarantee a continuous supply of water maintained within safe limits.

Water analysis alone is not sufficient to maintain quality but must be combined with the periodic review and acceptance of the facilities involved. This approval consists of the evaluation and maintenance of proper protection of the water source, qualifications of personnel, water supplier's (purveyor's) adequate monitoring work, and also evaluation of the quality and performance of laboratory work.

Hence, it could be summarized that potable water must meet the physical. chemical and bacteriological parameters when supplied by an approved source, delivered to a treatment and disinfection facility of proper design, construction and operation and in turn delivered to the consumer through a protected distribution system in sufficient quantity and pressure.

WATER DEMAND

Introduced in opposition to a traditional supply-side management, the water demand management has been conceived as a flexible tool that is offered in accordance to the community's needs. On the basis of the local systems, an assessment is provided about the efficiency of the water consumed, and consequently about the management solutions that can be proposed in order to realize savings of water, which can avoid heavy and costly interventions on the environment for acquiring more volumes of water (e.g. for new dams, wetland drainage, canalizations etc). The regulatory mechanisms provided by the demand side management have the effect to reduce the global water demand, protecting at the same time the fundamental water needs for human activities and for the ecosystem functioning (Scanlon *et al.*, 2004)

1.2 STATEMENT OF THE PROBLEM

Water scarcity is no longer strange news to the ears of an average Nigerian, hence the introduction of sachet (pure) water. The question here is how pure is the water that is largely being consumed by the average Nigerian.

1.3 OBJECTIVES OF THE STUDY

The objectives of this study are:

1. To ascertain the quality of water being sold as potable packaged (sachet) water to the people of Minna and its environs
2. To compare result obtained with the Nigerian Standard for Drinking Water Quality(NSDWQ)

1.4 JUSTIFICATION OF THE STUDY

To justify the purpose of this research, there is no other location suitable to ascertain the validity of the course of this research than Niger State where the temperature is high attaining an average of 34^{o}c and where water is inevitably a necessity for individual survival.

1.5 SCOPE OF STUDY

This study is limited to the physical, chemical and bacteriological assessment of potable packaged sachet water in Minna, Niger state.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 STANDARDS OF WATER QUALITY

Some of the sources of water quality standards are Federal Water Resources Ministry, Federal Ministry of Health and National Food and Drug Agency (NAFDAC). Furthermore, these various levels specified will take cognizance of the different uses for which water quality must be maintained. The requirements, as regards suitability, of water for industrial use, for drinking, for boilers and so on, may differ widely and each may be quite demanding. The ultimate objective of the imposition of standards (which may necessitate extensive treatment prior to use) is the protection of the end uses. This may be these by humans, animals, agriculture or industry. In the present context, however, the main considerations are in regard to safeguarding public health and the protection of the whole aquatic environment. Both have very high quality requirements which complement each other to a great extent (Scanlon, 1994).

Both Directives and Regulations are aimed primarily at the safeguarding of human health by protecting both waters and animal (as part of the food chain), as well, of course, as the aquatic environment at large. Because of the importance of these Directives and Regulations and their complexity (including the interrelationship between different Directives) their main provisions are for convenience summarized below insofar as they deal with quality standards (Petrella, 2001).

Water is the essence of life and safe drinking water is a basic human right essential to all. Water is essential for the well being of mankind and for sustainable development. Though water is necessary for human survival, many are denied access to sufficient potable drinking water supply and sufficient water to maintain basic hygiene. The effects of drinking contaminated water result in thousands of deaths every day, mostly in children under five years in developing countries (WHO, 2004). In addition, diseases caused through consumption of contaminated water, and poor hygiene practices are the leading cause of death among children worldwide, after respiratory diseases (WHO, 2003).

Globally, 1.1 billion people rely on unsafe drinking water sources from lakes, rivers and open wells (Photo 1a). The majority of these are in Asia (20%) and sub-Saharan Africa (42%). Furthermore, 2.4 billion people lack adequate sanitation worldwide (WHO/UNICEF, 2000; WHO/UNICEF-JMP, 2004).

2.2 SOURCES OF WATER

Surface water is an essential component of the natural environment and a matter of serious concern today. Rivers, lakes, estuaries, and seas have been exposed to wastewaters from industrial, agricultural, and domestic sources for decades. Consequently, the quality of surface water has rapidly deteriorated in many regions, and polluted surface water is now a grave public health and ecosystem problem (White and Rasmussen, 1998; Wu, 2005). Furthermore, population growth and elevated living standards have been coupled with ever increasing demands for clean water. More water is also required for growing environmental concerns such as aquatic life, wildlife refuges, scenic values, and riparian habitats (Herman, 2000).

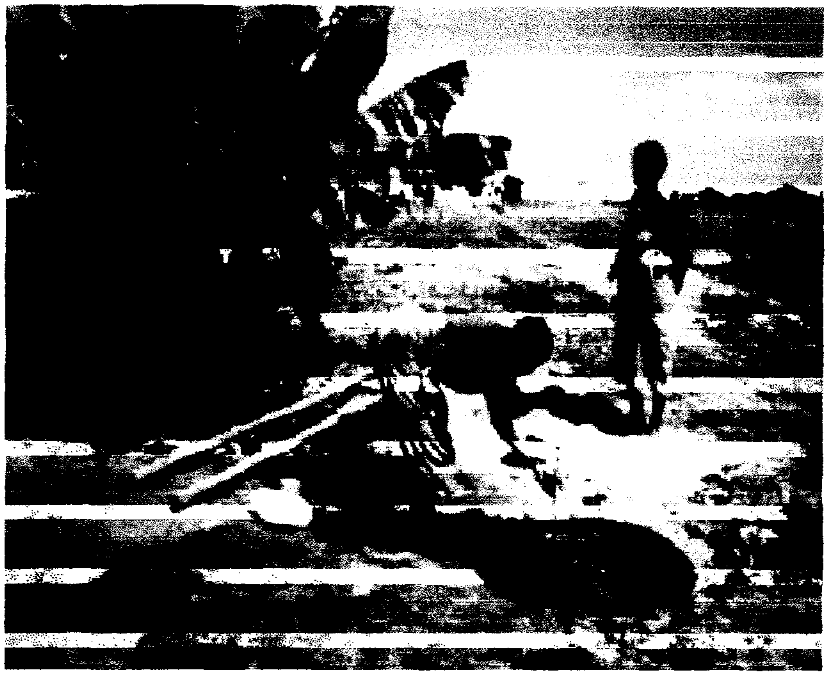

Figure 2.1: A woman collecting water from a well for domestic use

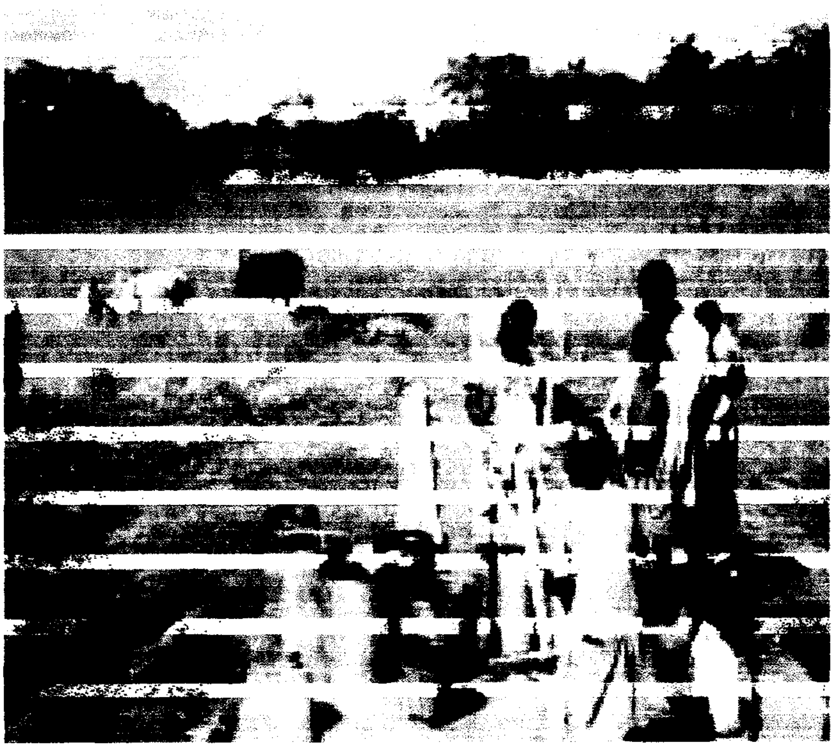

Figure 2.2: Children collecting water from a hand pumped borehole.

Figure 2.3: Women and children collecting water for domestic purpose from a stream.

Figure 2.4: A young girl collecting water from Tagwai dam for domestic use.

Tagwai dam located in Chanchaga Local Government area of Niger State which plays a crucial role in water supply, fishing, waste disposal, lake reclamation, agriculture, and industry. However, the catchment area of this dam has been subject to deforestation, agricultural intensification, soil erosion, urbanization, and industrialization. As a result, water pollution and water shortages have now become a severe problem, which has received little or no attention from the public and the government. This dam supplies Minna and its environs with water for domestic and agricultural use with inadequate water analysis being carried out on it. The water from this dam is "treated" and supplied to those that produce the sachet water and the public as a whole; of which are either treated or not before being supplied/sold to the public.

2.3 CHARACTERISTICS OF WATER.

2.3.1 Physical Composition of Water

The most important physical characteristics of water are its total solid content, which compose of floating matter, settle able matter, and colloidal matter in solution. Other important physical characteristics include; odor and taste, temperature, colour.

A. Total Solids

Analytically, the total solid content of a water is defined as all the matter that remain as residue upon evaporation between 103 ^{0}C to 105 ^{0}C, matter that has a significant vapor pressure at this temperature is lost during evaporation and is not defined as solid (Meltcalf and Eddy, 2004). Settleable solids are those solids that will settle at the bottom of a cone shaped container (called an inholf cone) in a 60 minute period, settleable solids are an approximate measure of the quantity to sludge that will be removed by primary sedimentation.

B. Odour and Taste

Odour and taste in water is usually caused by gases produced by the decomposition of organic matter or by substances added to the water. Fresh water has a distinctive, somewhat odour, which is less objectionable than the odour of water that has undergone anaerobic (devoid of oxygen) decomposition. Other substances that add to taste in water include algae, magnesium and iron salts e.t.c.(Meltcalf and Eddy, 2004).

C. Temperature

Temperature of a waterway is significant because it affects the amount of dissolved oxygen in the water. The amount of oxygen that will dissolve in water increases as temperature decreases. Water at O^0C will hold up to 14.6 mg of oxygen per litre, while at 30^0C it will hold only up to 7.6 mg/L. Temperature also affects the rate of photosynthesis of plants, the metabolic rate of aquatic animals, rates of development, timing and success of reproduction, mobility, migration patterns and the sensitivity of organisms to toxins, parasites and disease. Life cycles of aquatic organisms are often related to changes in temperature. Temperature ranges for plants and animals can be affected by manmade structures such as dams and weirs and releases of water from them (Meltcalf and Eddy, 2004).

D. Colour

Historically, the term condition was used along with composition and concentration to describe water. Condition refers to the age of the water which is determined qualitatively by its colour and odour. Fresh water is usually a clear-coloured (Metcalf and Eddy, 2004). However as the travel time in the collection systems increases and more anaerobic conditions develop the colour of the water changes sequentially from clear-coloured to light grey and ultimately dark grey. In most cases, the light grey and dark grey colour of the water is due to the formation of metallic sulphides which form as the sulphide produced under anaerobic conditions reacts with the metals in the water (Wu, 2005).

2.3.2 Chemical Composition of Water.

The chemical constituents that make up the chemical composition of water include; organic matter, inorganic matter and gases.

A. Organic Matter.

In a water of strength, about 75% of the suspended solids and 40% of the filterable solid are organic in nature. These solid are derived from both the animals and plant kingdoms and the activities of man as related to the synthesis of organic compounds. Organic compound are normally composed of a combination of carbon, hydrogen and oxygen together with nitrogen in some cases. Other important elements such as sulphur, phosphorous and iron may also be present.

B. Inorganic Matter.

The inorganic constituent of water is composed of chlorides, heavy metals, nitrogen, pH, phosphorus, sulphur, alkalinity and priority pollutant. Several inorganic components of water are important in establishing and controlling water quality. The concentrations of inorganic substances in water are increased both by the geological formation with which the water comes in contact with before being collected for treatment and packaging. Because the concentration of various organic constituents can greatly affect the beneficial uses of the waters, it is well to examine the nature of some of the constituents, particularly those added to the surface water.

C. Gases

Gases are mostly found in untreated water. The gases commonly found in untreated water includes; nitrogen (N_2), oxygen (O_2), carbon dioxide (CO_3), hydrogen sulphide(NH_3) and methane(CH_4) (Metcalf and Eddy, 2004). The first three are common gases of the atmosphere and will be found in all waters exposed to air. The latter two are derived from the decomposition of the organic matter present in water bodies.

Although the constituents that make up chemical composition of water are stated above, the category that are of primary importance in both the design and operations of water treatment plants and the management of water quality is the organic content. The concentration of organic matter is expressed in terms of the amount of oxygen required for its oxidation (BOD and COD).

According to UN Department 1990, water are usually treated by supplying them with oxygen so that bacteria can utilize the waste as food. Basically, there are three ways of expressing the oxygen demand of water:

D. Theoretical Oxygen Demand (ThoD).

This is the stoichiometric amount of oxygen required to oxidize the organic fraction of a sample (Agunwamba, 2001). It is the theoretical amount of oxygen required to oxidize the organic fraction completely to carbon dioxide and water (UN Department 1990). Water is usually so complex in nature that the ThoD cannot be calculated in practice, it is approximated by the chemical oxygen demand (COD).

E. Chemical Oxygen Demand (COD)

The chemical oxygen demand of the water is a measure of the oxygen equivalent of the organic matter susceptible to oxidation of a strong chemical oxidation. (Agunwamba, 2001). This is obtained by oxidizing water with a boiling acid Dichromate solution. This process oxidizes almost all organic compounds to carbon dioxide and water, the reaction usually process to more than 95% completion (Mara, 1998).

F. Biological Oxygen Demand (BOD)

According to Agunwamba, (2001), Biological Oxygen Demand is the measure of the Oxygen required to break down organic matter by micro organism for a period of five days at 20^0c. It is also a measure of the concentration of biodegradable organic matter in water which is usually expressed on a five day, 20^0c basis for convenience, because BOD_5 is easier to measure than ultimate BOD (BODu) (Mara, 1998).

G. Dissolved Oxygen (DO)

The amount of oxygen in water, to a degree, shows its overall health. That is, if oxygen levels are high, one can presume that pollution levels in the water are low. Conversely, if oxygen levels are low, one can presume there is a high oxygen demand and that the body of water is not of optimal health.

Apart from indicating pollution levels, oxygen in water is required by aquatic fauna for survival. In conditions of no or low oxygen availability, fish and other organisms will die.

Oxygen enters water as a result of two processes:

1. **Diffusion** - diffusion of oxygen into water is accelerated when the water turbulence is increased (moving through rapids and waterfalls) and when there is a strong wind blowing. Additionally, oxygen will diffuse into cold water at a higher rate than it will into warm water (FAO, 2002).

2. **Photosynthesis** - during daylight hours, aquatic plants use the sun's energy to create energy they can use for growth. A by-product of this process is oxygen which is released into surrounding water (FAO, 2002).

H. pH

pH is a measurement of how acidic or how basic (alkaline) a solution is. When substances dissolve in water they produce charged molecules called ions. Acidic water contains extra hydrogen ions (H+) and basic water contains extra hydroxyl (OH-) ions.

pH is measured on a scale of 0 to 14. Water that is neutral has a pH of 7. Acidic water has pH values less than 7, with 0 being the most acidic. Likewise, basic water has values greater than 7, with 14 being the most basic. A change of 1 unit on a pH scale represents a 10 fold change in the pH, so that water with pH of 6 is 10 times more acidic than water with a pH of 7, and water with a pH of 5 is 100 times more acidic than water with a pH of 7 (Allan, 1998).

2.3.3 Biological Composition of Water

The biological constituents of water composed of bacteria, viruses, algae and protozoan. The biological water treatments depend on the activities of micro-organism.

i. Bacteria

Bacteria are single celled prokaryotic eubacteria. Most bacterial can be grouped into four general categories; Rod, Spheroid, Curved Rod or Spiral and Filamentous (Metcalf and Eddy, 2004).

According to Mara (1998), bacteria are usually classified in one of the following tributes according to the range in which their optimum temperature occurs: psychrophilis $< 20^{o}c$, Mesophilis 20-45 ^{o}c, thermophilis >45 ^{o}c.

The bacterial of importance in the aerobic treatment of sewage are the rod shaped and for facultative are mesophilic. It is important to know that they are excellent oxidizers of dead organic matters (Saprophytes). They are all capable of exuding a slummy fluculent layer which in some treatment unit (e.g. activated sludge) is an important mechanism in the treatment process (Mara 1998). Coliforms and intestinal bacterial do not play any significant role in the treatment processes; they are merely passengers in the system.

ii. Virus

Viruses are obligate parasitic particles consisting of a strand of genetic material deoxyribonucleic acid (DNA) or ribonucleic acid (RNA) with protein coat (Metcalf and Eddy, 2004).

Viruses are peculiar micros in that they do not directly use organic or inorganic compounds i.e. they do not have the ability to synthesis new compounds) during growth; they reproduce by invading a host cell whose reproductive processes they redirect to manufacture more virus particles (Mara, 1998). They are extremely small (about 0.02-0.2 μm long) and when they behave as stable chemicals molecules and thus can remain inactive for many years.

iii. Algae

Algae are mostly multicellular photosynthetic organisms, which are extremely varied in their shapes and sizes (Mara, 1998). Carbondioxide is used as the source for the synthesis of new cell and oxygen evolved from the water by the classic mechanism of plant photosynthesis.

$$6CO_2 + 12H_2O \xrightarrow{light} C_6H_{12}O_6 + 6H_2O + 6O \qquad 1$$

Algae can be a great nuisance in surface waters because, when condition are right, they will rapidly reproduce and cover streams, lake and reservoirs in large floating colonies called blooms which in-turn serve as a source of drinking water in many communities. Algae blooms are usually characteristically of what is called a eutrophic lake, or a lake with high content of the compounds needed for biological growth (FAO, 2002).

iv. Protozoa

Protozoa are single celled eucaryotic micro-organism with cell walls. The majority of protozoa are aerobic or facultative anaerobic chemotrophs. The protozoa of importance in water engineering include amoebas, flagellates, and free-swimming and stalked alliates. Protozoa feed on bacteria treatment processes and in the purification of streams because they maintain normal balance among the different groups of micro-organism (FAO, 2002).

2.4 A COMPREHENSIVE APPROACH FOR ASSESSING WATER SCARCITY

Understanding the causes of water scarcity is a matter of fundamental importance. The insufficient distribution of safe water is traditionally presented as a consequence of the unsustainable demographic growth, particularly in developing countries. The population pressure determines increasing national water stress, defined as a ratio between the total volume of water theoretically available in a country and the total internal population, equivalent to a value below 1000 m^3/year/per capita. The macro-regionalization of water scarcity indicates that eighty countries, involving the 40% of the total world population, are currently suffering for water stress. The logical solutions sorting out from the consideration of water stress would rather being concentrated on increasing water supply, from one side, and on policies for population control, from the other. However, the issue is more complex that this and it is particularly related to the relation with poverty, social vulnerability, and territorial management. The macro-indicator of water stress does not explain the real elements of the problem, such as the unequal distribution of water access even in situations over the water stress threshold; the situation of the hydraulic infrastructures, that are obsolete and insufficient to cover all settlements; the impacts of upstream activities on downstream areas; the pressure on marginal and polluted water resources; and many others.

Therefore the following sections of this chapter present a brief overview about the different obstacles to water availability for all, to conclude with the idea that it would be more effective to face the problem by different tools offered by a "water poverty" approach and by more comprehensive development programs of integrated water resources management (IWRM) (Ganoulis, 1994).

2.4.1 Localized water scarcity

Great resources are currently mobilized to contrast the trend of increasing water deficit in large areas of the world. The aggregated values that have been presented have a strong communicative power, and are able either to increase a global concern among the public opinion world-wide, or to leverage new funding from donor countries and private companies (Rapport, 1998).

However, Rapport (1998) further reported that there are two major weaknesses of this perspective. The first one relates to the territorial and seasonal variability of the water availability. According to the variability, the communities have developed, on one hand, flexible productive patterns to ensure their own food security, particularly with husbandry and rain fed or small irrigated agriculture, and on the other hand, sustainable consumption patterns integrated with traded goods. The second weakness of the water stress perspective derives from the elements considered in the ratio water quantity/population number. In other words, the problem is presented only as a physical scarcity, exacerbated by natural stress, and as a consequence of the cultural habits of poor populations that lead to unsustainable pressures over the water resources. Within this perspective, very important elements are missing:

a) The conditions of infrastructures bringing water to settlements and to agricultural/industrial plants, and channelling the drainage system. In fact, not all communities are connected to water networks, particularly in rural areas and slums; wastewaters are often not disposed and are left in natural and urban environments, causing serious damages to human and ecosystems health;

b) the institutional framework related to the responsibilities for providing security and human development, which include provision of basic services for all (e.g. education and health, access to water and sanitation, housing, income safety nets etc.), thus contributing to alleviation of poverty and of social risks. Human development is a precondition for all development sectors: it is only starting from decent social status, that communities are able to participate in decision-making process, to better undertake sustainable livelihood systems, and to face the water poverty problems.

For the above reasons, more complex indicators can better help to describe the water scarcity situation and future trends, based on resource availability, access, community capacity, sector's use, and on the state of the environment, to understand strength and limits for an integrated water management and the future progress that can be carried by a development policy for the water sector (Lawrence *et al.* 2002).

2.4.2 Consumption patterns

The demographic projections indicate that by 2025 a world population growth of 2.5 billion of people, with a stronger concentration in mega cities. This trend poses a stronger constraint to the challenge proposed by the goal 7 of the Millennium. A greater weight over the water balance seems to be induced by the demands connected by the changing consumption patterns that a stronger globalization (induced by information networks and trade) has uniformed. Total consumption of goods is surely increased, but more importantly it has a changed pattern, with an increase in type of goods having a stronger impact on water resources, at different steps of the productive process. Restricted elites have higher consumption of goods and services that are not in line with the restricted resources locally available and with the limited recharge systems of the water bodies (Dezuane, 1997).

In the Mediterranean region, a greater pressure over the local resources is caused by non-local consumers. The intensive development of tourist resorts during the past decades has severely increased the water demand. The tourist flows are particularly concentrated on the coastal areas, with a presence of vulnerable water table: in fact, the pressures for water abstraction produce a marine ingression in the groundwater, causing a contamination for water salinity. The long term damages caused by unsustainable pressures from the tourist settlements is paid in terms of a worsening availability of safe drinking water and by a environmental degradation due to changes in chemical features of the water resources sustaining the wet ecosystems. For these situations, particularly in the coastal areas of the Southern Mediterranean region, there are no effective regulations for monitoring and sanctioning the unsustainable pressures, nor mechanisms for compensation of the social and ecological damage, also because the assessment tools are not often available. Besides the tourism, other water-exigent sectors are expanding in line with the new development trends. The linkage between type of commodities produced and pressure over the water resources has been estimated in terms of volumes of water embedded in the specific production processes ("virtual water", Allan 1998). For instance, for the production of a car it has been estimated an average of 400.000 l of water used during the industrial process; while the UNDP Human Development Report of 1998 show that between 1975 and 1995 the presence of motor vehicles in South-Eastern Asia has developed by 1400%. The virtual water has been calculated particularly for evaluating the agricultural productions and the diet compositions. According to the content of animal proteins rather than a percentage of vegetal staples consumed, a great difference is shown in terms of water pressures. According to Renault and Wallender (2000), the composition of the average diet in the United States determines a consumption of 5,4 m3/person/day, while a subsistence diet corresponds to only 1 m3 of water consumed. This explains a lot about the weakness of the demographic concern related to water stress, and shows how the pressure is more influenced by the social and economic wealth. In the arid Middle East it is not uncommon to see beautiful gardens and golf clubs watered with continuous irrigation, beside barren areas where deprived communities reside. The water availability is, again, a matter of human and economic development, of social awareness and education, and of good governance for widening the access opportunities for all. The economic wealth offers various opportunities of choice about alternative sources of water for meeting the human needs. One example is given by the expensive technologies offering alternative sources of *physical* water, such as the desalination plants utilized e.g. by Israel, Saudi Arabia and the Emirates; or by adopting a strategy of *virtual* water trade, with importation of goods requiring huge amounts of water and that in a foreign country could be produced at a lower cost. On the contrary, the financial constraints reduce the opportunities for accessing new technologies and developing alternative sources. The consumption of physical water locally available as well as restricted strategies for food security are the only chances to survive under water poverty conditions (Ganoulis, 1994).

2.4.3 Disruptive and Inefficient Management of Water Resources

The problem is worsened by the inefficient management of water resources, either in terms of operation and maintenance of the distribution networks, or as rational allocation of the resource. The main losses are caused by damages and bad maintenance of the canalisation networks that in many cases are old and obsolete. The problem do not only regards the Developing countries, but is also relevant in Europe, even in cases where the management responsibility has been shifted from central institutions to municipalized agencies, and with an important private presence, that would be supposed to facilitate a more efficient approach. At a world scale, the total loss of collected water has been estimated at 37%; the distribution systems of drinking water are losing the 50% of water, while in the downstream irrigation canals, losses are estimated by 40% of the distributed volumes (Petrella 2001). Moreover, the problem is worsened for a low efficiency in utilisation of water in agriculture, and for this reason the international community is calling for an effort to meet the objective of allocation efficiency resumed by the slogan *more crop per drop* (SIWI-IWMI 2004). Another critical factor is constituted by the large presence of big dams that, besides causing wide damages to the traditional socio-territorial systems and negative environmental impacts, their presence if also weakly justified according to water and hydro-power efficiency standards (WCD 2000).

2.4.4 Increase of Pollution Sources

The last factor of water crisis is the loss of the original chemical-physical properties of the water resources on which various human uses and ecological functions are based. In cases where their characteristics do not respond to minimal quality criteria of safety related to the different uses, a risk is potentially open either for the communities, or for the ecosystems served by the contaminated water. The causes for contamination are various, depending either on the massive use of chemical products and heavy metals in the productive and domestic discharges, and on the missing treatment of the wastewaters discharged in the freshwater. In order to reduce the pollution of freshwaters, there are cases of injection of contaminated water underground, with a damage for the groundwater courses. Another source of contamination comes from the saline intrusion in the water table of the coastal areas, caused by a heavy human pressure compared to the slow recharge capacity of the groundwater. The organic pollution is also strongly affecting the environment, particularly in urban peripheral areas in developing countries, where the health alarm is at a highest level, as the MDGs assess, recording a deficit of sanitation services for around 3 billion people in the world (Ganoulis, 1994).

The qualitative degradation of the freshwaters is also raised by indirect causes, among which the soil erosion, particularly on the river banks, induced by deforestation practices and desertification processes. The erosion material charging the watercourses produces a negative impact either on the water quality or on the river capacity, causing phenomena of dangerous flooding. The human mismanagement of water resources produces heavier impacts because of the effects of climate change.

2.4.5 Scarcity as a Matter of Governance

From the above-described causes for the current water crisis, a lesson that could be learnt is that the issue cannot only be reduced to a problem of *physical scarcity*. The problem of equal access for all in many countries around the world is not only significant in conditions of water stress, but also in situation of theoretical abundance. Thus the problem is also caused by an *instrumental scarcity*, meaning that instrumental resources are missing, such as financial resources, adequate infrastructures, institutional response to community demands, monitoring and control of contamination processes, etc. The lack of sufficient water resources for the development of all human beings does reflect the asymmetric social relations among groups using those resources for their productive and reproductive needs (Raffestin 1998).

The water poverty is then a matter of good *governance* of the resource, as it was already stated by the second World Water Forum (The Hague 2000). The policies oriented towards the MDGs cannot avoid the exercise of democratic management of the natural and instrumental resources. Starting from the consideration of the multi-functionality of the water resources for the human and territorial needs, the strategies have to mainstream different principles □

guarantee for the right to a minimum vital consumption of safe water, that has been calculated as a quantity of 50l/person/day (Gleick 1996); □

considered as a fundamental tool for poverty alleviation and human development, based on systems of sustainable livelihood and enhancing local cultures; □

water has to keep the highest value for the resource, to enable the support to a multiplicity of utilisations, meaning that any form of utilisation would not be allowed to damage other sectors uses; □ct the health

of affected human communities, as well as the ecological functions and the maintenance of biological diversity; a ban has to be ensured towards disruptive and polluting uses of water resources, and effective instruments for controlling the consumption at efficiency levels have to be realised. This list is meaningful since it represents a limit to the locally-negotiable decisions regarding water management. In other words, the participatory decision-making observed within a good governance system has to respect will and needs of the local populations, but also to ensure the observation of interests that are more pertaining values of other socio-territorial systems or at different scales: for instance, affecting communities downstream of the same catchments, or affecting global commons of the entire world (e.g., water balances co-responsible for climate change) (Gleick, 1994).

2.4.6 Prioritization of Water Values

The past section has introduced the general causes of water poverty, as a knowledge-basis for a theoretical situation to be reversed on a positive trend. Each constraint could logically be reformulated as a priority goal for the future; however, from the overview offered, it is clear that no technical solution could be self-sustaining, but the challenges have rather to be faced by integrated programs, as it has been proposed by the Integrated Water Resources Management (IWRM) approach. As discussed, at different scale, and via instruments of good governance and public participation, a prioritization of potential uses and modalities of usage, as well as decision about non-use for conservation purposes, could be decided. From the prioritized functions, according to the characteristics of the resource and to the expected impacts over the resources, a system of evaluation of the water uses could be elaborated (Gleick, 1994).

2.4.7 Economic Evaluation versus Protection of Access for All

The evaluation of natural resources is a useful instrument for defining priorities for use and safeguards, thus for favouring quality conservation while limiting unsustainable uses. The definition and tools elaborated in the field of evaluation and management of environmental goods are utilised, by analogy, for the issues concerning water resources. The principle of economic evaluation of water has been introduced by the UN Conference of Dublin in 1992, in preparation to the Rio Summit on Sustainable Development of the same year. According to the Dublin declaration, water, as scarce resource, has to be managed on a rational and efficient manner, in order to limit the qualitative and quantitative degradation; and according to three sorts of fundamentals for a sustainable management: the *ecological fundamentals*, proposing a holistic vision of the water resource and an inter-sectorial approach; the *institutional fundamentals*, indicating the need for a broader involvement of the affected communities and, in particular, women groups, non-governmental organizations, and the private sector; and finally, the *instrumental fundamentals*, proposing a particular attention for the opportunity-costs related to the alternative water uses as well as the adoption of economic tools for compensating the damages caused to the ecosystems (e.g. *user pays*, *polluter pays*, etc.) (Gleick, 1994).

CHAPTER THREE

3.0 MATERIALS AND METHODS

3.1 MATERIALS

3.1.1 Description of Area of Study

Niger State is one of the 36 states created in Nigeria with her capital in Minna located between latitude 9°34' - 9°37'N and longitude 6°36' - 6°39'E, (Ndako 2004) with an annual rainfall of 578mm and a mean temperature of 34° (Minna metrological centre, 2008).

The development of new laboratory instrumentations is of great benefit to the water and wastewater experts. The new instrument designs have incorporated automatic sample handling, sequential analysis and improved data presentation. The current change to digital output, in contrast to meter readings, has reduced error and increased the speed of the determination.

In addition to the expanded variety in the types of laboratory analyses performed, there has been an increase in the number of individual samples to be analyzed. To meet the increased work load, laboratory operations have been redesigned to take advantage of automatic instrumentation wherever possible. The instruments and apparatus used in this research work are;

-Atomic Absorption Spectrometer.

-Dissolved Oxygen Meter (JENWAY MODEL 9071).

-Conductivity Meter (HACH MODEL CO 150).

-Portable pH/MV/Temperature Meter (HACH MODEL EC10).

-Turbidity Meter

-Thermometer

-pH Meter

-Incubator

-Condenser

-Electric Oven

-Bunsen Burner

-Analytical Balance

-Graduated cylinders (100ml, 10ml, 1ml)

-Measuring Cylinders (100ml, 10ml, 1ml)

-Pyrex beakers (500ml, 100ml, 10ml)

-Conical Flask

-Burette (50ml)

-Pasteur Pipette (2ml, 5ml, 10ml)

-Crucibles (25ml)

-Desiccators

-Volumetric Flask

-Funnels

-Filter Papers

-Pipette (25cm)

-Sample Bottles of Borosilicate Glass

-Flame Photometer

-Steam Bath

-Distillation Apparatus

-Ground Glass Joint

-Horizontal Shaker

-Evaporating Dish.

List of Some of the Reagents Used:

-Sodium hydroxide pellets

-Oxalic acid

-Potassium permanganate $KMnO_4$

-Sodium nitrite

-Sodium sulphate

-Sodium hydrogen trioxocarbonate(iv) $NaHCO_3$

-Hydrochloric acid HCl

-Chloroform

-Mangenese sulphate

-Starch solution

-Solid KI free from iodate

-Alkaline iodide

-Sodium thiosulphate solution

-Dipotassium chromate (vi) $K_2Cr_2O_7$

-Silver nitrate

-Chloride

-Sodium chloride

-Potassium chloride

-Phosphoric acid

-Soda lime

-Calcium chloride

-Sulphuric acid

-Mercury Tetraoxosulphate (vi) $HgSO_4$

-Silver Tetraoxosulphate Ag_2SO_4

-Iron (ii) Tetrasulphate(vi) Heptahydrate $FeSO_4$ $7H_2O$.

3.2 METHODS

3.2.1 Sample Collection Techniques

Six different packaged water samples were collected from the open market at intervals of three weeks from the same producing packaged water company. The water samples were collected between 0800 hours and 1000 hours.

The Samples were collected and treated as follows;

a) Samples for physiochemical and bacteriological parameters to be analyzed were collected in a two (2) litre plastic bottle. Plastic were used to prevent sample contamination from metallic samples.

b) The plastic containers are thoroughly washed and rinsed three times with the effluents to be sampled before the actual samples were collected.

c) Samples collected were preserved in a refrigerator on arrival at the laboratory.

3.2.2 Sample Identification.

To identify and locate samples easily, all samples carried self adhesive labels. These were affixed on the sample bottles instead of the cover to prevent lost or misplacing, causing sample mix-up. The information carried on the sample label includes; location, date and time.

3.3 EXPERIMENTAL PROCEDURE

3.3.1 Determination of Physical Parameters of Water.

3.3.1.1 pH Determination.

The pH of the effluent sample was determined using the HACH MODEL EC10 portable pH/mv/temp Meter.

The model EC10 features a custom digital LCD display the pH measurement. This meter has all the features of a simple pH meter plus multivolt mode, sealed keypad, electrode holder, tilt strand, ergonomic design and battery/ line power.

The required MODE was selected using the keypad. The meter electrodes were rinsed with distilled water and the pH electrode probe was immersed into the sample contained in the beaker. The display was allowed to settle and the result was read.

3.3.1.2 Electrical Conductivity Determination.

The electrical conductivity of the effluent sample was determined with a HACH MODEL CO150 conductivity meter. This meter features a micro processor design which automates complicated and time-consuming calibration and measurement procedures for a wide variety of applications. Water quality, salinity, acids, bases and other samples can be easily analyzed or conductivity with the available conductivity probes.

The conductivity meter was pressed to conductivity mode. The probe was rinsed with distilled water and inserted into the sample contained in a beaker, while the display was allowed to stabilize before recording measurements.

3.3.1.3 Turbidity Determination.

Turbidity was determined by Nepheleiometric method. Turbidimeter consist of a Nephelometric with a light source for illuminating the sample and one photoelectric detector, a read out device to indicate intensity of light scattered at 900 to the path of incident light.

The sample was thoroughly shaken to allow air bubbles disappear. The shaken sample was poured into turbidimeter tube and immersed into an ultrasonic bath for two seconds, causing complete bubbles release. Turbidity was read directly from the instrument scale as Nepheiometric Turbidity Units (NTU).

3.3.1.4 Total Dissolved Solid Determination.

A well mixed sample was filtered through a standard glass fibre and the filtrate was evaporated to dryness in an already weighed dish and dried to constant weight at 180c. The increase in dish weight represents the total dissolved solids.

The sample was stirred with a stirrer and pipette, 60ml was measured into a glass fibre. Then, wash with three successive 10ml volumes of reagent-grade water allowing complete drainage between washings and continue suction for about three minute after filtration was completed. Total filtrate (with washings) was transferred into a weighed evaporating dish and evaporated to dryness on a steam bath. Dry for about 1 hour in an oven at 180^{oc}, cool in a desicator to balanced temperature and constant weight.

$$\text{Total dissolved solids} = \frac{(Y - Z) \times 100}{25ml\ of\ sample\ volume} = mg/l$$

Where Y = weight of dried residue + dish

Z = weight of dish.

3.3.1.5 Total Suspended Solid

A well mixed sample was filtered through an already weighed standard glass fibre filter and the residue retained on the filter was dried to a constant weight at 105^{oc}. The increase in weight of the filter represents the total suspended solids. The sample was stirred with a stirrer and while stirring 25ml of the sample was pipette into a glass-fibre filter. Wash with three successive 10ml volumes of reagent-grade water and allow complete drainage between washings, and continued suction for about three minute after filtration was completed. The filter was carefully removed from filtration apparatus and transferred into stainless steel. Dry for about 1 hour at 105^{oc} in an oven, cool in a desicator to a balanced temperature and constant weight.

$$\text{Total suspended solids} = \frac{(Y-Z) \times 100}{25ml\ of\ sample\ volume} = mg/l$$

Where Y = weight of filter + dried residue

Z = weight of filter.

3.3.1.6 Total Hardness.

The plastic measuring tube was filled with the water sample to be tested and the contents were then poured into a mixing bottle. Three drops of buffer solution were added into the mixing bottle and was swirled followed by a drop of Maver hardness indicator solution. EDTA (ethylene-diamine-tetra-acetic acid) titrant was then added to the solution in the mixing bottle drop by drop. The bottle was swirled at each drop and each drop of the EDTA titrant added into the mixing bottle was counted. The addition continued until a color change from pink to blue was seen or noticed. The hardness in mg/l as calcium carbonate

($CaCO_3$) is equal to the number of drops EDTA titrant required to bring about color change multiplied by 20.

3.3.1.7 Calcium Hardness

The plastic measuring tube was filled with the water sample to be tested and contents of the tube were then poured into mixing bottle followed by addition of 8N potassium hydroxide. A clipper was used to open calver calcium indicator powder pillow which was added into the solution in a mixing bottle. EDTA (ethylene-diamine-tetra-acetic acid) titrant was then added to the solution in mixing bottle drop by drop. The bottle was swirled at each drop and each drop of EDTA titrant added into the mixing bottle was counted. The addition continued until a color change from pink to blue was seen or noticed. The hardness in mg/l as calcium carbonate ($CaCO_3$) is equal to the number of drops of EDTA titrant required to bring about color change multiplied by 20.

It should be noted that magnesium-hardness can be gotten as magnesium hardness = total hardness – calcium hardness.

3.3.1.8 Total Alkalinity

A measure of 40ml of 0.025M Na_2CO_3 solution sample of the water sample in a conical flask was added to 60ml and 3 drops of methyl orange indicator was use, 0.05M of H_2SO_4 was use to titrate until a color change from yellow to orange was noticed.

3.3.2 Determination of Inorganic Matter Composition.

3.3.2.1 Chloride Ion Determination.

It was determined by titration with silver nitrate;

Procedure/Reagent

1. The following three reagents were prepared.

a. 48g of silver nitrate was dissolved in 1 litre of distilled water and 1ml was equivalent to 1mg chloride.

b. 1.6g of sodium chloride standard and 1ml contains 1ml chloride

c. Potassium chromate indicator, 5g per 100ml was added to the silver nitrate solution to produce a slight red precipitate and was filtered.

2. 100ml of water sample was measured into a flask and 1ml of potassium chromate solution was added and titrated with silver nitrate with constant stirring until a slight red colour persists.

$$\text{Chloride} = \frac{\text{volume of silver nitrate for sample} - \text{blank}}{\text{volume of water sample (ml)}} X\ 100 = mg/l$$

3.3.2.2 Phosphate Ion Determination.

Phosphate was determined by the turbidimeter method. Colloidal Barium sulphate was formed by the reaction of sulphate with barium ion, a barium chloride hydrochloric acid solution in the presence of glycerol and ethyl alcohol. The colour intensity was measured using DR 2000 spectrophotometer at 42mm wavelength.

3.3.2.3 Sulphate Ion Determination

Sulphate is a minor ion occurring in natural water and wastewaters. Direct anthropogenic sources of sulphate include industrial and municipal waste.

To determine sulphate, an excess of barium chloride $BaCl_2$ was added to the water sample. The barium ion reacted with the sulphate to precipitate barium sulphate crystals, the colloidal suspension was measured using a spectrophotometer and the sulphate concentration was determined by comparing with standards.

3.3.2.4 Nitrate

This is one of the four inorganic forms of nitrogen compounds that are of sanitary significance. This is measured using the spectrophotometer. The stored programme number for nitrate was entered and a wavelength dial was rotated. By pressing the enter bottom on the device, mg/l NO^- H was displayed. A sample cell was filled with 25ml of the sample to be tested followed by the addition of the contents of one nitraver 5 nitrate reagent powder pillows to the cell (prepared sample). The shift timer bottom on the device was pressed and the cell was vigorously until the timer beeped in one minute. The content of the sample was allowed to stand for 5 minutes. Another sample cell filled with 25ml of distill water was placed into the cell holder and closed until the timer beeped, 0.00mg/l NO_3^- H was displayed. By removing the black and placing the prepared sample in the cell holder the value of the nitrate was displayed and removed.

3.3.2.5 Trace Metals Determination.

Prior to metal analyses, each sample of 100ml was acidified with concentrated HNO_3 (0.5ml). 25ml of each sample was poured into a beaker and diluted with 1.25ml HCl. The mixtures were heated for 15 minute on a steam bath and the final volume was adjusted to 25ml. Graded concentrations of the standard metal solutions were similarly prepared (0.2, 0.4, 0.6, 0.8, 1.0 and 1.2ppm) and aspirated into the flame and the absorbance read in the atomic absorption spectrometer. The absorbance of the standard calibration curve from which the concentrations of the metals present in the sample extrapolated. Metals detected were iron, calcium, magnesium and lead.

3.3.3 Determination of Organic Matter Composition.

Over the years a number of different tests have been developed to determine the number of organic content of water. In general, the test may be divided into those used to measure gross concentration of organic matter greater than 1ml and those used to measure trace concentration in the range of 10-13mg/l. The laboratory methods commonly used today to measure gross amounts of organic matter (greater than 1mg/l) in water include;

1. Biological Oxygen Demand (BOD)
2. Chemical Oxygen Demand (COD)
3. Total organic carbon (TOC).
4. Theoretical 0xygen Demand (ThoD)

Trace organic matter in the range of 10-13mg/l are determined using instrumental methods including gas chromatography and mass spectroscopy. Within the past 10 years, the trace organic compound has improved significantly and detection of concentration in the range of 10-13mg/l is now almost a routine matter (Metcalf and Eddy, 2004).

3.3.3.1 Dissolved Oxygen Determination.

The Dissolve Oxygen (DO) was determined in the field with JEN WAY MODEL 9071, Dissolved Oxygen Meter. The measurement system consists of a "clark" type polorgraphic oxygen electrode and an oxygen metre. The units give the user readout of dissolved oxygen in mg/l or % and have a temperature measurement range of -30 to150c. The required mode was selected. The dissolved oxygen probe was immersed in the beaker containing the sample to be measured. The model 9071 dissolved oxygen metre simultaneously display dissolved oxygen and measurement results. It is possible to fix dissolved oxygen by Winkers method and subsequent analysis in the laboratory.

3.3.4 Bacteriological Analysis

This is the determination of the indicator of organism in a sample of water. This is also referred to as coliform count. The test was carried out using the Most Probable Number (MPN).

An indicator, bromoresol purple indicator was added into a series of sterilized culture bottles. A change of colour from pink to yellow after 48 hours indicated the presence of coliform. The number of coliform available was estimated by the use of MPN table. The culture media was prepared by dissolving approximately 1g of beef boullion and 4g of powdered milk in 250ml of distilled water. 15ml of media was then introduced into each 15 screw capped sterilized bottle followed by the addition of the drops of bromoresol purple indicator solution.

10ml of water sample was introduced in the first group of culture sterilized bottle which contain the media and indicator solution. The second group of the six sterilized bottles was introduced with 1ml of water sample. And the third group of six sterilized bottles was introduced with 0.1ml of water sample by means of a sterilized syringe. The bottles were then incubated at about 35^{oC} for two days.

After two days, the bottles were observed for colour change, positive test bottles that have colour change to pink were obtained. A MPN table was used to estimate the number of coliform present in the water.

MPN values per 100ml of sample and the percentage confidence limits for various combinations of positive and negative result when (five 10ml, five 1ml and five 0.1ml) test partition are used.

CHAPTER FOUR

4.0 RESULTS AND DISCUSSION

4.1 Presentation of Results

Some rural and major populations are heavily dependent on small reservoirs other sources for their water supply, and are concerned about the quality of this water for direct consumption and other uses. Such concerns can be raised by what appears to be water pollution, or by disease symptoms perceived to be water related. In these cases, chemical, physical and biological water quality measurements were taken to ascertain the suitability of water for consumption. Table 4.1 below shows the physicochemical and bacteriological analysis of some sachet water samples in Minna.

Table 4.1 Physicochemical and bacteriological analysis of sampled sachet water in Minna

S/No	Parameters	Sample A	Sample B	Sample C	Sample D	Sample E	Sample F	W.H.O. limit (2004)	NAFDAC Lin (2004)
1	Electrical conductivity (us/cm)	100	90	110	370	170	140	1000	-
2	Total dissolved solids (mg/L)	50	45	55	190	80	70	1000	500
3	Temperature (^0C)	35	35	35	35	35	35		Ambient
4	Suspended solids (mg/L)	1	0	0	0	0	0	25	-
5	Ph	7.2	7.4	7.3	8.1	6.9	7.2	7.0–8.5	6.5-8.5
6	Turbidity (NTU)	2	1	0	0	1	0	5.0	5
7	Colour (TCU^2)	15	10	0	0	4	0	15	15
8	Iron content (mg/L)	0	0.007	0	0.02	0.02	0.01	0.3	-
9	Total hardness (mg/L)	47	50	52	135	16	19	100	
10	Hardness (ca) as $caco_3$ (mg/L)	18.8	20	20.8	54	16.0	14	50	75
11	Hardness (mg) as $caco_3$	28.2	30	31.2	81	17.0	9.0	50	30

	(mg/L)								
12	Nitrate as Nitrogen (mg/L)	1.4	0.9	0.4	1.0	5.3	4.8	50	-
13	Nitrite (mg/L)	4.4	3.96	1.76	4.4	-	-	0.2	0.2
14	Sulphate (mg/L)	57.0	72	19	15	18	13	250	250
15	Phosphate	0.07	0.023	0.13	1.16	0.03	0.01	0.3	-
16	Total alkalinity (mg/L)	46.0	75.0	43.0	140.0	18.0	15.0	100	100

Bacteriological analysis

15	Total Coliform (cfu/100ml)	23	4	0	43	0	9	Most not be detectable in any 100ml per sample.	10
16	E. Coli (cfu/100ml)	7	0	0	5	0	0	Most not be detectable in any 100ml per sample.	0

4.2 Discussion of Results

4.2.1 Physiochemical Analysis of Water

Electrical Conductivity (us/cm)

It was discovered that the samples from A to F had values ranging from 90 and 370 from Table 4.1 which are below the maximum permissible limit of 1000 (WHO, 2004).

Total Dissolved Solids (Mg/L)

The values of 50, 45, 55, 190, 80, 70 from table 4.1 of the parameter above for samples A to F respectively were all within the standard limit of 500 (NAFDAC, 2004).

Suspended Solids (Mg/L)

It was discovered from Table 4.1 that only Sample A had some suspended solids inside it but still below the maximum permissible limit of 25.0 recommended by W.H.O. while others had no suspended solids.

pH

The pH of the water for all the samples fluctuated greatly. Sample E had relatively the lowest pH of 6.9 with samples A and F having value of 7.2 from Table 4.1. The overall pH pattern showed that the pH values were relatively within the NAFDAC range of 6.5-8.5.

Temperature

The temperature of most of sachet water (a.k.a. pure water) was not fixed as they are usually transported directly under the influence of the sun thus giving it an atmospheric temperature. This implies that the temperature before the start of the analysis was measured to be 35 ^{0}C which corresponds with atmospheric temperature. Though, temperature does not have any direct impact on the sachet water apart from evaporation process that takes place hence reducing content of the sachet.

Turbidity

It was observed from Table 4.1 that sample A had the highest turbidity value of 2 while sample B and E had values of 1 while the others had zero values but they are all within the maximum permissible limit of 5.0. (WHO and NAFDAC, 2004)

Colour (pt. co)

From the tested conducted, it was discovered that the colour of the various samples of water ranged between 0 and 15 from Table 4.1 with sample A having the highest value of colour which was not above the standard limit of 15 (WHO and NAFDAC, 2004).

Iron (Mg/L)

When Iron was tested for, samples A to F had their values ranged "between" 0.07 to 0 from Table 4.1 which was within the maximum permissible limits of 0.3 mg/L. Although present in drinking water, iron is seldom found at concentrations greater than 0.3 milligrams per liter (mg/l) or 0.3 parts per million (as recommended by W.H.O and NAFDAC) which can cause water to turn a reddish brown colour.

Water Hardness

It was observed that for calcium hardness the values obtained ranged between 14 and 54 mg/l from Table 4.1 with sample D more than the permissible limit 50 mg/l recommended by W.H.O and NAFDAC while the magnesium hardness was discover to range between 9 and 84 mg/l which indicates that the same sample D had exceed the permissible limits of 50 mg/l.

Nitrate Nitrogen (Mg/L)

It was observed that the value for the samples of the parameter above ranged from 0.4 to 5.3 from Table 4.1 which were all below the maximum permissible limit of 50 (WHO, 2004).

Nitrate (Mg/L)

It was observed that samples A, B, C and D had values ranging between 1.76 and 4.4 from Table 4.1 which is far higher than the recommended value by both W.H.O. and NAFDAC of 0.2.

Sulphate

The values of 57.0, 72, 19.0, 15.0, 18, 13 from Table 4.1 of the parameter above for samples A to F respectively were all within the standard limit of 250 (WHO and NAFDAC, 2004).

Phosphate

It was observed that the value for the samples of the parameter above ranged between 0.07 and 1.16 from Table 4.1 with sample D only, more than the standard limit of 0.3 (WHO, 2004).

Alkalinity (Mg/L)

The total alkalinity values for the samples ranged between 15 and 140 from Table 4.1 with sample D higher than the recommended value by both WHO and NAFDAC of 100.

4.2.2 Bacteriological Analysis of Water Samples

Total Coliform (cfu/100mL)

The values of 23, 4, 4, 0, 43, 0, 9 for Samples A to F respectively from Table 4.1 showed that only sample A and D with 23 and 43 total coliform counts were higher in their values. The recommended Total coliform count by NAFDAC (2004) is 10 while the W.H.O (2004) says that it most not be detectable in any 100ml per Sample.

E. coli (cfu/100mL)

The E. coli content for the samples tested showed that samples A and D had 7 and 5 E. Coli counts while others had 0 counts. The recommended value of the E. Coli count by NAFDAC

(2004) is 0 while the W.H.O. (2004) standard states that most not be detectable in any 100ml per Sample.

CHAPTER FIVE

5.0 CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusions

The following conclusions can be drawn based on this research work

1. Among 6 water samples analyzed most of the physical, chemical and bacteriological parameters were found to have the values according to the standard values prescribed by WHO and NAFDAC for all the parameters which proves their safety for human consumption without danger to the health of the consumer, except for sample A and D with a higher values of Total coliform count of 43 and 23, and E.coli of 5 and 7 respectively which are unsafe for consumption without prior-treatment
2. Most of the sachet water factories never at any particular time send samples of their production to the necessary agencies for the required tests before sales to the consumers.
3. From the part of the government to the consumers of these products, there should be concern about the human health which has increased the number of patients in the various private and public medical out fits.

5.2 Recommendations

Based on the result of this research, the following recommendation can be made;

1. The Niger State government in-conjunction with Federal Ministry of water Resources should provide good, clean and safe water for the people of Minna which will in-turn reduce the production of sachet water.

2. Sample A and D are advised to stop production and enhanced their production line as there water may pose health risk to the general public

3. There should be seminars and conferences for these producers of sachet water to keep them abreast with modern ways of water quality appraisal.

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