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TITOLO:

Feasibility study for ensuring a reliable and sufficient Water supply at Umuezeokoha Community in Ezza North Local Government Area of Ebonyi State of Nigeria.

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ABSTRACT

With the present water scarcity that is drastically affecting many rural communities in Africa particularly Nigeria, many cases of health, social and economic effects to these communities as a result of water scarcity are on daily increase. The federal and state government, institutions, organizations, NGO's etc need the appropriate means and measures to effectively and efficiently provide the over 50% of the Nigerian population that are currently living in the rural community with no sustainable safe access to drinking water so as to avoid epidemic outbreaks of waterborne diseases, social and other effects that would eventually lead to socio-economic destruction of the community and hence endanger the state and the country at large. This study aims at providing a feasibility study for ensuring a reliable and sufficient water supply at Umuezeokoha Community in Ezza North Local Government Area of Ebonyi State of Nigeria. As the possible solutions (by water tankering, Aqueduct, drilling a new well on site) for ensuring a reliable, and sufficient water supply to the community are considered, drilling a new water borehole at the community presents greater possibilities towards ensuring a reliable, viable and sufficient water supply to the community. These sustainable accesses to safe drinking water to Umuezeokoha community could be adopted by other communities in all states of Nigeria and other countries in similar contexts. However, any structural and developmental processes should be incremental. The reverse rotary drilling method applied for drilling a borehole here may also be used by government and non-governmental organizations that are in the field of providing water to rural poor communities to improve there competitiveness and competences.

ACKNOWLEDGEMENTS

I wish to express my profound gratitude to almightily God, my dear family and friends for there love, care and prayers during these two years of my masters and at this time of my thesis.

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INTRODUCTION

Global concern on uncertainties in the water sector has risen over the years. Poor and unsustainable practices in management of freshwater reservoirs and fragile aquifers, coupled with the challenges of the rising urban population and industrial activities have only made the situation get worse and worse.

International efforts at containing water related risks over the years are very well documented in the literature (Castro, 2007). These include tackling desertification, controlling water pollution, developing conflict prevention measures, monitoring and preventing water related threats and hazards, promoting policies aimed at scaling down deficiencies and inequalities in the allocation of water especially in developing and transitional economies. Concerns over these issues are louder and more important in developing countries which harbor the world's poorest people and are constantly affected by leadership problems and weak citizen's involvement in water management issues and debates. The second world water assessment report (UNESCO, 2006) has identified the world water crisis (associated with the lack of an adequate water supply and sanitation for people) to be primarily a crisis of governance, so governance is very crucial in the water management issues in the developing countries. **Goal 7, target 10 of the Millennium Development Goals aims at halving by 2015 the proportion of people without sustainable access to safe drinking water and basic sanitation.**

A good clean water supply and adequate sanitation system are considered to be the most important factors in ensuring good health in a community. Improved water supply and sanitation systems were major elements of the public health measures that drastically cut death rates and improve health levels in industrialized countries. Though its not generally appreciated, this measures have been considerably more important than curative medicine in contributing to good health, long life expectancy and low infant mortality. Infact, diarrhea the largest killer in developing countries is closely related to poor water quality.

The urgent need for clean water for drinking, cooking, bathing and other household needs had long been recognized. However, its estimated that over 2 billion people still lack safe domestic water supplies and 2.5 billion lack adequate sanitation (World Health Organisation 2003, Meinzen-Dick and Rosegrant, 2001). This statistics, no doubt, holds true mostly in the developing economics of Africa, Asia and Latin America where poverty has assumed endemic root. Understanding water risks in developing countries implies coming to terms with issues of unsafe drinking water and scarcity, which varies in time and space, water related threats, as well as quality and quantity issues. In most countries, there are increasing various degrees of water uncertainties arising from over pumping of the aquifers, falling water tables and sharp deterioration of the aquatic ecosystems. These often lead to many consequences on the most vulnerable groups in the population especially those who do not have the power to influence and affect a change in behavior. Against this background is the need for effective system of governance to regulate practices, protect the ecosystem and minimize uncertainties and risk (Ugwunwa, 2002). Unfortunately, governance issues in the water sector have been the major problems facing most developing countries in meeting the challenges of water related targets and development goals.

1.6 million people die every year from diarrhoeal diseases (including cholera) attributable to lack of access to safe drinking water and basic sanitation and 90% of these are children under 5, mostly in developing countries

1. LOCAL CONTEST ANALYSIS

1.1 The Nigeria Country

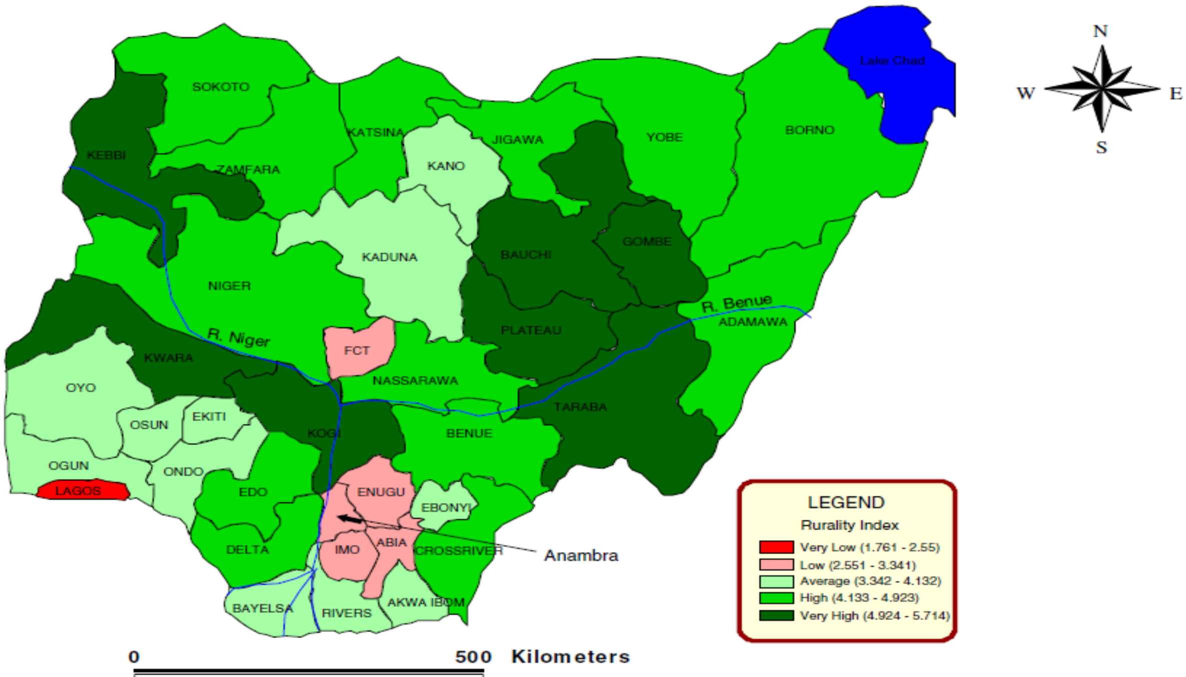


Figure 1.2: Map of Nigeria showing Ebonyi State.

Nigeria, is officially called the **Federal Republic of Nigeria**, its a federal constituted republic comprising thirty –six states and its Federal Capital Territory, Abuja. The country is located in West Africa and shares land borders with the Republic of Benin in the west, Chad and Cameroon in the east, and Niger in the north. Its coast in the south lies on the Gulf of Guinea on the Atlantic Ocean. The three largest and most influential ethnic groups in Nigeria are the Igbo, Hausa and Yoruba. In terms of religion Nigeria is roughly split half and half between Muslims and Christians with a very small minority who practice traditional religions.

The people of Nigeria have an extensive history. Archeological evidence shows that human habitation of the area dates back to at least 9000 BC. The area around the Benue and Cross River is thought to be the original homeland of the Bantu migrants who spread across most of central and south Africa in waves between the 1st millennium and the 2nd millennium.

The name *Nigeria* was taken from the Niger River running through the country. This name was coined by Flora Shaw, the future wife of Baron Lugard, a British Colonial administrator, in the late 19th century.

1.2 Condition of the political, economic and social development in Nigeria

Nigeria is a Federal Republic modeled after the United State, with executive power exercised by the president and with overtones of the Westminster model in the composition and management of the upper and lower houses of the bicameral legislature. The current president of Nigeria is Goodluck Jonathan, who succeeded to the office in 2010. The president presides as both Head of State and head of the national executive and is elected by popular vote to a maximum of two years term.

The president's power is checked by a Senate and a House of Representative, which are combined in a bicameral body called the National Assembly. The Senate is a 109-seat body with three members from each state and one from the capital region of Abuja; members are elected by popular vote to four-year terms. The House contains 360 seats and the number of seats per state is determined by population. Nigeria's three largest ethnic groups (Hausa, Igbo and Yoruba) have maintained historical preeminence in Nigerian politics. Nigeria's current political parties are pan-national and irreligious in character (though this does not preclude the continuing preeminence of the dominant ethnicities). The major political parties at present include the ruling Peoples Democratic Party which maintains 223 seats in the House and 76 in the Senate (61.9% and 69.7% respectively). Nigeria is listed among the "Next Eleven" economies, and is a member of the Commonwealth of Nations. The economy of Nigeria is one of the fastest growing in the world, with the International monetary fund projecting a growth of 9% in 2008 and 8.3% in 2009. It is the third largest economy in Africa, and is a regional power that is also the hegemony in West.

The history of Nigeria reveals that agriculture was the mainstay of the economy prior to the attendance of independence in 1960. Agricultural produce was exported to the more developed sub-regions of the world for cash. However, this trend changed after the Nigeria civil war and by 1971, there was a shift from agriculture to petroleum. The value of agricultural products fell from more than US $1.5 billion to about US $0.3 billion between 1973 and 1981 (world Bank, 1982). Today agriculture constitutes only 31.7% of the Gross Domestic Product (GDP).

There are two kinds of welfare services in Nigeria—those provided by voluntary agencies and those provided by the government. Voluntary agencies comprise those fully or partially subsidized by the government, those financed by a parent body such as a church or mosque, and those financed from subscriptions of their members. Workers are protected under the Labor

Code Act (1958) and the Workmen's Compensation Act, which provides protection for workers in case of industrial accidents. A national provident fund scheme, inaugurated in 1961, was the first broad social security measure in Nigeria. The scheme is contributory and is designed to make systematic financial provisions for workers when unemployment occurs due to old age or illness. This program covers employees of firms with five or more workers, and a special system exists for public employees.

Although sex discrimination is banned under the 1999 constitution, traditional practices still deprive women of many rights and the adoption of Shari'ah law by many northern states has more severely limited the rights and freedom of women. Women may not obtain a passport without her husband's permission. It is customary for all assets to be turned over to the parents after the death of a male, leaving the widow economically destitute. Segregation by gender occurs in some schools, health facilities, and, in some states, on public transportation. Purdah, the Islamic practice of completely segregating a woman from men other than those within her family, is practiced in some families, primarily in the north. In Sharia courts, women's testimony is given less weight than that of men. Female genital mutilation (FGM) is widespread throughout the country despite government opposition. Domestic violence is widespread, and wife beating is permissible under the penal code.

Nigeria's human rights situation has improved under different administrational governments, but service abuses remain. Arbitrary arrest and detention are still used to silence the government's critics. There are also reports of torture and extrajudicial killings. Prison conditions, furthermore, are considered to be life threatening. Overcrowding and poor sanitary conditions are compounded by limited food, water and medicine for inmates. Sentences of stoning and amputation are still used (mainly for the Muslim community). Health, health care, and general living conditions in Nigeria are poor. Life expectancy is 47 years (average male/female) and just over half the population has access to potable water and appropriate sanitation; the percentage is of children under five has gone up rather than down between 1990 and 2003 and infant mortality is 97.1 deaths per 1000 live births. HIV/AIDS rate in Nigeria is much lower compared to the other African nations such as Kenya or South Africa whose prevalence (percentage) rates are in the double digits. In 2003, the HIV prevalence rate among 20 to 29 year-olds was 5.6%. About Nigeria, like many developing countries, suffers from a polio crisis as well as periodic outbreaks of cholera, malaria, and sleeping sickness. As of 2004, there has been a vaccination drive, spearheaded by the W.H.O., to combat polio and malaria that has been met with controversy in some regions.

1.2.1 Policy and Safety

There are four distinct systems of law in Nigeria:

- English law which is derived from its colonial past with Britain;
- Common law, a development of its post colonial independence;
- Customary law which is derived from indigenous traditional norms and practice, including the dispute resolution meetings of pre-colonial Yoruba land secret societies and the Èkpè and Okónkò of Igbo land and Ibibio land;
- Sharia law, used only in the predominantly Muslim north of the country. It is an Islamic legal system which had been used long before the colonial administration in Nigeria but recently politicized and spearheaded in Zamfara in late 1999 and eleven other states followed suit. These states are Kano, Katsina, Niger, Bauchi, Borno, Kaduna, Gombe, Sokoto, Jigawa, Yobe, and Kebbi.

The country has a judicial branch, the highest court of which is the Supreme Court of Nigeria. Nigeria is home to a substantial network of organized crime, active especially in drug trafficking. Nigerian criminal groups are heavily involved in drug trafficking, shipping heroin from Asian countries to Europe and America; and cocaine from South America to Europe and South Africa. The various Nigerian Confraternities or "campus cults" are active in both organized crime and in political violence as well as providing a network of corruption within Nigeria. As confraternities have extensive connections with political and military figures, they offer excellent alumni networking opportunities. The Supreme Vikings Confraternity, for example, boasts that twelve members of a state Assembly are cult members. On lower levels of society, there are the "area boys", organized gangs mostly active in most cities who specialize in mugging and small-scale drug dealing. According to official statistics, gang violence in such big city resulted in 273 civilians and 84 policemen killed in the period of August 2000 to May 2001 (NPF 2010). This makes the safety of lives and property very low to compare to other OECD countries.

Presently, international data is not available on the crime situation on Nigeria - people incarcerated, juvenile convictions, total crime recorded, total recorded drug offences and others. However, the locally obtained information shows that acquisitive crime (including armed robberies, thefts/stealing, burglaries and house/store breaking) and the offences of violence (including murders, assault and rape) constitute an average of 73.05% of all crimes reported to the police between 1994 and 1997. The acquisitive crimes with an average of 39.75% were higher than the offences of violence with an average of 33.29% during the same period.

In view of the prevalent political and socio-economic situation, a bourgeoning unemployed, underemployed and frustrated youthful population, the relatively porous borders and corruption of the security network, the country is ripe and burdened with drug abuse, drug trafficking and related crimes.

1.2.2 Population and Poverty

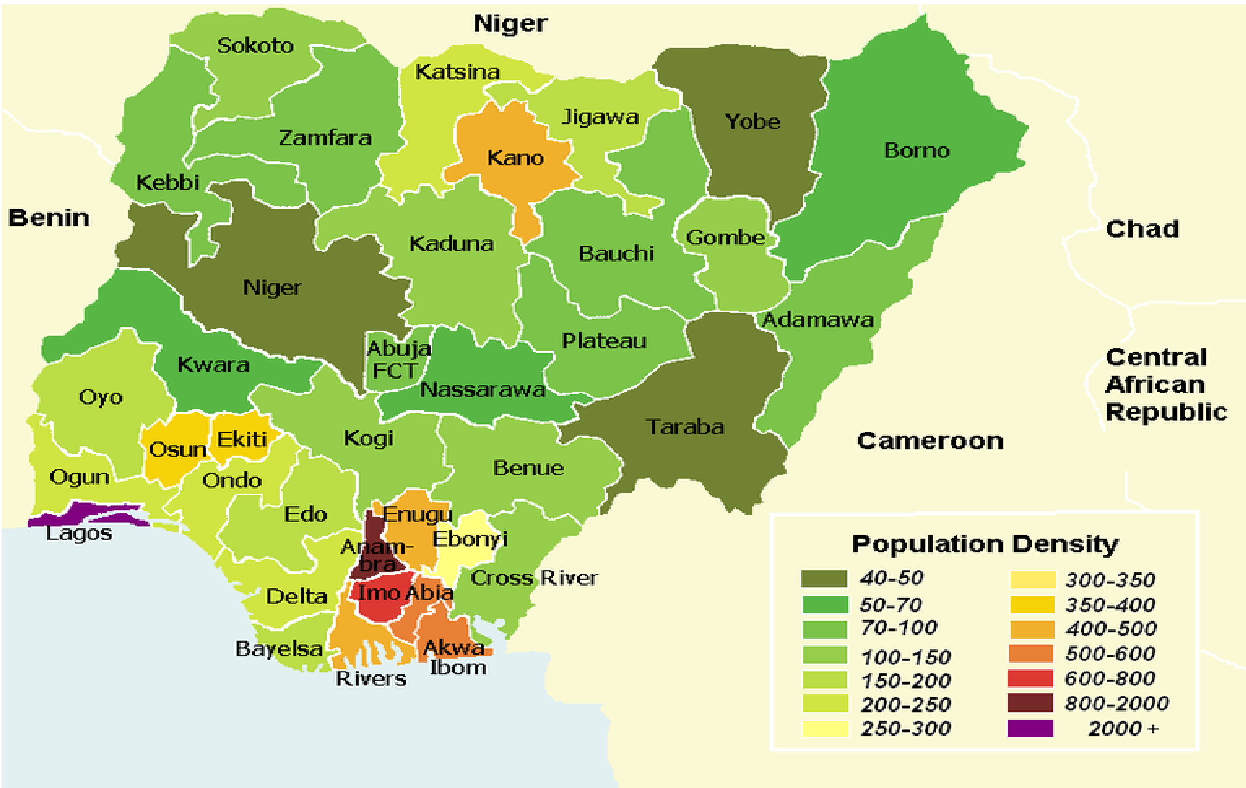


Figure 1.2: *Population density of Nigeria (NPC,2006).*

Nigeria is the most populous country in Africa, the eighth most populous country in the world, and the most populous country in the world in which the majority of the population is blacks (UN data 2009). The United Nations estimates that the population in 2009 was at 154,729,000, distributed as 51.7% rural and 48.3% urban, and with a population density of 167.5 people per square kilometer. In a 174-country world ranking, Nigeria is placed 151 in Human Development Index (HDI), 62 in the Human Poverty Index (HPI) among 85 countries, and 124 in Gender-related Development Index (GDI) among 143 countries. These indicators are indeed poor and overall, the country is rated among the low human development countries (UNDP, 2000).

Nigeria is divided into thirty-six states and one Federal Capital Territory, which are further sub-divided into 774 Local Government Areas (LGAs) with over ten thousand rural poor communities (UNDP,2001). The plethora of states, of which there were only three at independence, reflect the country's tumultuous history and the difficulties of managing such a heterogeneous national entity at all levels of government.

However, the composition of the population is in the main youthful, with over 58% as young people below 18 years, and an increasing dependency ratio estimated at 87.7%. A large proportion of this population favors and is living in the rapidly expanding urban area, presently estimated at over 42.2% and will likely hit 55.4% mark by the year 2015 (UNDP, 2000).

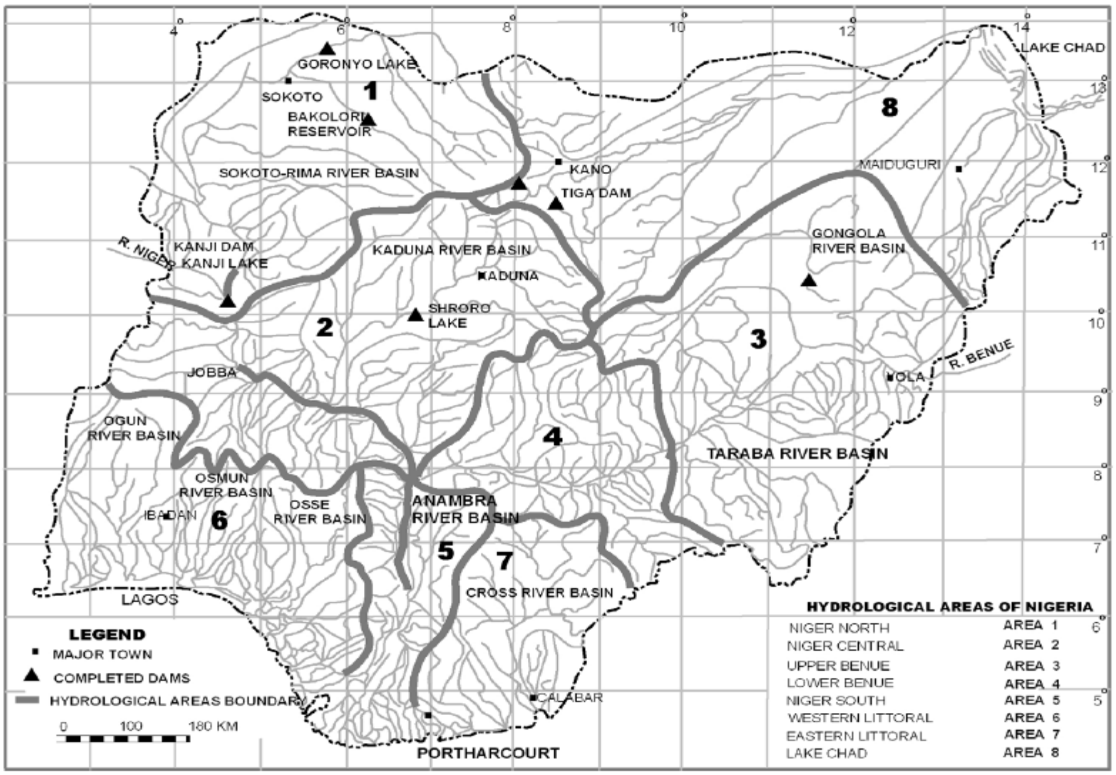
The population dynamics display profound inequities and disproportions when analyzed with the development indicators, such as: 21 doctors per 100,000 people, infant mortality rate of 112 per 1000 live births, maternal mortality of over 980 per 100,000 live births, life expectancy at birth projected at 50.1 years, People Living With HIV/AIDS (PLWA) is estimated at 5.4% of the population (mainly adults aged between 15 and 49 years), while total fertility rate is now 5.2, and contraceptive prevalence remains 6%. In the area of education, there is dearth of vital information, however, adult literacy rate is 61.1% while youth illiteracy rate (15-24 year) is estimated at least 15.3%.

There is high unemployment and underemployment, especially among the youth with spiraling poverty level in the country. At the moment, the national poverty line is estimated at 43% with over 70.2% of the people earning less than US 1$ a day (United Nations Office on Drugs and Crime, 2010). And many rural communities suffering due to scarcity of water that crippled there economic sustenance.

In Nigeria, water scarcities in the rural communities has grown over the years in relations to the dramatic changes in the demographic, socio-economic and ecological characteristics and the altitudinal behavior of the governments to the pitiable situation in these areas. The gap between the south and the north in Nigeria is increasingly becoming yawning-the north being “water scarce” while the south is presumed “water abundant”. Within the south, there are internal variations and variability with rising uncertainties in south-south and southeastern states.

In the world today, 160 million people are infected with schistosomiasis causing tens of thousands of deaths yearly; 500 million people are at risk of trachoma from which 146 million are threatened by blindness and 6 million are visually impaired. intestinal helminths (ascariasis, trichuriasis and hookworm infection) are plaguing the developing world due to inadequate drinking water, sanitation and hygiene with 133 million suffering from high intensity intestinal helminths infections; there are around 1.5 million cases of clinical hepatitis A every year reported by WHO and UNICEF in 2008.

Water supply in major cities in Nigeria appears to follow the geological structure of the region (refer to the hydrogeological Map of Nigeria below). Our study area lies within Area 5.



Hydrogeological Map of Nigeria: Sources (FAO, 2008).

In this study, I attempt to consider the present situation of water scarcity in poor rural areas in southeastern Nigeria, using **Umuezeokoha Community**, Ezza North local government area of Ebonyi State Nigeria as a case study. The effects of this on the population have been evaluated and some technical possibilities to ensure safe water supply have been identified. The urgent need for water supply infrastructures for this community has been the main reason for carrying out this work.

In particular geology and hydrogeology of the study area has been examined to ascertain existing underground water resources, general variability and access conditions, as well as current local water-resource management practices.

2. DESCRIPTION OF THE SITUATION IN UMUEZEOKOHA COMMUNITY IN EBONYI STATE OF NIGERIA.

There is need for the description of the study area to enable better understanding of the situation for intervention and this is carried-out in the following ways:

2.1 General Description of the Study Area

Umezeokoha Community is located in North Western (from Abakiliki) part of Ezza North Local Government Area of Ebonyi State, South Eastern of Federal Republic of Nigeria (Fig. 2.1). Its made up of four rural poor villages of Okaleru (2400 population), Ugbogha (2425), Omega (1385), and Evara (2540), with a total population of **8750** estimated at year *(*2006 National population census*)* and a total surface area of about **87.5 km^{2}** .

At an **exponential growth rate of 7% per year**, as it has been registered in the past 10 years (Ebonyi State census board result, 2008), it is expected that the population will be **281,481** by the **next five decade** (**50 years**) and **17,212.57 in the next one decade (10 years).** The number of children and females outnumber other categories.

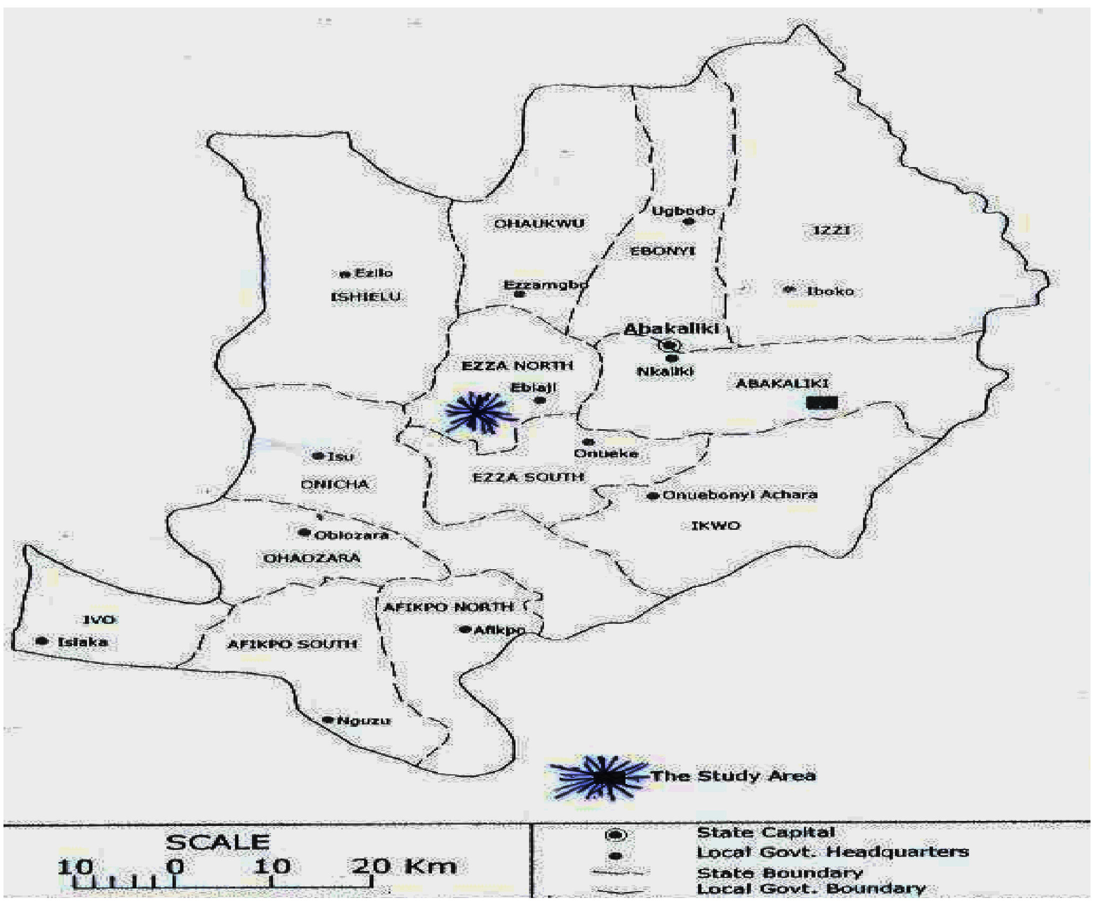


Figure 2.1: Map of the study area showing Umuezeokoha Community in Ezza North.

The major occupation is non-mechanized farming, though this hardly ensures mere subsistence as about 90% of the population survives with at an astonishing revenue level below one (1) dollar a day. No other activities (even small crafts) are present in this community. No power supply (electricity) is available. Basic, essential public services are not present such as schools, hospitals or clinics. A drinking water supply service is not available, as well as a waste collection and disposal system. All is left to the individual familial group.

At present the population of the Umuezeokoha Community in Ezza North Local Government Area of Ebonyi State, Nigeria has no access to clean, safe and permanently available freshwater sources. Rainwater collection is performed in an open collection area situated in the centre of the village, where rainwater accumulates during the rainy season. The maximum storage capacity of this collection tank is approximately **200m^3** (it's likely the tank is a cone type of).

This volume is sufficient for no more than four days after the end of rainy events and poses serious risks to human health as evidenced before.
During the dry season water is supplied to the community by the government by truck which is not consistent on daily basics. But individual families has to source for water on there own by hauling on feet or with a bicycle or hand wheelbarrow irrespective of the government help which is not consistent to enable them meet up to there water demand.

Though not regularly, the local government supplies about 23,000 liters per day to this community, which is equivalent to 2.63 L per capita and day and is well below the water supply quantity recommended as the minimum vital by the World Health Organisation (50 Liters per capita and day; WHO, 2003: "Domestic Water Quantity, Service Level and Health" [1]) and even below what is recommended as minimum vital under temporary, emergency periods (20 Liter per capita and day).

At present, the people of this community have to walk about 2,5 km (or by bicycle, as the road is very poor and inaccessible) to another community to have access to water during the dry season. As an alternative, women and children travel a very long distance with their clay pots and plastic containers on their heads, wasting 8 to 9 hours a day to go in search of water, and, many times they come back without having found any. In the neighbouring community, drinking water is available only through hand-pumps, and the most common water supply is a private well, owned by a familial group. People come to this community and buy water to be resold back at Umezeokoha Community.

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[1] www.who.int/water_sanitation_health/diseases/WSH03.02.pdf

Access to drinking water means that the source is less than 1 kilometer away from its place of use and that it is possible to reliably obtain at least 20 litres per member of a household per day. Safe drinking water is water with microbial, chemical and physical characteristics that meet WHO guidelines or national standards on drinking water quality;

Access to safe drinking water is the proportion of people using improved drinking water sources: household connection; public standpipe; borehole; protected dug well; protected spring; rainwater.

The pictures below shows the women and children in search of water:

Poverty, insufficient water supply, inappropriate and unhygienic water storage are the major causes for lack microbiological contaminations, which leads to persistent outbreak of cholera and high number of Guinea worm disease[2] cases. In fact, during the raining season, villagers harvest rain and surface water for drinking and domestic use and store it in a pond where the water becomes contaminated.

There is no doubt that this situation has contributed to the backdrop in both economic and social development of this Community. The lack of safe water in Umuezeokoha Community have created both health, economic and social effects to the people as highlighted below. Hence, the

[2] Also named dracunculiasis, it is caused by *Dracunculus medinensis*, a threadlike parasitic worm that grows and matures in people. Worms grow up to 3 feet long and are as wide as a paper clip wire. People get infected when they drink standing water containing *Copepods* like *Cyclops* (tiny water fleas) that are infected with the even tinier larvae of the Guinea worm.

possibility of providing a safe water supply for this Community may be a first necessary step for its further social and economical development.

Health Effects

a) compromised hygiene and sanitation due to poor access to water lead to increase exposure to diseases; available statistics from a neighboring community health center show that poor water supply and sanitation increase related diseases such as Typhoid fever, diarrhea, cholera, Guinea worm, malaria, skin rushes among rural dwellers in this community;

b) Women and children **suffer of pains, persistent weakness, high risk of contracting HIV/AIDS and other STDs due to sexual abuse (rape, etc.);**

c) **Pain induced labor are often experienced by women that are pregnant (which leads most times to pre-mature delivery** as a result of their long distance search for water and heavy load on their head).

d) Increase in death due to delayed access to medical attention as a result of the far distance to hospital.

Economic Effects

a) Loss of Man-Hour in search of safe water.
b) high expenditure for medicaments to relieve poor-sanitation related diseases;
c) high cost of processing agricultural products into products for resale as a result of high cost of water from private water vendors;
d) Low agricultural and zoo technical productivity as a result of poor access to water supply.

Social Effects

a) Poor attendance at school by students, especially girls, as they first search for water for domestic use before or instead of going to school;
b) early drop out of school by girls due to persistent absence from classes;
c) high rate of rural – urban migration among the middle aged class;
d) high rate of conflict within existing earthen pond especially during the dry season;
e) diffuse criminality; also, women and children are especially exposed to ritual killers and rapes;
f) teenagers' unwanted pregnancies.

A recent research conducted by students of Medical college University of Nigeria Nsukka *(college journal vol. 3 2007)* shows that **about 75%** of people in this community are illiterate (peoples right are not protected and civil rights are denied), life expectancy is 53 years for men;

47 years for women. Gross Enrollment **58%** for men; **42%** for women, Adult literacy **rate 68% for men**; **32% for women**. The Human Development Index (HDI) in this area is very low if compared to other communities in the state.

The suffering the people of this area undergo, particularly women, and children (this has really made them to be highly vulnerable to series of abuses) as a result of insufficient water supply that has triggered off acute poverty, inappropriate and unhygienic water storage.

Most vulnerable, most affected population of the abuses are women, children, elderly and sick population:

2.1.1 Geology and the Hydrogeology of the area

Geologically, the study area is within the Abakaliki Basin of southeastern Nigeria. The Abakaliki Basin (Aptian to Santonian) is a subsidiary depress in the Benue trough of Nigeria**. It is flanked on the southwest by the Afikpo synclinorum (Late camparian-Maastrichian).** The study area lies within the Albian Asu River group and consist mainly of rather poorly bedded shales, occasionally sandy, splintery metamorphosed mudstones. Lens of sandstone and sandy limestone are higly jointed and fractured. The Albian shale formation in the study area are intruded by younger intrusive. The intrusive bodies in combination with numerous faults and joint systems have created fractures and secondary porosity in the study area. Topology of the study area is moderately flat (Ground surface). The study area is in the drainage area of Ebonyi River that flows on the southern side of the study area. The approximate distribution of the Abakiliki shale occurs roughly over a radius of twenty-five kilometers. Paleontologically, its mainly characterized by species of Mortoniceras and Elobiceras (Reyment, 1963). The sediments are folded and fractured, particularly in the country south of Abakiliki; the fold axes stretch **NE-SW**. The formation is associated with lead zinc mineralization. The shales are deeply wealthered. Radioleria occur and echinoids may be locally abundant. Pelecypods and gastropods are relately rare (Reyment, 1963).

In addition, the genetic environment of the study area is discussed within the overall stratigraphic and tectonic setting of the Lower Benue Trough. The Benue Trough is an 800 km long and 100-l50km wide, NE-trending, elongated, intra continental, rift-like basin which formed during the Early Cretaceous in relationship with the opening of the South Atlantic (Fig. 2.4). Sedimentation, characterised by periods of transgression and regression, started in the pre-Albian or mid-Albian (Burke ***et al.,*** 1970,1973) with the Asu River group, followed by later Cretaceous sediments, up to the Maastrichtian. Tertiary sediments are limited to the Niger delta and the Chad basin in the **SW and NE**, respectively (Table 1).The sedimentary fill in the basin (more than 5OO0m) has been affected by two sets of tectonism, in pre-Turonian and Santonian times (Uma and Lohnert,1992**). In the Lower Benue, the latter involved compressional movement along an established NE SW trend and resulted in the folding and uplift of the Abakaliki area (Abakaliki-Benue folded belt), with NW-SE and N-S fractures.** The folding episode in the Lower Benue was not only characterised by contemporaneous **subsidence** of the Anambra platform and displacement of the depositional axis westward, but is also thought to have been marked by a number of minor intermediate intrusions as well as associated lead-zinc mineralisation. The folded and fractured Asu River group rocks (shale in the lower Benue, and limestone and sand stone equivalents in the middle and upper Benue respectively) are hosts for the associated lead-zinc and fluorite-barite mineralisation (Akande ***et al.,***1992).

Within the Lower Benue, the Umuaezekoha Community is located between latitude **6°25’55.47”** N and longitude **7°59’33.349”.** The area lies within the **western flank of Abakiliki Anticlinorium** (Fig. 2.3) with exposed Asu River Group (Fig. 2.2) lithologies (Abakiliki shales, pyroclastics with interbeded sandstone/siltstone). Asu River Group is overlay by the Eze-Aku formation having a thickness that varies from 100 – 300m (Mbipom ***et al.,*** 1990). Topographically, the area ranges from 1OOm in the lowland to about 600m in the hills (Ekwere and Ukpong, 1941), with annual rainfall of about 2000mm during the wet season, and less than 80mm during the dry period (November-March).

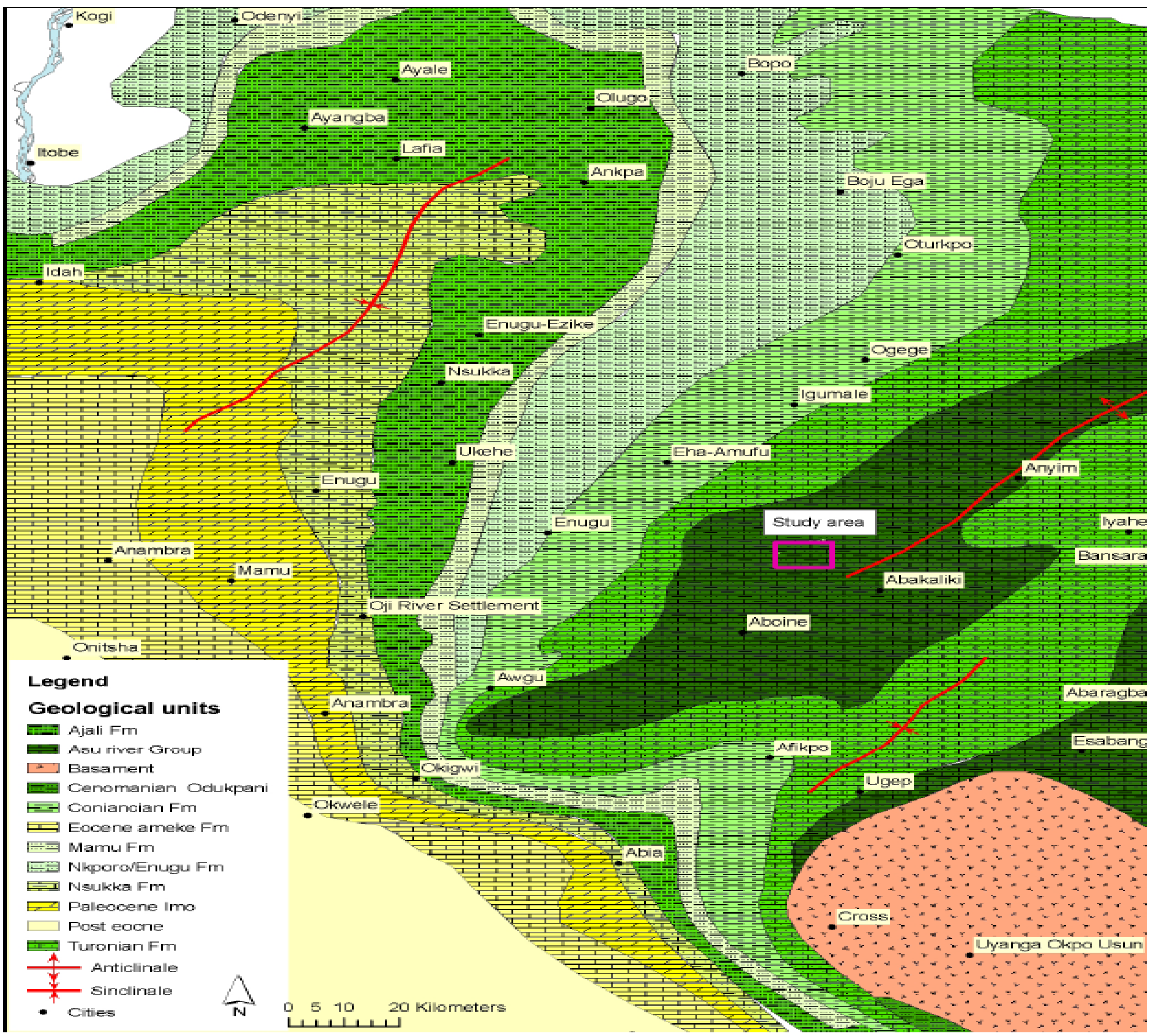


Figure 2.2: Geological Map

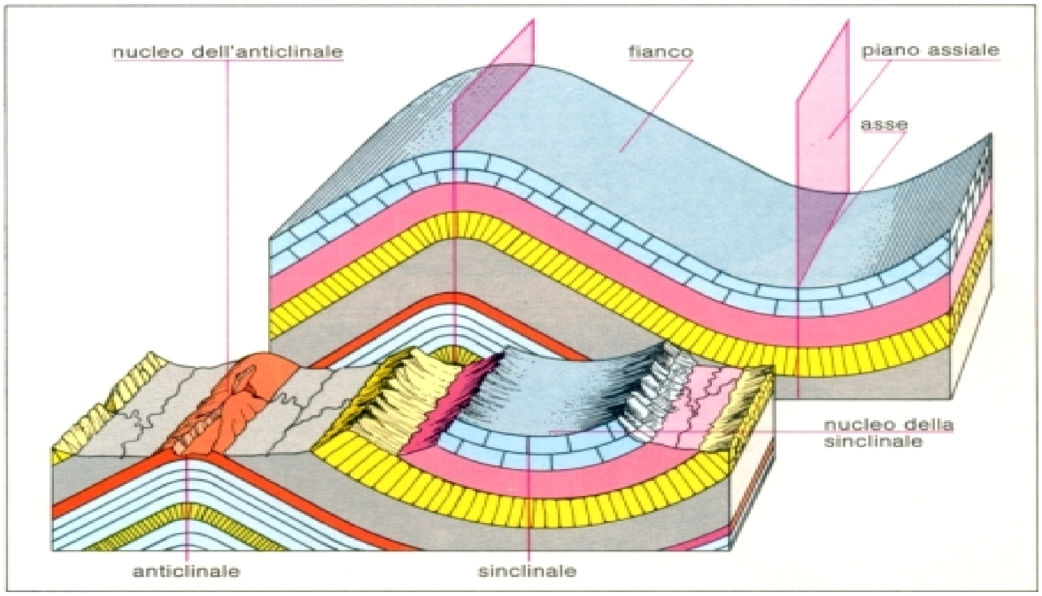
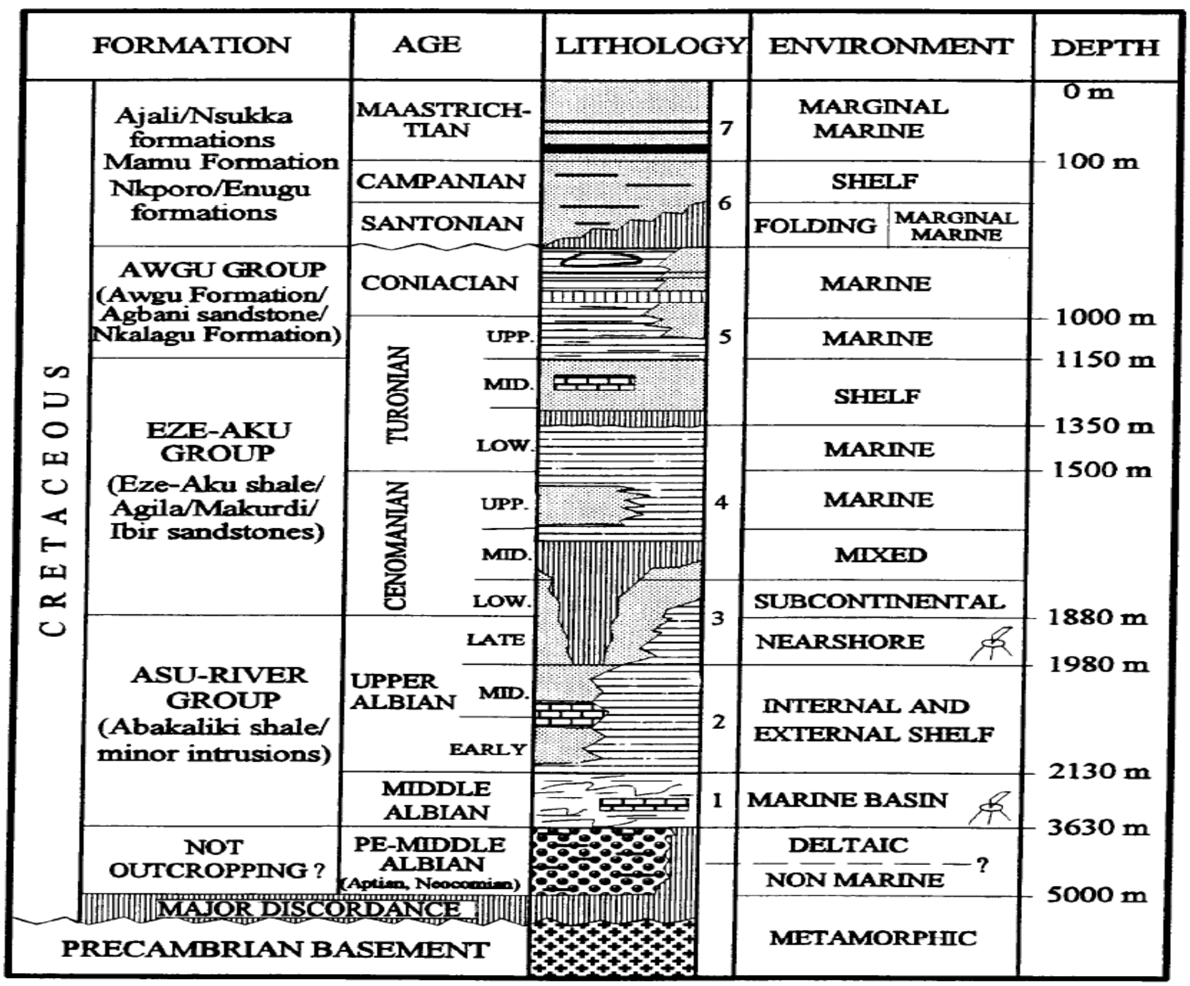


Figure 2.3: Anticlinorium representation.

Stratigraphical setting

Table 1. Generalised stratigraphical setting of the Lower Benue Trough (modified after Ojoh, 1990;Petters, 1991 and Murat, 1970)



	FORMATION	AGE		LITHOLOGY	ENVIRONMENT	DEPTH
CRETACEOUS	Ajali/Nsukka formations Mamu Formation Nkporo/Enugu formations	MAASTRICHTIAN		7	MARGINAL MARINE	0 m
		CAMPANIAN		6	SHELF	100 m
		SANTONIAN			FOLDING / MARGINAL MARINE	
	AWGU GROUP (Awgu Formation/ Agbani sandstone/ Nkalagu Formation)	CONIACIAN			MARINE	
		TURONIAN	UPP.	5	MARINE	1000 m
	EZE-AKU GROUP (Eze-Aku shale/ Agila/Makurdi/ Ibir sandstones)		MID.		SHELF	1150 m
			LOW.		MARINE	1350 m
		CENOMANIAN	UPP.	4	MARINE	1500 m
			MID.		MIXED	
			LOW.		SUBCONTINENTAL	
	ASU-RIVER GROUP (Abakaliki shale/ minor intrusions)	UPPER ALBIAN	LATE	3	NEARSHORE	1880 m
			MID.	2	INTERNAL AND EXTERNAL SHELF	1980 m
			EARLY			
		MIDDLE ALBIAN		1	MARINE BASIN	2130 m
	NOT OUTCROPPING ?	PE-MIDDLE ALBIAN (Aptian, Neocomian)			DELTAIC ? NON MARINE	3630 m
	MAJOR DISCORDANCE					
	PRECAMBRIAN BASEMENT				METAMORPHIC	5000 m

The generalised stratigraphic framework of the Lower Benue and its corresponding inferred depositional palaeoenvironments are shown in Table 1 above, while the tectonic setting and stratigraphic history of the Abakaliki area of the Lower Benue are presented in **Figs. 2.4a, b and c** below (Oggia, 2001).

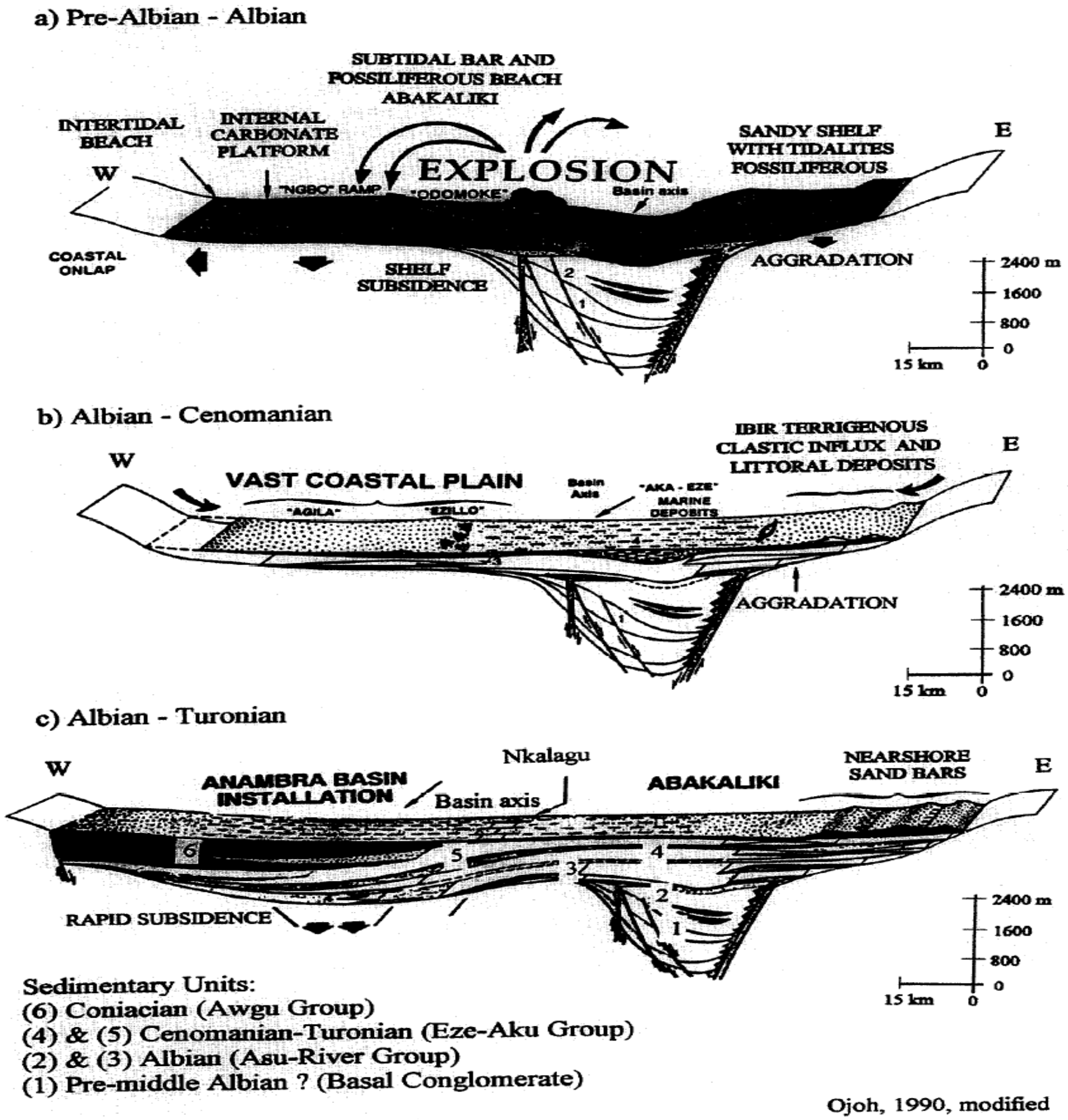


Figure 2.4: Tectonic setting and stratigraphic history of the Abakaliki area.

Before the Santonian tectonic episode, the Abakaliki region was a major depocentre in the Lower Benue Trough, with accumulation of approximately 3600m of marine sediments, from mid-Albian to the Coniacian (Ojoh, 1990). The Albian transgression was characterized by marine conditions, with a shelf environment of deposition for the Asu River Group (mainly shales with minor sandstone facies), and later with the associated volcanic intrusions and pyroclastics (Fig. 2.4a).The Cenomanian was characterised by aregressive continental to transitional marine environment, with a high elastic sediment influx (Keana/Makurdi sandstone), which created a wide coastal plain predominantly to the west (Anambra platform) of the basin

(Ojoh, 1990). This may have led some earlier workers (Reyment, 1965,Nwachukwu, 1972) to suggest the absence of Cenomanian deposits in the main Abakaliki basin itself (Fig. 2.4b). The subsequent Upper Cenomanian- Middle Turonian transgressive phase was characterised by the Benue-trans-Sahara seaway (Tethian) with the deposition of fossiliferous black shales (Eze-Aku shale group). During this period the Abakaliki area (basin) was said to have evolved into a (stable) platform with subsidence localized to the western shelf (Fig. 2.4).The localised subsidence and gradual migration of the basin's axis to the west, coupled with continuous rise in sea level into the Coniacian, led to the creation of the Anambra basin (Fig 2.4c) with deposition of thick Upper Turonian-Coniacian sedimentary units (Awgu formation). The Santonian folding and uplifting of the Abakaliki sub-basin displaced the axis of sedimentation and limited the deposition of Santonian to Maastrichtian sediments to the Anambra basin (west flank) and the resulting Afikpo basin (syncline) on the eastern flank; with the Abakaliki anticlinorium between the two as a structural high. In addition, an erosive phase during the Campanian (after folding) is believed to have been responsible for reworking of the earlier sediments in the Abakaliki subbasin. The evolution and stratigraphic setting of the Benue Trough are discussed in Reyment,1965; Offodile, 1976a; Olade, 1975;Nwachukwu, 1972; Tolade, 1975; Wright, 1976;Adighije, 1979; Ofoegbu, 1984 and Benkhelil,1982, 1986 among others.

Hydrogeologically (Fig 2.5 below). As no rivers or permanent water streams are present in the area surface, it is essential to investigate the presence of underground water in the area.

Groundwater development is not extensive in this area and literature information are quite absent. Weathered rocks, alluvium and fractured zones form the aquifers. However, pockets of weathered and fractured rocks may form isolated groundwater reservoirs. The thickness and length of the weathered and fractured zone control groundwater storage. Actually, the presence of fractures plays a fundamental role in the hydrogeological characterization of rock masses; it determines an increase in hydraulic conductivity of different magnitude along the main direction of the fracture.

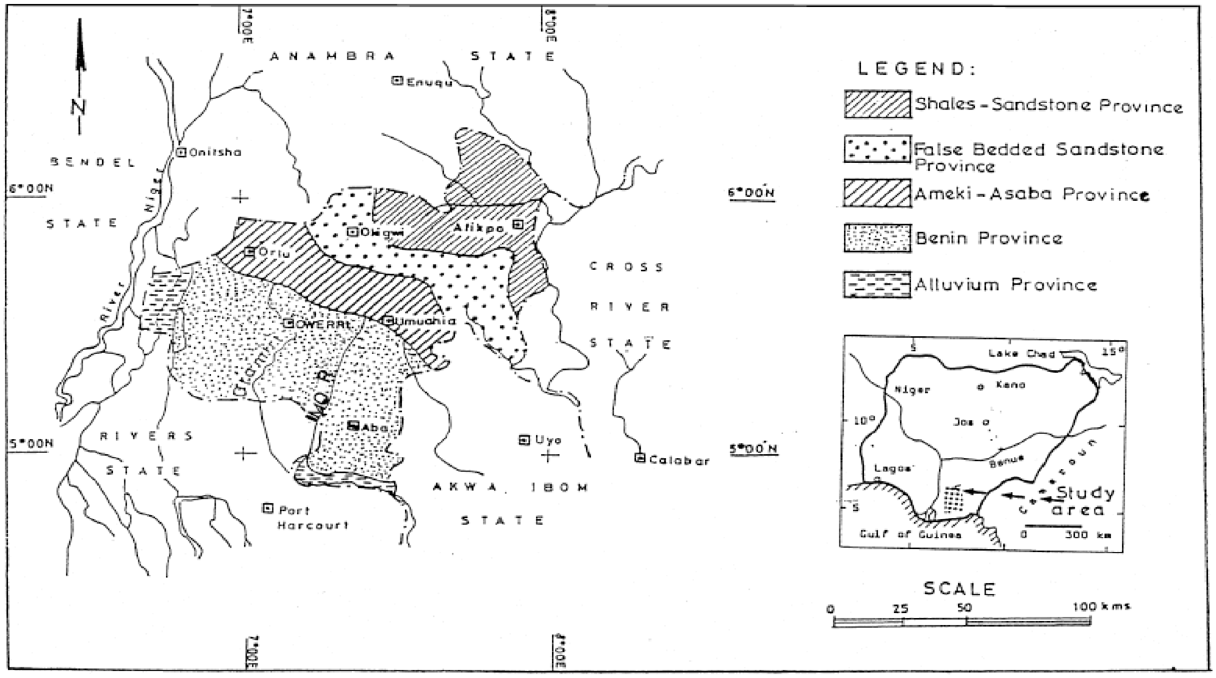


Figure 2.5: Hydrogeological map of study State. (Kas Ibe, 1999)

Existing wells around the study area:

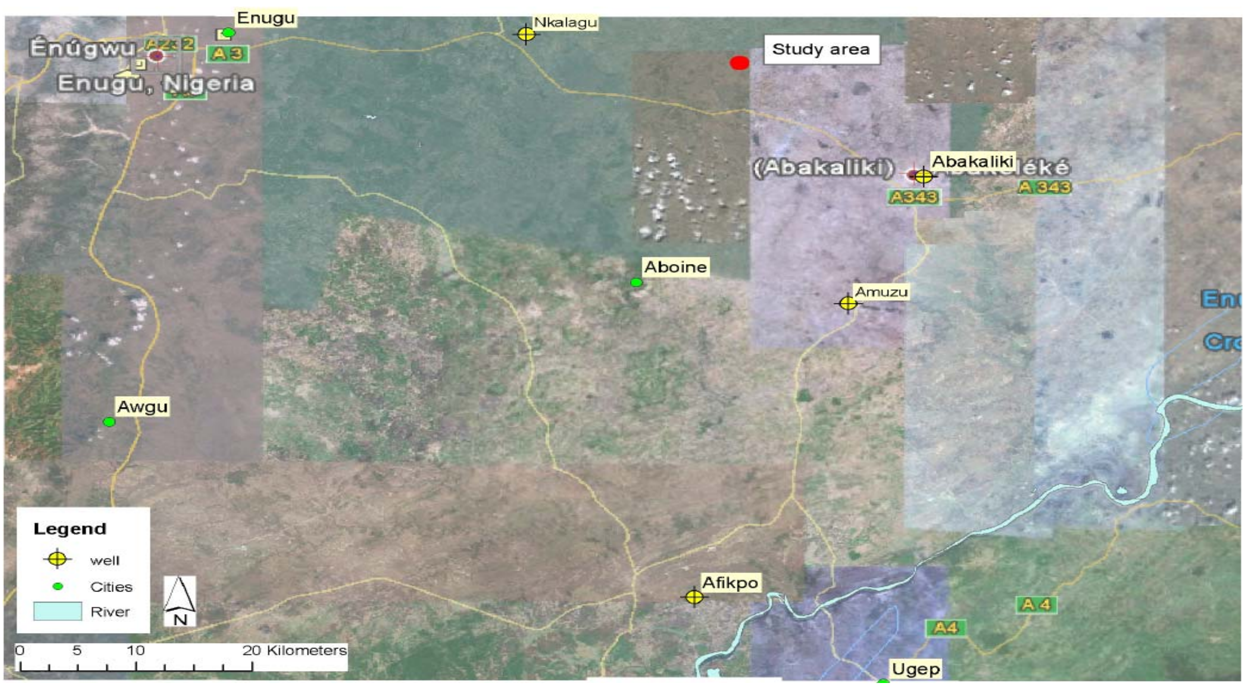


Figure 2.6: Operational wells around the study area.

1. **Abakiliki:** The community is located at the North Western part of Abakiliki. From Abakiliki to Umuezeokoha Community is about 18km (Fig. 2.6). Abakiliki currently have more than 50 operational wells, depth of drilled well is 68m, dimension of 9inches, discharge is 2L/s and water depth of 6m. **Nkalagu:** From Nkalagu to the community is about 35km (Fig. 2.6) and

currently with more than 20 operational wells, depth of 64m, dimension 10inches, discharge of 2L/s, and water depth of 6m.

2. **Amuzu:** Amuzu is located at the Southern part of Abakiliki (Fig. 2.6). From Amuzu to the community is about 40km and currently with 15 operational wells, depth of 65m, dimension 9inches, discharge of 2L/s, and water depth of 6m.
3. **Isiagu (Aboine):** Isiagu is located at the south western (IVO Local Government Area) part of Abakiliki (Fig. 2.6). From Isiagu to the community is about 25km and currently with more than 12 operational wells, depth of 64m, dimension 10inches, discharge of 2L/s, and water depth of 6m.
4. **Afikpo:** Afikpo is located at the southern part of Abakiliki (Fig. 2.6). From Afikpo to the community is about 47km and currently with more than 22 operational wells, depth of 61m, dimension 11inches, discharge of 3L/s, and water depth of 7m.

2.1.2 The Geomorphology And Physiography of the Study area

The geomorphology of the area under study includes:

Relief: The study area is within the Cross-River plain with an average elevation ranges from 46 to 72m above mean sea level (Fig. 2.7). The highest elevation is about 90m. The present geomorphic cycle has attained a sub-mature stage with advanced truncation of structure. The two Altimetry profile graph (Fig. 2.8 & 2.9) of the study area shows that it's relatively a low area (flat area).

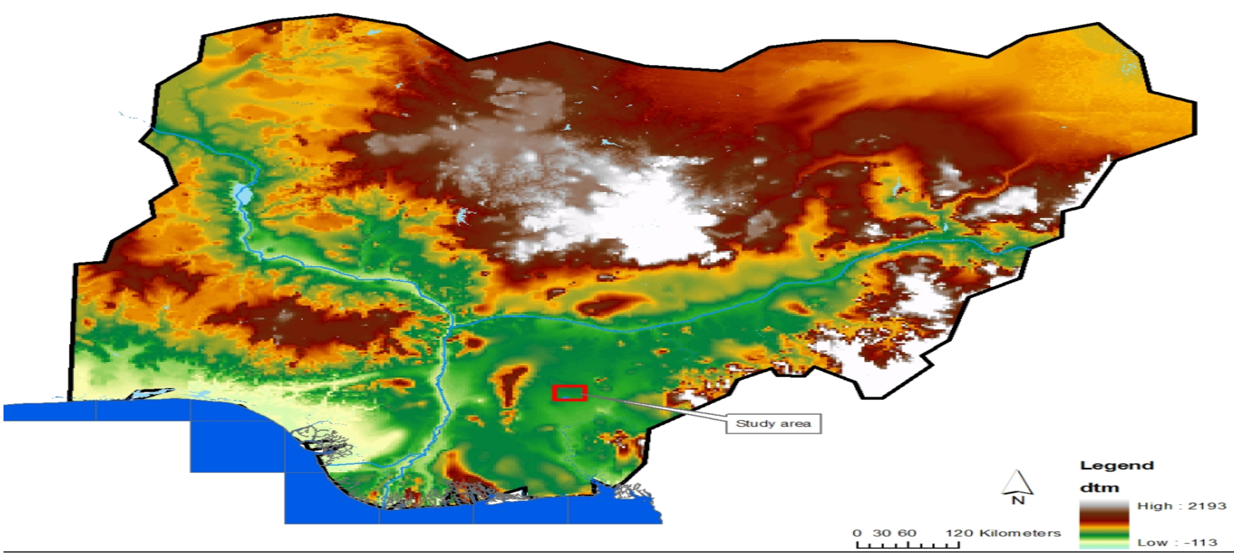


Figure 2.7: The Elevation of the Nigeria boundary.

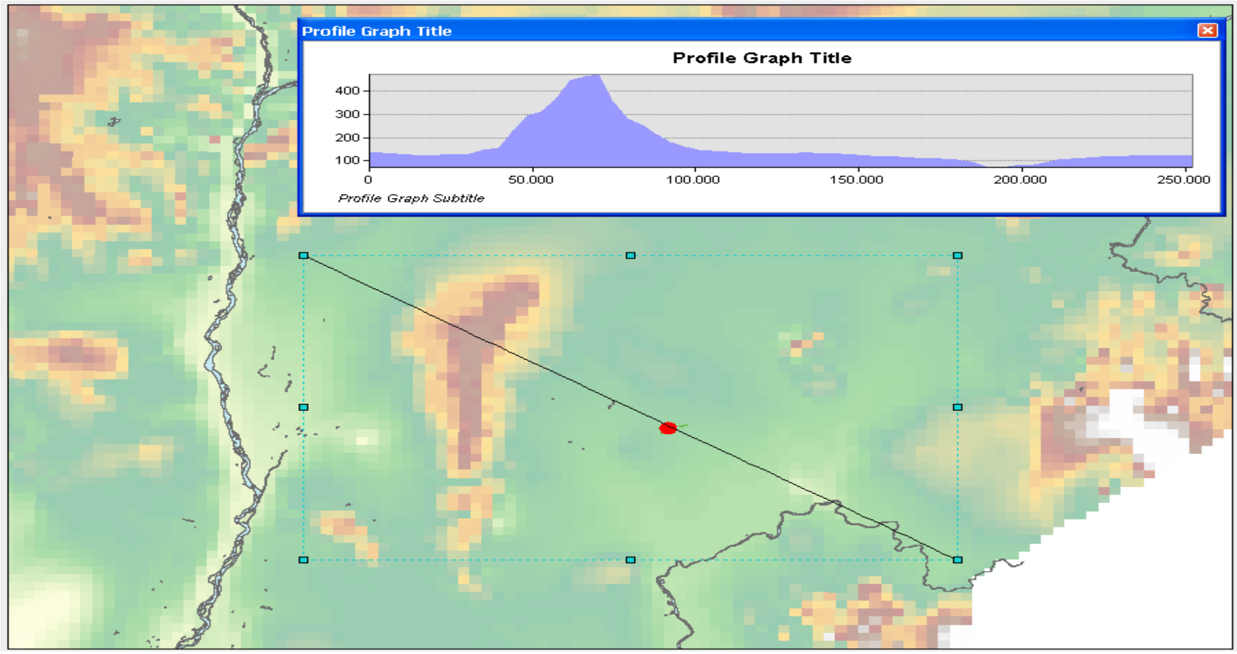


Figure 2.8: Altimetry of study area.

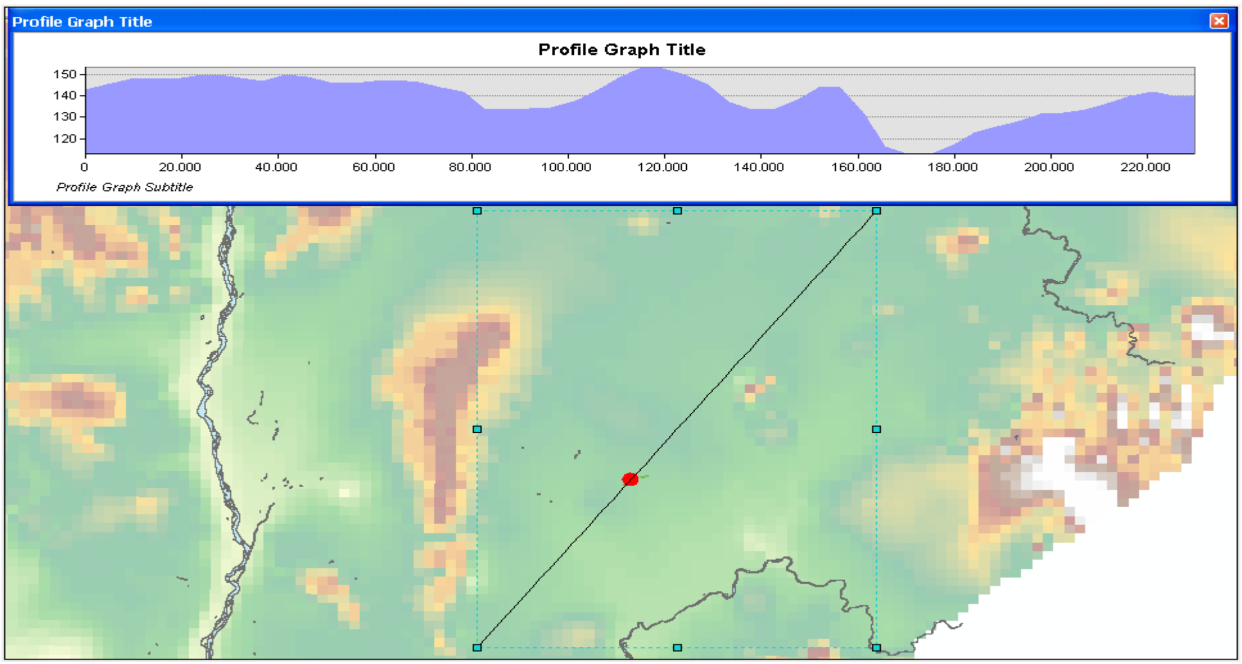


Figure 2.9: Altimetry of the study area.

Drainage: The presence of humid area, slow flowing Ephemeral River with shallow deeply incised channel in the area forms a dendritic drainage pattern (Fig 2.10). The discharge rate increases in the raining season, which makes their channels to ponds during the dry season. The drainage pattern in the area is of lithologic control as they are seen to be meandering(Fig 2.10). **This drainage system was initiated on the flanks of Okigwe-Abakiliki Anticlinorum.**

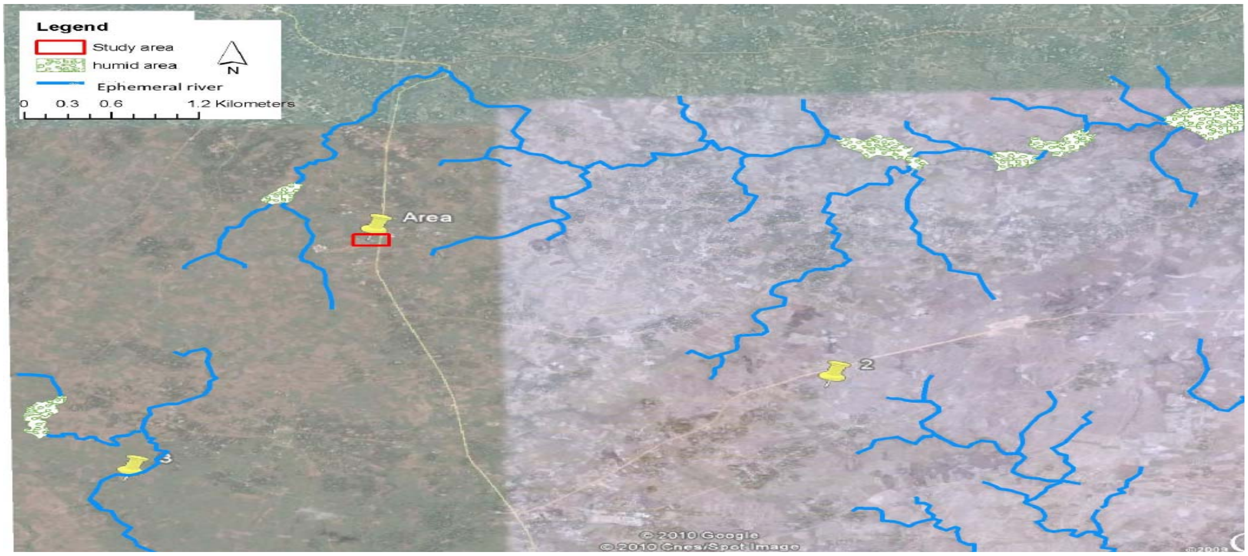


Figure 2.10: Morphology of the study area showing the humid area and the.

Soil: The soil is usually water logged during the wet season due to the interplay of lithology and climate. The soil is pale-colored and lateritic in almost all the area. The soil and the rocks are highly weathered (chemical weathering).

Erosion is not severe since the area is almost low-lying except along the river banks were slumping occur. The swampy nature of some part of the area makes it suitable for cultivation of food crops. The physography of the area is made of undulating plain rising gradually to Juju hill.

Vegetation: The area lies in the rainforest/savanna vegetation (Igbozunike, 1975). In the rainy season, the area is characterized by full grasses, marshy and swampy terrain. Therefore, geological mapping can only be done effectively during the dry season between the month of December and March.

Climate: The area falls within the rainforest belt of Eastern Nigeria and has a dry month (December to March) (Inyang, 1975). The driest month has less than 2.9cm rainfall annually (Ofomate, 1975). The wet season are within April to Novernber and punctuated by a little dry period in August called "August break" after which comes a long period of dry season. This corresponds to the period of Northeasterly dry winds (Iyang, 1975). The area has an average temperature of 28°C (Olayinka and Belogun, 1976). The dry season, from November through April, is a hot period of little or no rainfall. Table 1 displays the total monthly rainfall for

Abakiliki years (October 1 – September 30) 1978/1979 through 1985/1986. The average annual rainfall is about 2,250mm, and the average annual temperature is about 27°C.

The prevailing wind is from the southwest in the wet season and from the northwest in the dry season. The average annual wind speed is about 8.7km/hr. At 09:00h, the most humid time of the day, the mean humidity is 84.54% in the wet season and 77.50% in the dry season. The average relative humidity in the wet season is 79.05%; in the dry season it is 67.40%.

Table 2 below: Total monthly rainfall, Abakiliki Meteorological Station, Nigeria, water years 1979-1986. Not recorded (NR).

Month	1979	1980	1981	1982	1983	1984	1985	1986
April	965.8	167.2	221.7	180.5	102.5	54.3	204.8	149.5
May	309.4	213.3	161.3	342.4	326.5	254.3	218.5	359.3
June	200.5	430.6	497.1	345.1	303.6	293.8	372.8	279.2
July	227.5	297.7	309.9	341.2	429.9	274.8	285.0	416.2
Aug.	355.9	366.3	415.3	325.7	258.7	157.9	338.1	433.5
Sept.	366.9	319.7	251.0	122.2	313.3	23.3	291.5	125.2
Oct.	432.5	534.6	241.6	543.5	268.5	573.5	297.1	250.7
Nov.	53.5	107.6	167.8	31.1	97.1	32.1	29.8	64.4
Dec.	0.1	0.0	NR	0.0	0.0	38.8	5.1	3.6
Jan.	26.0	NR	84.9	59.2	0.0	0.0	51.6	105.3
Feb.	89.7	9.9	17.0	110.6	1.0	3.5	8.8	15.5
March	143.1	87.6	104.4	134.4	50.0	109.5	259.9	147.2
Total	2470.9	2539.5	2472.0	2535.9	2151.9	1815.8	2363.0	2344.6

2.1.3 Fracture Orientation and investigation methods:

Shell D' Arcy under took regional Geological/geophysical surveys of the Eastern Nigeria in search of oil in 1998- 1941 and 1946, (Simpson, 1954). According to their report on earth movements, which occurred during the cretaceous period resulted in a series of folds in the sequence of Asu- River Group, Eze-Aku formation and Awgu shale. Shell Arcy estimated the thickness of the Asu-River Group to be 1702m (Sampson, 1954).

The Albian Asu-River Group is dominantly shale with a few sandstone and limestone beds. The unit occupies the central part of the Abakaliki anticlinorium. (Reyment, 1965).

The only cenomania deposit, known as the Odukpani Formation (Reyment 1965), occurs on the Calabar Flank. The absence of cenomanian strata in the rest of the basin and the discordance in dip between the Albian Asu-River Group and the overlying Turomian Eze-Aku formation, reported at a number of localities in Afikpo basin, might be indicative of a significant time gap with tectonic implications (Nwachukwu,1972). The basin morphology and other tectonic elements as prevailed during the first sedimentary cycle (Albian to santanian).The majority of azimuthal apparent resistivity measurements are taken to investigate subvertical fracturing within the rock mass. When plotted in polar form, if the apparent-resistivity variation conforms to an ellipse then it is taken to represent anisotropic homogeneity. This is usually interpreted as indicating fracture set or the direction of greatest fracture connectivity (Tylor; and Fleming, 1988) and measures of the anisotropy that can be used to estimate fracture porosity (Tayor and Fleming 988). Leonard Mayer (1984) obtained correlations between the orientation of the major area of the apparent resistivity ellipses and the measured direction of joint set over calcitic dolomite and limestone. Skjenna and Jorgensen (1994) reported similar correlations over gneiss and granite while Cohn and Rudman (1995) used the method define local fracture patterns in Karst.

In order to be able to remove or rather reduce the number of erroneous interpretations, there is a requirement that is possible to separate homogeneous from none homogenous anisotropy. Bolshako et al. (1997) reported their successful separation by a spectral analysis of the azimuthal resistivity diagram.

The theoretical development of the response of a homogeneous but anisotropic rock mass to a collinear apparent resistivity measurement has been covered by Leonard-Mayer (1984) and Taylor and Fleming (1988). Lane, Haeni and Watson (1995) extended the analysis to a non-linear square array. The apparent resistivity (in Ωm) for any one electrode spacing, obtained by expanding the electrode array along each azimuth, are plotted against azimuth in a polar diagram. If this is circular then is that either there are no measurable fracture sets or the volume of rock investigated was insufficient (because the electrode array spacing was too small) for the rock to behave anisotropically. If distinct ellipses result then the major axis of the ellipse is coincident with the strike of the fractures. This is true, regardless of whether the fracture- fill is more or less resistive than the host rock (Nunn, Barker and Bamford, 1983), because the resistivity along strike is the arithmetic mean and is always higher than the resistivity across strike, which is the harmonic mean.

Many different electrode-array configurations have been used for data collection. Taylor and Fleming (1988) and Carpenter Keely and Kaufman (1994) employed a standard Wenner array, whilst Leonard-Mayer (1984a,b) used collinear Wwnner and Wenner-Lee (also known as the lee-partitioning) arrays. Skjernaa and Jorgensen (1994) used the collinear schlumbeger array for their study. The square array was originally developed as an alternative to Wenner or Schlumberger arrays when a dipping subsface,fracture,bedding or foliations are present (Habberjam and Watkins, 1967). A complete discussion of the square array and methods of data analysis is provided by Habberjam (1979). Techniques for analyzing directional resistivity data provided by the square-array method have been developed (Habberjam, 1972) but the method has not been widely used. The square array has been modified to the crossed square array (Habberjam, 1972) as a technique with grater sensitivity to anisotropy, in order to reduce anisotropic effects from standard resistivity measurements. Lane et al. (1995) utilized the sensitivity of the square array to anisotropy in their investigations of fracture detection. Bolshakov et al. (1995) employed the non-linear dipole equatorial array in which the potential and current dipoles are parallel and offset at the array spacing.

2.1.4 Geologic Field Mapping of Abakiliki Town and Environs

Umuezekoha Community Ezza North is about 18km to Abakiliki town and Abakiliki central was chosen for the geological field mapping.

The study area spans about 177km² with scatted shale outcrops. Within the study area 8 locations were mapped. Some of these outcrops were found along road cut, river channels, quarry site and in areas were the overburden has been scraped out.

The geologic field mapping stated on the 15th December, 2006 with the location of outcrops, measurement of strike, dip and the orientation of fracture, as well as the aperture and length of the fracture planes. The equipment used during the geologic field mapping are geologic compass, measuring tape, Global positioning system (GPS) and photographic camera.

Most of the fractured zones observed in the field consisted of fractures in the vertical direction with few in subvertical direction. The fracture lengths, widths and strike are irregularly distributed. Appendix 1 shows the locations and the measured parameters such as fracture strike. Fracture length, width, strike and dip of the bedding planes. Each of the locations are characterized by different fracture trends, which indicate that the deformation was as a result of force coming in different direction.

In some locations, the fracture are measured on hard rock (pyroclastic) while others are measured on shale. The fractures on the locations GFM 1, GFM 4, and GFM 5 dominate in Northeast-Southwest direction. While locations GFM 2, GFM 6, and GFM 8 dominate in the Northwest-Southeast direction.

In locations were the strike of the bed were measured, they strike in the same direction (ie NW-SE). The dip amount ranges from 20° to 34° except in location GFM 8 where the shale has been strongly deform resulting to different geologic structures like folding and faulting. The dip amount measured was vertical (ie 90°).

The histogram in figure 4 shows the distribution of the fracture strike with azimuth. The fracture strike and width are irregularly distributed. The polar plots in figure 8.9 and 10 shows the orientation obtained from geologic field mapping (GFM) by grouping locations with similar fracture characteristics and the overall fracture characteristics of all the locations.

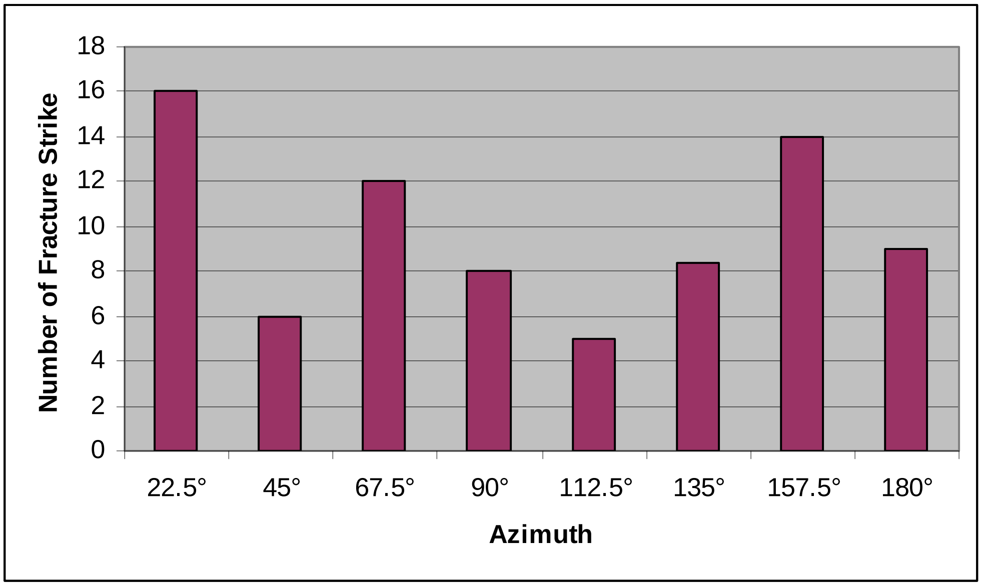


Figure 2.11: The distribution of fracture strike with azimuth.

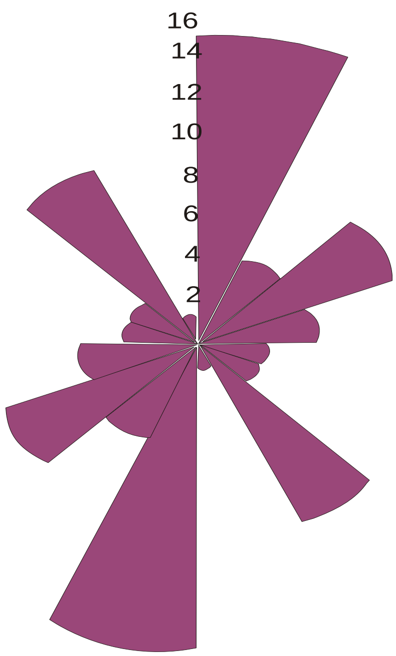


Figure 2.12: Polar plot of the fracture orientations obtained from geologic field mapping of outcrops at locations GFM1, 3, 4 and 5.

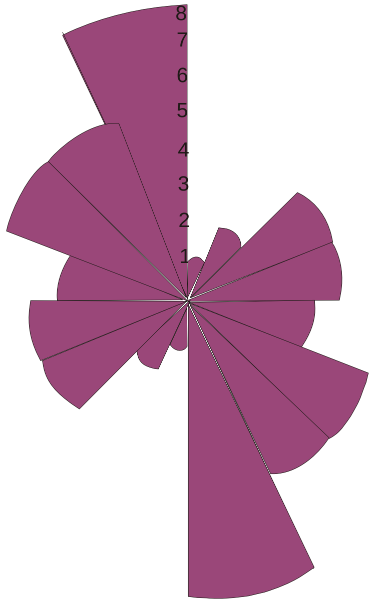


Figure 2.13: Polar of the fracture orientations obtained from geologic field mapping of outcrops at locations GFM 2, 6, 7 and 8.

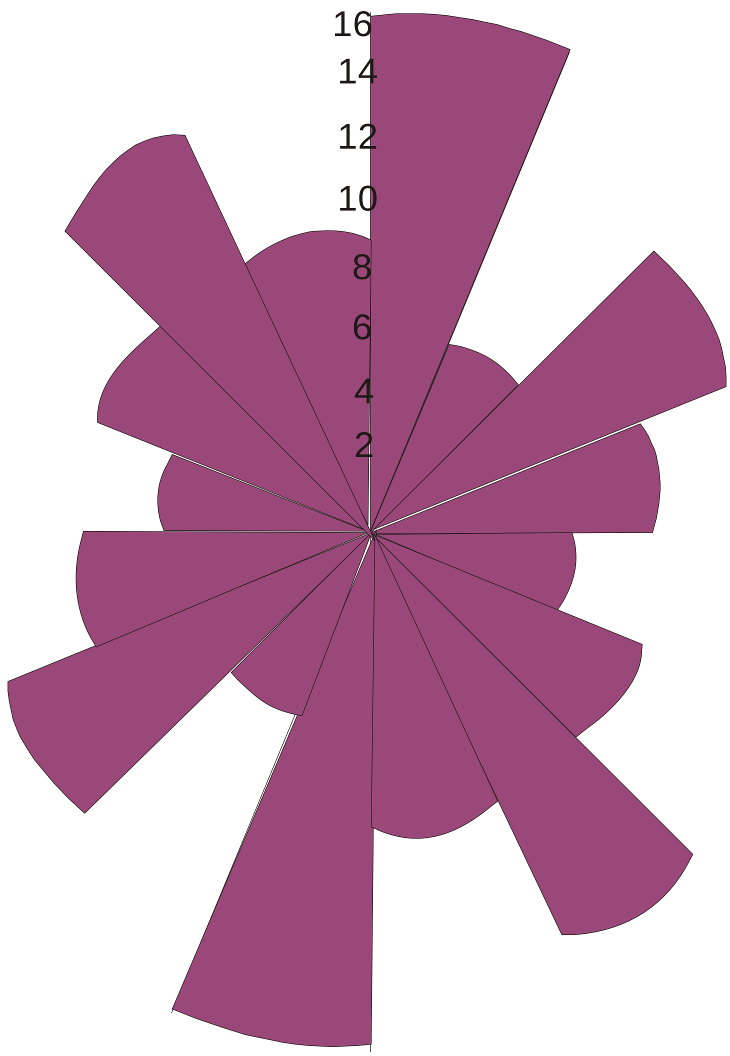


Figure 2.14: Composition polar plot of the fracture orientation obtained from geologic field mapping of the outcrops at all the eight locations in the study area.


Some exposed outcrop along the quarry site


Another exposed outcrop along river channel

Another outcrop along road cut

The geologic structure found in Abakiliki Girls High School (GFM 8) gave some information about the deformation history of the Asu River Group in southeastern Nigeria. The widely accepted mechanism of deformation of the Benue rift involves asthenospheric uplift or mantle plume, crustal stretching and thinning and emplacement of igneous bodies in the lithosphere and block faulting (Olade, 1975; Ofoegbu et al, 1990). There has been evidence that magmatic activities are likely to have been associated with earliest periods in the evolution of the Benue rift that took place in the Jurassic to early cretaceous (Umeji and CarenVachetle, 1983).

Mechanism for the initiation of intracontinental rifting, other than the mantle plume model, which had been proposed for the Benue rift; include the transform fault model due to the existence of transform faults along the northern margin of the Gulf of Guinea (Grant, 1971; Emeryy et al, 1975 and Benkhelil, 1986). The other is a membrane stress from the movement of the lithosphere plates relative to the geoid.

The fold, fault and the fractures that spread across the Abakiliki anticlinorum and Afikpo synclinorum in the Benue rift suggest that there was a deformational episode in the rift. The folds, faults and fracture in the rift originated from vertical movement resulting from the rising and cooling of magma, which intruded the sediments of the area in the santonian time (Umeje, 2000).

The folding observed in two locations (GFM 5 and 8) are flexure folding, were it was observed the compressional force is acting parallel the bedding and the convex side is subjected to tensional force. Under conditions of extreme deformation, after an initial phase of flexure folding, which was suspected to be during the santonian period, closely spaced fractures develop along with a normal fault, which strike parallel to the fold axis. The fold is asymmetrical; this is because the axial surface is inclined. The dip amount of the bed is 20° as shown in figure 11.

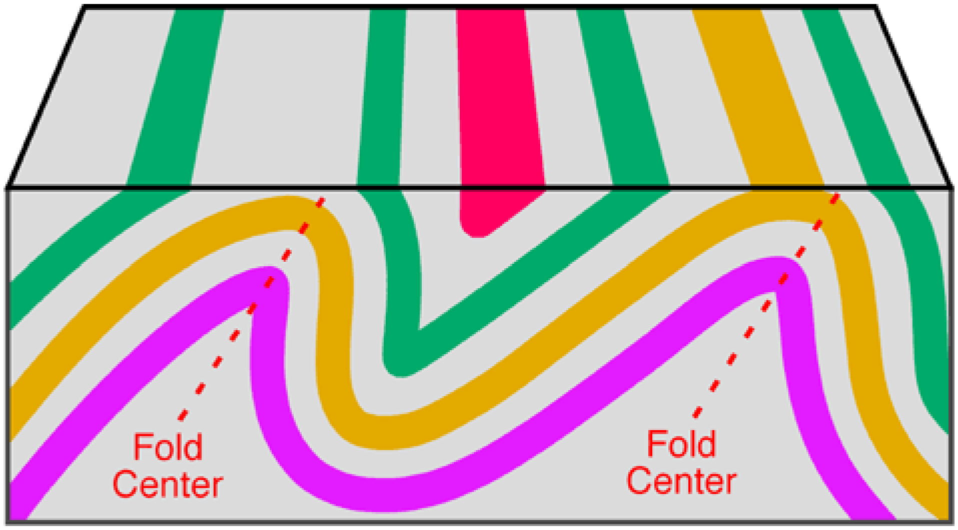


Figure 2.15: Asymmetrical fold.

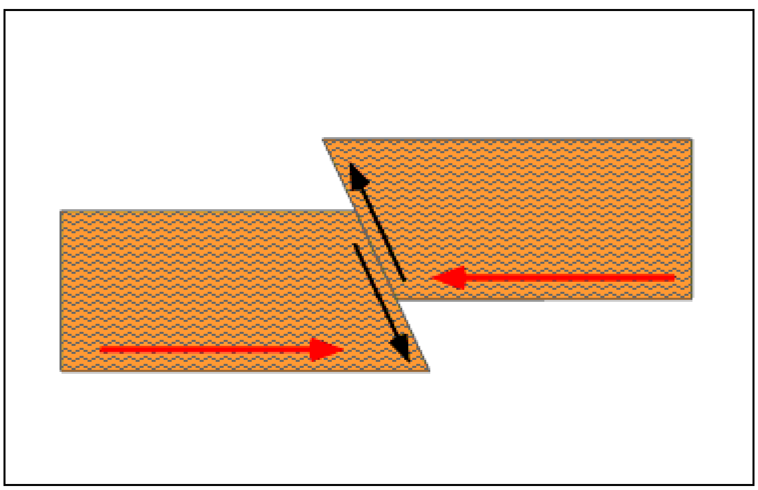


Figure 2.16: Reverse fault.

The fault in location GFM 8 is younger than the fold since the strike is trend in the same direction with the axial plane of the fold. This suggested that the folding took place under a wide range of temperature and confining pressures. This suggestion was made based on the various degrees of baking of the shales, and the dip amount of the bed, which was measured to be 90° on the outcrop ("vertical overturned beds").

2.1.5 Calculation of Fracture Parameter from Geologic Field Mapping

The fracture porosity ϕ_f was estimated from field measurements of fracture width (w) and length (L) along a scan line. (Hossain, 1992; Boadu, 2005) as:

$$\phi_f = \frac{\sum_{i=i}^{m} li \times wi}{\sum li x h} ----5$$

Where m is the number of fracture and h defines the span of maximum fracture length.

The fracture porosity was calculated ; for each rotational angle (ie Azimuth).

1. $0^0 - 22.5^0$
$\Sigma liwi = 0.443$
$h = 6.2$

by substituting these value above into equation 5 we will be able to calculate fracture porosity of all the rotational angles (Azimuth).

$$\phi_f = \frac{0.443}{6.2 \times 36.4} = \frac{0.443}{225.68} = 0.002$$

2. $22.6^0 - 45.0^0$
$\Sigma liwi = 0.576$
$\Sigma li = 20.1$
$h = 9.0$

Also by substitution

$$\phi_f = \frac{0.576}{8.0 \times 20.1} = \frac{0.576}{160.8} = 0.004$$

3. $45.1^0 - 67.5^0$
$\Sigma liwi = 1.152$
$\Sigma li = 32.38$
$h = 10.0$

$$\phi_f = \frac{1.152}{32.38 \times 10.0} = \frac{1.152}{323.8} = 0.004$$

4. $67.6 - 90^0$
$\Sigma liwi = 0.475$
$\Sigma li = 9.83$
$h = 3$

$$\phi_f = \frac{0.475}{9.83 \times 3} = \frac{0.475}{29.49} = 0.016$$

5. $90.1^0 - 112.5$
$\Sigma liwi = 0.144$
$\Sigma li = 7.71$
$h = 4$

$$\phi_f = \frac{0.144}{7.71 \times 4} = \frac{0.144}{30.84} = 0.005$$

6. $112.6^0 - 135.0^0$
$\Sigma liwi = 1.589$
$\Sigma li = 14.2$
$h = 5$

$$\phi_f = \frac{1.589}{14.2 \times 5} = \frac{1.589}{71} = 0.022$$

7. $135.1^0 - 157.5^0$
$\Sigma liwi = 3.643$
$\Sigma li = 26.2$
$h = 7$

$$\phi_f = \frac{3.643}{26.2 \times 7} = \frac{3.643}{183.4} = 0.020$$

8. $157.6^0 - 180^0$
$\Sigma liwi = 0.064$
$\Sigma li = 9.24$
$h = 4$

$$\phi_f = \frac{0.064}{9.24 \times 3} = \frac{0.064}{27.72} = 0.002$$

These fracture porosities ϕ_f are secondary porosity that usually developed during tectonic fracturing of the rocks and serves as measure of fluid storage potential of the fractured rock mass. Another important parameter characteristic of a fractured rock mass that is related to its hydraulic properties is the surface-area- to-pore-volume ratio S_{AV}. This parameter, also termed the specific area (inverse of a hydraulic radius), is related to the permeability of the fracture porous media via the kozeny-Carman relation (Wels and Smith, 1994).

$$S_{AV} = \frac{2\sum_{i=i}^{m} li}{\sum_{i=i}^{m} liwi} --- 6$$

When Li and Wi are respectively the length and width (aperture) of ith fracture within a fracture zone containing M fractures. The lower the S_{AV}, the higher the fracture permeability and vice versa. The value of S_{AV} are estimated for the locations where information about fracture aperture and lengths are available from geological mapping using equation 6.

The specific surface area S_{AV} was estimated for the entire azimuth.

1. $0^0 - 22.5^0$

$\Sigma li = 36.44$

$\Sigma liwi = 0.443$

by substitution with equ 6

$$S_{AV} = \frac{2\times 36.44}{0.443} = \frac{72.88}{0.443} = 164.5$$

2. $22.6^0 - 45.0^0$

$\Sigma li = 20.1$

$\Sigma liwi = 0.576$

$$S_{AV} = \frac{2 X 20.1}{0.576} = \frac{40.2}{0.576} = 69.79$$

3. $45.1 - 67.5^0$

$\Sigma li = 32.38$

$\Sigma liwi = 1.152$

$$S_{AV} = \frac{2\times 32.38}{1.152} = 56.22$$

4. $67.6^0 - 90.0^0$

$\Sigma li = 9.83$

$\Sigma liwi = 0.475$

$$S_{AV} = \frac{2\times 9.83}{0.475} = 41.39$$

5. $90.1^0 - 112.5^0$

$\Sigma li = 7.71$

$\Sigma liwi = 0.144$

$$S_{AV} = \frac{2\times 7.71}{0.144} = 107.08$$

6. $112.6^0 - 135.0^0$

$\Sigma li = 14.2$

$\Sigma liwi = 1.587$

$$S_{AV} = \frac{2\times 14.2}{1.589} = 15.06$$

7. $135.1^0 - 157.5^0$

$\Sigma li = 26.2$

$\Sigma liwi = 3.643$

$$S_{AV} = \frac{2\times 26.2}{3.643} = 14.38$$

8. $175.6^0 - 180^0$

$\Sigma li = 9.24$

$\Sigma liwi = 0.064$

$$S_{AV} = \frac{2\times 9.24}{0.064} = 288.75$$

3. DEVELOPING OBJECTIVES AT UMUEZEKOHA COMMUNITY

3.1 The Strategic area of intervention

The strategic area of intervention is the provision of sustainable access to safe drinking water for the rural poor umuezeokoha community.

3.2 The water

Drinking water supply service is not available in this community. Source of water is left to the individual familial group.

At present the population of the Umuezeokoha Community in Ezza North Local Government Area of Ebonyi State, Nigeria has no access to clean, safe and permanently available freshwater sources. Rainwater collection is performed in an open collection area situated in the centre of the village, where rainwater accumulates during the rainy season. The maximum storage capacity of this collection tank is approximately 200m^3 (it's likely the tank is a cone type of) and this storage is not enough to take care of the current population density of about 9000. This storage is always contaminated, which leads to persistent outbreak of waterborne diseases in the community.

This volume is sufficient for no more than four days after the end of rainy events and poses serious risks to human health as evidenced before.

During the dry season water is supplied to the community by the government by trucks which is not consistent on daily basics. But individual families has to source for water on there own by hauling on feet or with a bicycle or hand wheelbarrow irrespective of the government help which is not consistent to enable them meet up to there water demand.

At the moment, the local government supplies about 23,000 liters per day to this community, which is equivalent to 2.63 L per capita and day and is well below the water supply quantity recommended as the minimum vital by the World Health Organization (50 Liters per capita and day; WHO, 2003: "Domestic Water Quantity, Service Level and Health" [3]) and even below what is recommended as minimum vital under temporary, emergency periods (20 Liter per capita and day).

[3] www.who.int/water_sanitation_health/diseases/WSH03.02.pdf

3.3 General Objectives

The general objective of this work is to help local population in increasing their quality of life by eradicating diseases, poverty and related social problems. One of the main causes is the lack of local safe water supply. Water sources are located as far as 18km away and transport of water by trucks is expensive. Therefore, insufficient water supply, as well as inappropriate and unhygienic water storage has caused the microbiological contamination of the water which has lead to periodical water borne diseases such as cholera outbreaks and high number of guinea worm disease (*Dracunculus medinensis*). This in turn severely limits any effort towards the development of this community. Providing access to a sustainable and safe drinking water supply is a vital prerequisite to ensure any possible perspective of development for this Community. Also, basic sanitation will contribute immensely to the social and economic development of this rural poor community. Therefore the involvement of the local population is a prerequisite essential to support any action to achieve the general goal.

3.4 Specific Objectives

As local projects have never been proposed, no information, nor studies have been carried out in the study area. Therefore the specific objective is to produce a feasibility study to evaluate the local situation under the hydro-geological, sanitary, environmental, social and economical point of view and to propose some alternative that will be evaluated at a further step of the project to identify the most viable, sustainable and economical one.

4. IMPLEMENTATION OF A DRAFT FEASIBILITY STUDY FOR ENSURING A SAFE AND SUFFICIENT WATER SUPPLY AT UMUEZEOKOHA COMMUNITY.

The thesis aim is to development a draft feasibility study, this study starts from the analysis of potential technical solution for safe and sufficient water supply at the community.

4.1 Water Supply

Water supply is the process of self-provision or provision by third parties in the water industry, commonly a public utility, of water resources of various qualities to different users. Irrigation is covered separately. Water supply systems get water from a variety of locations, including groundwater (aquifers), surface water (lakes and rivers), conservation and the sea through desalination. The water is then, in most cases, purified, disinfected through chlorination and sometimes fluoridated. Treated water then either flows by gravity or is pumped to reservoirs, which can be elevated such as water towers or on the ground (for indicators related to the efficiency of drinking water distribution see non-revenue water). Once water is used, wastewater is typically discharged in a sewer system and treated in a wastewater treatment plant before being discharged into a river, lake or the sea or reused for landscaping, irrigation or industrial use.

Continuity of water supply is taken for granted in most developed countries, but is a severe problem in many developing countries, where sometimes water is only provided for a few hours every day or a few days a week. It is estimated that about half of the population of developing countries receives water on an intermittent basis.

In 2004 about 3.5 billion people worldwide (54% of the global population) had access to piped water supply through house connections. Another 1.3 billion (20%) had access to an improved water source through other means than house, including standpipes, "water kiosks", protected springs and protected wells. Finally, more than 1 billion people (16%) (UN report 2008) did not have access to an improved water source, meaning that they have to revert to unprotected wells or springs, canals, lakes or rivers to fetch water. The higher percentage resides in Africa. Access to an improved source of water does not necessarily imply that it is safe to drink from that source.

In Nigeria, water supply to the over 150 million of its population has not been met. Nigeria is 50 years old and lots of its citizen both in the urban and in the rural area has been highly denied access to safe drinking water and basic living amenities. And this is considered among the hindrances towards sustainable development of the country that is blessed with so many natural resources.

The Nigerian Government has long considered the provision of water supply and sanitation services to be the domain of the federal, state and local governments. However, the public sector has not been successful in meeting more than a small portion of the demand for water and sanitation of residential and commercial users. Services are in critically short supply. For example, out of the 95 million people living in urban and semi-urban areas, less than half have reasonable access to reliable water supply. Many households, often the poorest, end up purchasing water from private water vendors which are much more expensively than from the public supply. Water supply services, where they exist, are unreliable and of low quality and are not sustainable because of difficulties in management, operation and pricing and failure to recover costs. Many water supply systems show extensive deterioration and poor utilization of existing capacities, due to under-maintenance and lack of funds for operation.

Additionally, the high cost of imported equipment especially in terms of a depreciating currency, and inadequate cost recovery policies have contributed to large financial deficits in many State Water Authorities (SWAs). This has left most SWAs dependent upon state subventions to finance operations and maintenance of their water systems, to service debt and to finance new investments. The states' own financial constraints have often limited the amount and dependability of recurrent and capital subventions requiring the SWAs to defer maintenance and limit new investment. This Strategy Note, prepared in conjunction with the Federal Ministry of Water Resources (FMWR), presents a joint vision for sector development, and provides a proposed lending strategy for the Bank (banks operating in the country) in the water supply in four segments, namely**, urban**, **small towns**, **rural**, and **water resources management**. Because water supply is central to improvements in so many aspects of human development, **health**, **education**, **urban** and **rural development**, **development of industry** and **general economic development**, and so, central to the Bank's primary mission of poverty reduction, it is proposed that water supply should become a primary focus in the Bank's program of assistance to Nigeria.

The government strongly believes that urban water supply is a public amenity that is not only crucial for the wellbeing of the people but is also critical to the socio economic development of the urban environment. However, despite the fact that water make up a huge proportion (97%) of the earth's surface, drinkable water is still a very scarce commodity. Part of this recurrent problem of water shortage has been attributed to rapid population growth and high urbanization rates (Stren, 1989;Edward, 2005). With the peculiarities associated with this task of providing good quality water to the urban population, effective planning and management cannot be overlooked (Caincross,1988; Akpala, 2006).

Table 4-1 below gives an example of water situation in some major states of Nigeria (Chimauzo Ewerem, 2000). This data that is majorly based on the rurality of the states, the population, poverty level and hydrogeological data has been very instrumental for revenue allocation in the states.

Water situation in some major states of Nigeria (Chimauzo Ewerem, 2000). This data is majorly based on the rurality of the states, the population, poverty level and hydrogeological data.

STATE	MAJOR SOURCE OF WATER SUPPLY	CONSUM. PER PERSON PER DAY	MAJOR WATERBORNE DISEASES	INFANT MORTALITY RATE	LIFE EXPERTANCY FOR MEN AND WOMEN
ABIA	Borehole	25 Liters	Typhoid fever and Hepatitis A.	120.9 deaths/1,000 live	Man: 58 years Women: 49 years
ABUJA	Borehole	45 Liters	Typhoid fever and Hepatitis B.	61.5 deaths/1,000 live	Man: 57 years Women: 48 years
AKWA-IBOM	Borehole	22 Liters	Typhoid fever and Hepatitis A.	119.4 deaths/1,000 live	Man: 57 years Women: 49 years
ANAMBRA	Borehole	28 Liters	Typhoid fever and Hepatitis A.	121.8 deaths/1,000 live	Man: 58 years Women: 49years
BAYELSA	Water Tanker	12 Liters	Cholera, Typhoid fever and Hepatitis A.	134.4 deaths/1,000 live	Man: 53 years Women: 49 years
CROSS - RIVER	Borehole	21 Liters	Diarrhea, Typhoid fever and Hepatitis A.	122.3 deaths/1,000 live	Man: 57 years Women: 47 years
EBONYI	Water Tanker	13 Liters	Diarrhea, Cholera, Guinea worm Typhoid fever and Hepatitis A.	138.6 deaths/1,000 live	Man: 53 years Women: 47 years
ENUGU	Water Tanker	29 Liters	Cholera, Typhoid fever and Hepatitis A.	123.4 deaths/1,000 live	Man: 58 years Women: 47 years
KANO	Water Tanker	19 Liters	Cholera, Diarrhea, Typhoid fever and Hepatitis A.	140.9 deaths/1,000 live	Man: 53 years Women: 47 years
KADUNA	Water Tanker	18 Liters	Cholera, Diarrhea, Typhoid fever and Hepatitis A.	141.7 deaths/1,000 live	Man: 54 years Women: 47 years
LAGOS	Borehole	47 Liters	Typhoid fever and Hepatitis A.	51.98deaths/1,000 live	Man: 58 years Women: 49 years
NIGER	Water Tanker	17 Liters	Cholera, Diarrhea, Typhoid fever and Hepatitis A.	124.1 deaths/1,000 live	Man: 53 years Women: 47 years
OSUN	Borehole	25 Liters	Typhoid fever and Hepatitis E.	120.8 deaths/1,000 live	Man: 58 years Women: 4 years
RIVERS	Borehole	33 Liters	Typhoid fever and Hepatitis B.	117.3 deaths/1,000 live	Man: 58 years Women: 47 years
SOKOTO	Water Tanker	24 Liters	Cholera, Diarrhea, Typhoid fever and Hepatitis A.	121.5 deaths/1,000 live	Man: 53 years Women: 47 years

The government has reinstated its efforts towards increasing the lifes of its citizen irrespective of many challenges the states face. It has gone ahead to state that in small towns, water sub-sectors and the Bank will support and strengthen the government's policy of decentralizing ownership and management of water supply systems to attract and involve optimal community involvement and support by the private sector, including operation under contract, and regularizing the services of independent providers or franchisers. In small towns, the focus is on community ownership coupled with local private sector contracting for operations. In rural areas, the focus is on increasing the sharing of ownership and management by communities and local governments, with communities taking charge of operations and maintenance as well. Fiscally, both in small towns and rural areas, the focus must be on phasing out of subsidies for maintenance altogether, and restricting such subsidies to partial capital costs to engender greater community ownership and its development. The government attempts to provide a program that all donors can buy in to. There is great scope for donors to participate at various levels in the project proposed for Bank support, or to adopt additional states in parallel developments. The Federal Ministry of Water Resources (FMWR) would help to coordinate activities and ensure that policies are consistent.

To enable the government met the increasing demand of the growing population for water and to provide water to the rural poor communities in Nigeria that are facing water scarcity, other sustainable water supply has to be as well investigated, recommend and carried-out.

Possible solutions to be investigated:

Possible solutions to provide access to permanently safe drinking water to the Umuezeokoha Community, can be the following:

• Provide a local permanent water supply source by **drilling water well on site**, assuming that artesian aquifer that is found in the area nearby town (Abakiliki, Amuzu and Isiagu) extends until the site of the Umuezeokoha Community;

• In case this assumption is false and that no aquifers can be found under the Umuezeokoha Community site, then the possibility of taking water from the town located 18 km away (where the aquifer is present) should be considered; in this case a new water well should be drilled and the water extracted should be carried to the Umuezeokoha Community by laying a pipe line. **An Aqueduct** connection from any of the town above;

• In either case, the construction of a concrete water tank will be necessary to store the water and the need to take water from other areas where there is sufficient borehole water is put into consideration. This can be done by using trucks to supply water to the community (**Water Tankering)** on daily basis**.**

*4.1.1 Increase of water availability through trucks (**water tankering**)*

Water tinkering is a common method for delivering water. Most importantly, its applied immediately after an emergency has happened while more long term measures are being put in place; where the emergency is thought to be temporary and the situation will return to normal soon; and where security and political problems make it difficult to change to a more sustainable approach. In the last case, tankering may continue for long periods, sometimes for years.

Water tankering is a major logistical operation. It requires a fleet of vehicles that require frequent maintenance and proper management. Tankers full of water are heavy vehicles and operation may require regular attention to the access routes if they are to remain open. They key to a successful tankering operation is good management and proper financing.

<u>Approach</u>

Water tankering can be carried out in a variety of different container, some specifically designed for the task and others fabricated to meet an urgent need. Some figures below
shows a selection of different vehicles in which water is supplied to the communities.

Water Tankering from Abakiliki to the community.

Water Tankering from Abakiliki to the community to water their crops.

If possible, we try to use specially designed water tankers. They will be safer and more reliable. Temporary tankers made from flat bed trucks with potable storage tanks attached can be very dangerous if the tank is not securely fastened. The delivery of bottled water maybe a short term option but it is expensive and inefficient. It also produces a major solid waste problem from all the discarded empty water bottles.

Tanker management

Consider the following points when organizing a tankering program:

- Good management is the key to successful tankering. Identify reliable and capable supervisors. Closely monitor tanker performance, fuel consumption and spare parts use.
- Get clearance from local authorities and owners before using a water source. Check the water's quality and reliability before committing to its use.
- Tankers may have been used for carrying other liquids before the emergency. Always insist on all tankers being properly cleaned and disinfected before being used to carry water (see Note 3).

- Establish detailed contracts with private tankering contractors. Payment should be based on the quantity and quality of water delivered not the working time. Establish a monitoring system at the delivery point to check the quantities delivered.
- Make sure the routes to be taken by the tankers are capable of carrying the wheel loads. You may have to reinforce bridges and resurface sections of road.
- Choose the right tanker for the job. Some sites maybe inaccessible and unsuitable for large tankers. Others may require water to be transported overlong distances that would be unsuitable for small tractor drawn bowsers.
- Arrange an adequate supply of fuel. If the area has been hit by an emergency, supplies of fuel may be disrupted and there will be a high demand from other emergency services. It may be necessary to set up a temporary fuel storage depot to ensure are liable supply.
- A well managed tankering program is heavily dependent on staff relations. Drivers are particularly important. Make sure they are properly paid, have adequate rest periods and have the proper equipment. Make clear the divisions of responsibility for the different tasks such as loading, chlorination and pump operation. Don't forget to consider the security of the vehicle and its driver and make appropriate arrangements. If the driver is to look after other machinery (such as water pumps), make sure they are properly trained in their use and day to day maintenance.

Water distribution and collection

The simplest method of distributing water from tankers is to allow the public to collect it directly from the vehicle. This method is slow and reduces the number of trips the vehicle can do each day. Efficiency can be improved slightly by fitting a tap bar on the back of the tanker but the best method is to transfer the water from the tanker to a storage tank. The figures below show the public collecting water from the tanker and from the tap:

Public collecting water from the tanker

Women filling their water buckets at a public tap.


A woman satisfies her thirst with water from a new well.

The provision of storage tanks increases the efficiency of the tankering system and extends the time over which users can collect water. It also improves the quality of the water as it provides additional storage time before use. There are many different designs for storage tank, some specifically developed for emergency situations and others adapting existing equipment and ideas. Always raise tanks off the ground so that users can get their containers under the outlet tap. Tankering efficiency can be further increased by fitting the tanker with a water pump so that the water can be pumped into the storage tanks rather than allowing it to flow by gravity. Access is improved if the storage tank is connected to a tap stand. This moves the users away from the storage tank that reduces the problems associated with wasted water and vandalism and allows more people to collect water at the same time.

Providing water in an emergency is only successful if the users also have suitable containers to collect and store it. Domestic containers come in a wide variety of designs. One of the most popular is the jerry can. Provided it is fitted with a lid, the jerry can is
easily carried in the hand or on the head. The problem with jerry cans is that they are difficult to fill, causing a high proportion of water to be wasted, and they are almost impossible to clean on the inside. If used for extended periods they can become a serious health hazard. The other

common design of container is the bucket. These are cheap to buy, easy to fill but hard to carry when full. Water is easily spilt during carriage and the
large open water surface can easily lead to contamination. These problems can be reduced by fitting the bucket with a tight fitting lid that can be removed for filling and cleaning.

With respect to our study area, water is carried by a tanker from 18km distance of the capital city of Ebonyi State (Abakiliki town) to the community and at the community its filled into a reservoir tank (earthen) of capacity of **200m³** and from there, the community fetch the water from the earthen. Example of this situation is in the community is shown below:

People fetching water from the earthen tank.

Calculating tankering requirements for Umuezeokoha Community:

From my analysis, the community with current population density of 8750 and about 1028 households will require at least 179,900 liters of water a day to be tinkered in. The water is to be collected from a borehole that works 14,400L/d (that is 2L/s), this then means that more boreholes is needed to be able to supply the required liters of water as the one currently in use is not sufficient to do that (based on the 14,400l/d production). To estimate the number of tankers that is needed or required to deliver the quantity of water (179,900L/d). Assuming the entire needed borehole is located and are within the same place.

The following activities are assessed to take these times:

* Filling of the tanker	40mins
* Travel time from borehole to community	120mins
* Offloading time for the tanker	20mins
* Return travel time	80mins
Net turnaround time	**260mins**
* Add 30% for unforeseen activities	30mins
Gross turnaround time	**290mins**

Assume each tanker can work for 14 hours per day using two drivers then the number of trips each tanker can make in a day is **14 x 60/290 = 3 (approx.).** If each tanker can carry 5,000 liters per trip (as the case is in the community today), then one tanker can transport **5,000 x 3 = 15,000 liters per day**. Therefore the number of tankers needed or required to deliver the sufficient water to the community is **179,900/15,000 = 12 (approx.) tankers per day.**

The cost of delivery **5,000 liters** of water (currently) is **5,000 naira** (**at ₦ 191.323 for 1 Euro. World Currency Rate, Oct. 8th)** which is **26.14 euro.** So the total cost to deliver the required quantity per day will be **5000 x 3 x 12 = 180,000 naira per day which is 940.82 euro per day.** In a year, it will be **365 x 180,000** = **65,700,000 naira** (which is **343,398.34 euro**).

Advantages

1. It's the most appropriate during emergency.

2. Best to very remote areas of the community.

3. Most convenient in most remote areas of the community.

Disadvantages

4. Its very expensive to maintain.

5. Difficult to organize (poor management are bound to occur).

6. Regular fall of tanker due to bad road.

7. Security of vehicle and the driver is not guaranteed during communal crisis etc.

8. Tankers are not regularly maintained.

9. Water quality and reliability before usage is not checked.

10. Tankers are not properly cleaned and disinfected before being used to carry water as most tankers may have been used to carry other liquids.

11. Tankering is not environmental friendly solution.

4.1.2 Increase of water availability through ***aqueduct connection*** *with Abakiliki or Amuzu or Isiagu (Layering of pipes).*

A pipe is round tubular section or hallow cylinder used mainly to convey media. It can also be used for structural applications. In a layman's terms, pipe and tube are almost interchangeable, but in industry and engineering discipline, the terms are uniquely defined. Depending on the applicable standard to which it is manufactured, pipe is specified by the internal diameter (ID) and a wall thickness, a nominal diameter and a wall thickness, or an outside diameter (OD) and a wall thickness. Tube is most often defined by the outside diameter (OD) and a wall thickness but may be specified by any combination of dimensions (OD, ID, wall thickness). Pipe is generally manufactured to several long-standing and broadly applicable industrial standards.

Water Pipes are pipes or tubes frequently made of polyvinyl chloride (PVC), ductile iron, polyethylene, or copper, that carry pressurized and treated fresh water to buildings (as part of a municipal water system), as well as inside the buildings. Pipelines are useful for transporting water for drinking or irrigation over long distances when it needs to move hills, or where canals or channels are poor choices due to considerations of evaporation, pollution, or environmental impact. Water transportation is in the international movement of water over large distances. Methods of transportation fall into three categories:

1. aqueducts, which includes pipelines, canals, and tunnels.
2. container shipment, which includes transport by tank truck, tank car, and tank ship.
3. towing, where a tugboat is used to pull an iceberg or a large water bag along behind it.

Due to its weight, the transportation of water is very energy intensive. Unless it has the assistance of gravity, a canal or long-distance pipeline will need pumping stations at regular intervals. In this regard, the lower friction levels of the canal make it a more economical solution than pipeline. Water transportation is also very common in rivers and oceans.

Approach

The plan is to lay major pipe line from either of Abakiliki or Amuzu or Isiagu. But due to the current water source to the community which comes from Abakiliki (water tankering and individual haulage), i consider Abakiliki. This pipe line will run for about 18km distance (from Abakiliki town) where the water source is to umuezeokoha community. The 12 inches pipes will be laid to a total of 4000m from Abakiliki town crossing many communities of other local government to finally arriving at umuezeokoha community. These 12 inches pipes which is a total of 2,400 pipes constitute the main (or primary line) pipes that will be used to transport the water from the main source (Abakiliki town) to the Umuezeokoha civic center (which is the center of the four villages that makes up the community). From the center of the four villages that makes up the community is very closer to **Omega village** and from this center we run along another pipe line (the secondary line) with an estimated 600 quantities of 8 inches PVC pipe from the center to the centers of the 4 respective villages that makes up the community. The distance from the center to the respective villages is about 1000 meters (1 kilometer).

At these villages we installed 20 taps that will allow the villagers to open and fetch water at will and close the tap after fetching water. Table 4-2 below shows the cost of the Aqueduct project.

Table 4-2:

Cost of construction of the Aqueduct (The rate is at ₦ 191.323 for 1 Euro (world currency rate for 8th Oct 2010) :

S/no	Description	Qty	Unit	Rate	Amount ₦
1	Soil excavation of 18km (18000m): 18000 x 1m x 0.6m main pipes) (PVC pipes- 12inches) = 10,800m	10,800	Meter	600	6,480,000
2	Laying of main pipes (PVC pipes -12 inches)	**5,486**	Meter	960	5,266,560
3	Soil excavation for secondary lines: 1000m x 1m x 0.6m (PVC Pipes- 8 inches) = 600m	600	Meter	900	540,000 x 4 (4 villages) = *2,160,000*
4	Laying of secondary lines(PVC Pipes- 8 inches)	**203**	Meter	410	83,230 x 4 (4 villages) = *332,920*
5	Plumbing and accessories for the 4 villages			Lump	580,000
	Total				**14,819,480**
	Amount in Euro				**€77,457.91**

***These items are already known by the consultant (Quantity surveyor).**

Advantages

1. The quality of the water is guaranteed from the source.
2. Cost of water supply is low.
3. Water supply is assured.

Disadvantages

1. Constant water supply from the main source is not guaranteed may be due to power failure (as it's the only source for pumping water from the well) etc.
2. The cost of water supply may raise (increase) at any time (as the cost of water is at the disposal of the owner of the water who happens to be an individual in this case).
3. Pipe vandalization during communal crisis/violence or during a road construction (as the road where the pipeline will pass are still very bad and untaired).
4. Maintenance of the pipeline is still very poor due to inadequate skilled workers.
5. Pipe leakages can occur as a result of worn-out or improper laying of the pipes.
6. Water quality cannot be evaluated or assured (known) at all times (as this depends on the choice of the owner as the case may be in our case).
7. Construction of Aqueduct of this kind is very capital intensive.

*4.1.3 Groundwater Resources development on site (**drilling of a well on site**).*

In 1980, the International Decade of Drinking Water and Sanitation was declared by the World Health Organization, but tragically the news during the first half of the 1980s has been dominated by reports of devastating droughts in parts of Africa. Hence the importance to mankind of a continuous clean supply of water could not have been demonstrated more effectively. Unfortunately, however, many surface sources of water are subject to extreme temporal and spatial variations, as the African droughts testify. On the other hand, groundwater represents about 98% of the world 's supply of fresh water. This source is usually relatively pure and is not allowed by climatic extremes in the way that surface sources are. The challenge is to develop the groundwater resource. In Abuja and Rivers State something like 60% of the total water supply is satisfied by groundwater, and in the Lagos this figure rises to around 70%. Obviously, in those areas centered on major aquifers the figure is appreciably higher. As the demand for water increases in such developed areas, and opposition to the construction of new reservoirs mounts, then the development of groundwater schemes is likely to assume increasing importance. But in other areas like Ebonyi, Kano, Niger, Bayelsa etc where water supply is very low particularly groundwater, the need to construct many new reservoirs greatly mounts. Furthermore, a groundwater development scheme is not so capital intensive as that of a large reservoir project. Another advantage is that a groundwater scheme can be introduced gradually to keep pace with demand and a degree of flexibility is possible.

From geological and geophysical data's and information so far obtained and analyzed, we were able to discover a productive aquifer (artesian aquifer) and its exploration possibilities. Hence, the design of groundwater well at Umuezeokoha Community.

Well Design Objectives:

- Highest yield with minimum drawdown;
- Good quality water with proper protection from contamination;
- Sand-free water;
- Long lifetime (>50 years);
- Reasonable short-term and long term costs.

A water well is a hole, shaft, or excavation used for the purpose of extracting ground water from the subsurface. Water may flow to the surface naturally after excavation of the hole or shaft. Such a well is known as a ***flowing artesian well***. More commonly, water must be pumped out of the well.

Most wells are **vertical shafts**, but they may also be **horizontal** or at an **inclined angle**. Horizontal wells are commonly used in ***bank filtration***, where surface water is extracted via recharge through river bed sediments into horizontal wells located underneath or next to a stream. The oldest known wells, ***Qanats***, are hand-dug horizontal shafts extending into the mountains of the old Persian empire in present-day Iran.

But my main focus is on **vertical water-production wells** commonly used to supply water for domestic, municipal, and agricultural uses in many parts of Nigeria mainly in the South-Eastern part of Nigeria where my study area is.

Determining a Well Location

The location of a well is mainly determined by the well's purpose as in our case is mainly for drinking water purposes (though irrigation is as well taken into consideration). For drinking and irrigation water-production wells, groundwater quality and long-term groundwater supply are the most important considerations. The hydrogeological assessment to determine whether and where to locate a well should always be done by a knowledgeable driller or professional consultant.

The water quality criteria to use for drinking water wells are applicable to the local or state drinking water quality standards. For irrigation wells, the primary chemical parameters of concern are salinity and boron and the sodium-adsorption ratio. Enough ground water must be available to meet the pumping requirements of the wells. For large municipal and agricultural production wells, pumping rate requirements range from about 1892.706 to 15141.647 **l**iters **p**er **m**inute (**lpm**). Small- and medium-sized community water systems may depend on water wells that produce from 378.541 to 1892.706 **lpm**. Individual homes' domestic wells may meet their needs with as few as 3.785 to 18.927 **lpm**, depending on local regulations.

To determine whether the desired amount of ground water is available at a particular location and whether it is of appropriate quality, drillers and groundwater consultants rely on their prior knowledge of the local groundwater system, experience in similar areas, and a diverse array of information such as land surface topography, local vegetation, rock fracturing(where applicable), local geology, groundwater chemistry, information on thickness, depth, and permeability of local aquifers from existing wells, groundwater levels, satellite or aerial photographs, and geophysical measurements. In most cases, the well location is further limited by property ownership but in our case, the people of the community accepts (unanimously agreed) to relinquish there land for use no matter whose land is recommended for appropriate use for the location of the water well and the drilling equipments. When locating a well, one should also consider the proximity of potential sources of contamination such as fuel or chemical storage areas, nearby streams, sewer lines, and leach fields or septic tanks. The presence of a significant barrier between such potential sources and the well itself is very important for the protection of the well. To prevent any contamination of the waters extracted by the wells, it should be located up gradient to avoid any potential contaminant source.

The general situation in Umuezeokoha Community suggests that an artesian aquifer is present in the area at a depth between 60-68 meters (though a more detailed work as to be carried out to ascertain this values) and a hydrogeological survey should be performed further in order to investigate the viability of drilling a water well at **Umuezeokoha Community and water table level that lays at only 6m below the ground level exist in the specific area.**

The well location has been determined to be at **Umuezeokoha Community civic center**; a preliminary well design is completed. For many large production wells as the case may be, a test hole will be drilled before well drilling to obtain more detailed information about the depth of water-producing zones, confining beds, well production capabilities, water levels, and groundwater quality. The final design is subject to site-specific observations made in the test hole or during the well drilling. The overall objective of the design is to create a structurally stable, long-lasting, efficient well that has enough space to house pumps or other extraction devices, allows ground water to move effortlessly and sediment-free from the aquifer into the well at the desired volume and quality, and prevents bacterial growth and material decay in the well.

Umuezeokoha Community well will consists of a bottom sump, well screen, and well casing (pipe) surrounded by a gravel pack and appropriate surface and borehole seals (Figure 4.1). This chosen design is currently at use in areas such as Abakiliki, Afikpo, Nkalagu, Isiagu and Amuzu etc where the water system is currently in operational. These mentioned areas are not far from the community.

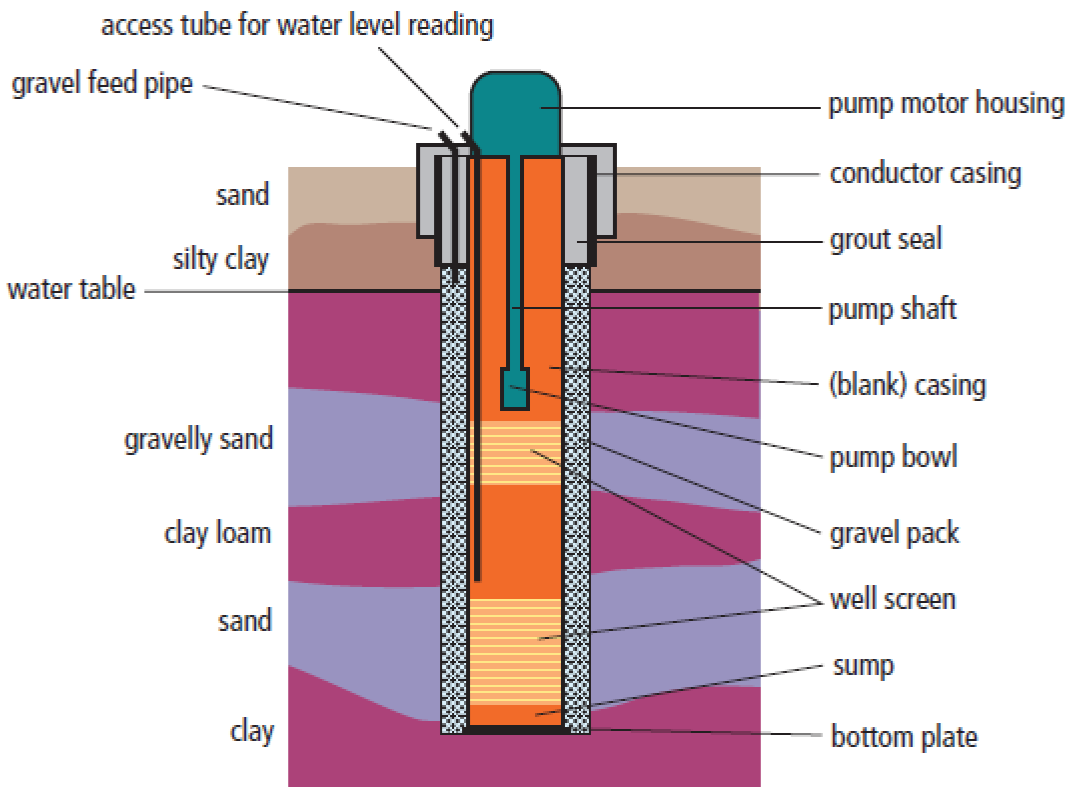


Figure 4.1: Components of a well.

Water enters the well through perforations or openings in the well screen at a depth of 68 meters. Wells can be screened continuously along the bore or at specific depth intervals. The latter is necessary when a well taps multiple aquifer zones, to ensure that screened zones match the aquifer zones from which water will be drawn. In alluvial aquifers, which commonly contain alternating sequences of coarse material (sand and gravel) and fine material, the latter construction method is much more likely to provide clean, sediment-free water and is more energy efficient than the installation of a continuous screen. Hard rock wells, on the other hand, are constructed very differently. Often, the borehole of a hard rock well will stand open and will not need to be screened or cased unless the hard rock crumbles easily.

The purpose of the screen is to keep sand and gravel from the gravel pack (described below) out of the well while providing ample water flow to enter the casing. The screen should also be designed to allow the well to be properly developed (see Well Development below). Slotted, louvered, and bridge-slotted screens and continuous wire wrap screens are the most common types. Slotted screens provide poor open area. They are not well suited for proper well development and maintenance, and are therefore not recommended. Wire wrap screens or pipe-based wire wrap screens give the best performance. Picture of Wrap Screen below:

Wrap Screen.

The additional cost of wire wrap screens can be offset if you only install screen sections in the most productive formations along the borehole. The purposes of the blank well casing between and above the well screens are to prevent fine and very fine formation particles from entering the well, to provide an open pathway from the aquifer to the surface, to provide a proper housing for the pump, and to protect the pumped groundwater from interaction with shallower ground water that may be of lower quality. The annular space between the well screen, well casing, and borehole wall is filled with gravel or coarse sand (called the ***gravel pack* or *filter pack***). But in most cases where the ground water is located in fractured rocks as the case of the community, it’s very possible that gravel pack may not be used in order to allow a greater casing diameter. However, most drillers drilling in fractured rocks take into consideration of giving a sizeable diameter before drilling commences in order to allow a greater casing diameter and also applied gravel packing.

The gravel pack prevents sand and fine sand particles from moving from the aquifer formation into the well and to increase the hydraulic conductivity in well surrounding area. The gravel pack does not exclude fine silt and clay particles; where those occur in a formation, its best to use blank casing sections. The uppermost section of the annulus is normally sealed with a bentonite clay and cement grout to ensure that no water or contamination can enter the annulus from the surface. The depth to which grout must be placed varies by state. Minimum requirements are defined by the Ebonyi State water resources in its 2008 Water Safety Act: 50 feet for community water supply wells and industrial wells and 20 feet for all other wells. And in our own case, i will also apply 50 feet (15.24 meters starting from the top) for umuezekoha community water supply well but in communities like Amuzu and Afikpo, the casing there is at 16.8meters, this was attributed because of the geology of the area (groundwater conditions) which is the same with our study area. But hydrogeologist suggest that its better to seal at between 16 to 17meters starting from the top if the area has ever experienced folding that has as also marked by number of minor intermediate intrusions and also associated lead to zinc mineralization. And Amuzu, Afikpo, Isiagu, Umuezeokoha etc belong to the Lower Benue which has folding episode and fractured Azu River group rocks which are hosts for the associated lead to zinc and fluorite to barite mineralization(Akande et al, 1992).

At the surface of the well, a surface casing is commonly installed to facilitate the installation of the well seal, the casing would be 1.5m above the ground level for better coverage, to decrease the possibility of putting something inside the well and to prevent water runoff from entering into the well. The surface casing and well seal protect the well against contamination of the gravel pack and keep shallow materials from caving into the well. Surface casing and well seals are particularly important in hard rock wells to protect the other wise open, uncased borehole serving as a well.

Drilling of Water Well at Umuezeokoha Community Center

Wells can be constructed in a number of ways. The most common drilling techniques in South – Eastern part of Nigeria are rotary, reverse rotary, air rotary, and cable tool. Auger drilling is often employed for shallow wells that are not used as supply wells. In unconsolidated and semi-consolidated materials, (reverse) rotary (Figure 4.2) and cable tool methods are most commonly employed. But in our own case, I will recommend for reverse rotary drilling, this is base on the geology of the area and the efficiency of rotary drilling in water drilling in many south eastern states of Nigeria.

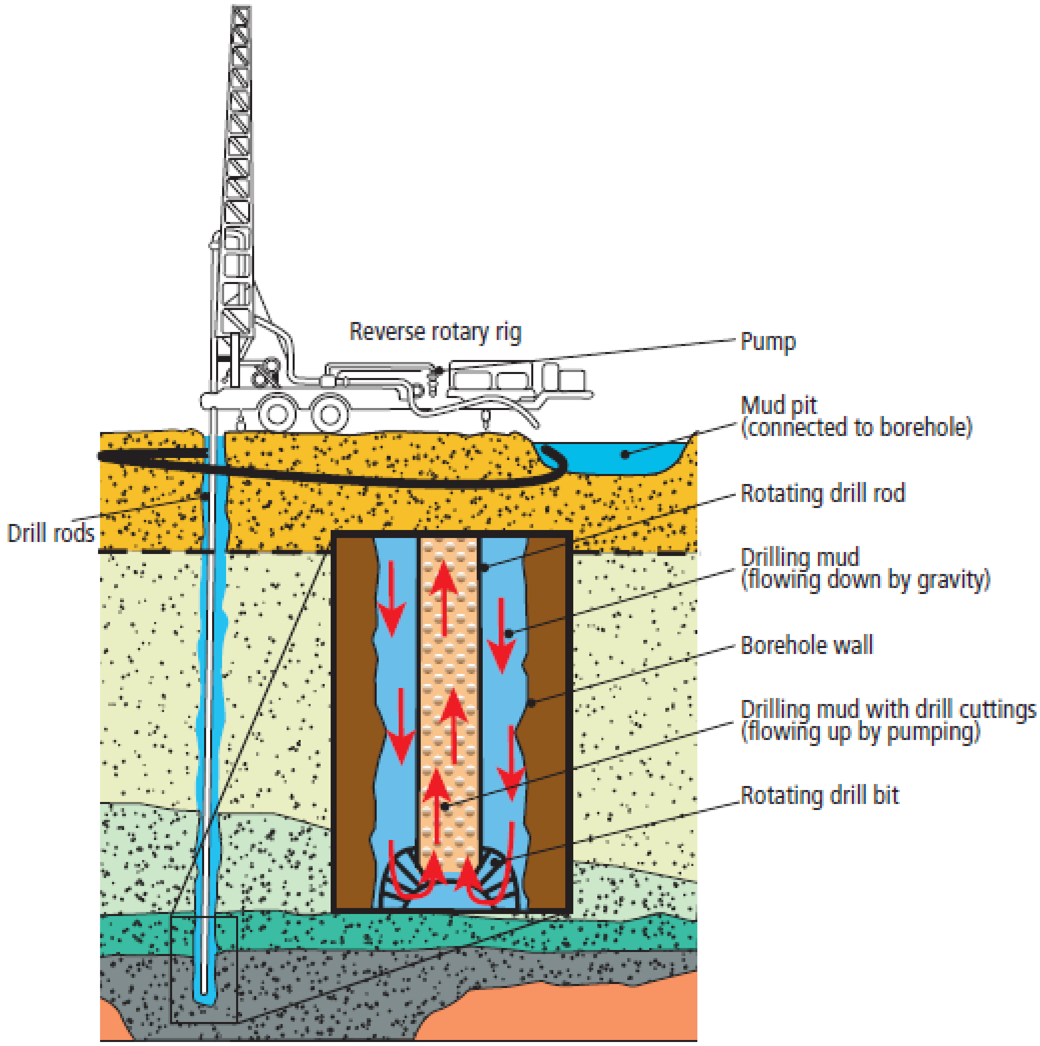


Figure 4.2: Principles of reverse rotary drilling.

Hard rock wells generally are drilled with air rotary drilling equipment. Properly implemented, all of these drilling methods will produce equally efficient and productive wells where groundwater is available. Cable tool drilling generally is less labor-intensive but takes more time than (reverse) rotary drilling. Reverse rotary and rotary drilling require large amounts of circulation water and the construction of a mud pit, something to be considered if the well is to be drilled in a more remote location with no access to water (as the case may be in our study area). It's very vital that we check accurately the quality of water that will be used during the circulation, back flushing and where the mud pit will be located, this is to avoid the transportation of any chemical or bacteria into the deep aquifer there by contaminating the deep aquifer.

During drilling, drillers must keep a detailed log of the drill cuttings obtained from the advancing borehole. In addition, after the drilling has been completed but before the well is installed, it is often desirable to obtain more detailed data on the subsurface geology by taking geophysical measurements in the borehole. Specialized equipment is used to measure the ***electrical resistance*** and the ***self-potential*** **or** ***spontaneous potential*** of the geological material along the open borehole wall. The two most important factors that influence these specialized logs are the texture of the formation and the salinity of the ground water. Sand has a higher resistance than clay, while high salinity reduces the electrical resistance of the geological formation. Careful, professional interpretation of the resistance and spontaneous potential log and the drill cuttings' description provides important information about water salinity and the location and thickness of the aquifer layers.

The information obtained is extremely useful when finalizing the well design, which includes a determination of the depth of the well screens, the size of the screen openings, and the size of the gravel pack material. Because of timing issues, it is better—especially in remote areas—to drill a pilot hole a good deal ahead of the well construction date and obtain all pertinent log information early on from the pilot hole. The well design can then be completed and the proper screen, casing, and gravel materials can be ordered for timely delivery prior to the drilling of the well. Note that a copy of all well log information should be given to the person who pays for the drilling job.

The Ebonyi State water resources keeps copies of all well logs and has a large collection of past well logs. These can be requested by a well owner if the original records are unavailable. The well log contains important information about construction details and aquifer characteristics that can be used later for troubleshooting well problems.

Well Development

After the well screen, well casing, and gravel pack have been installed, the well is ***developed*** to clean the borehole and casing of drilling fluid and to properly settle the gravel pack around the well screen. A typical method for well development is to surge or inject water or air in and out of the well screen openings.

This procedure may take several days or perhaps longer, depending on the size and depth of the well. A properly developed gravel pack keeps fine sediments out of the well and provides a clean and unrestricted flow path for ground water. Proper well design and good well development will result in lower pumping costs, a longer pump life, and fewer biological problems such as iron-bacteria and slime build-up. Poorly designed and underdeveloped wells are subject to more frequent pump failures because sand and fines enter the well and cause significantly more wear and tear on pump turbines. Poorly designed and underdeveloped wells also exhibit greater water level drawdown than do properly constructed wells, an effect referred to as ***poor well efficiency***. Poor well efficiency occurs when ground water cannot easily enter the well screen because of a lack of open area in the screen, a clogged gravel pack, bacterial slime build-up, or a borehole wall that is clogged from incomplete removal of drilling mud deposits.

The result is a significant increase in pumping costs. Note that well efficiency should not be confused with pump efficiency. The latter is related to selection of a properly sized pump, given the site-specific pump lift requirements and the desired pumping rate. Once the well is completed and developed, it is a good practice to conduct an ***aquifer test* (or *pump test*)**. For an aquifer test, the well is pumped at a constant rate or with stepwise increased rates, typically for 12 hours to 7 days, while the water levels in the well are checked and recorded frequently as they decline from their standing water level to their pumping water level. Aquifer tests are used to determine the efficiency and capacity of the well and to provide information about the permeability of the aquifer.

The information about the pumping rate and resulting pumping water levels is also critical if you are to order a properly sized pump. Once the well development and aquifer test pumping equipment is removed, it may be useful to use a specialized video camera to check the inside of the well for damage, to verify construction details, and to make sure that all the screen perforations are open.

Well Head Protection

The construction of the final well seal is intended to provide protection from leakage and to keep runoff from entering the wellhead (Figure 4.3). Minimum standards for surface seals have been set by the Ebonyi State water resources in its 2008 Water Safety Act. A backflow prevention device is intended to keep contaminated water from flowing back from the distribution system into the well when the pump is shut off. It will be better also to create a safe guard protection surrounding the well by fencing it of about 5m diameter, covered by concrete having a slope towards the external part (to avoid water runoff towards the well).

Figure 4.3: Properly completed well with elevated concrete seal (but with leaking lubricant).

Cost of drilling of a 9 inch diameter water borehole with generator (construction of the groundwater well at the community) (**The rate is at ₦191.323 for 1 Euro; world currency rate for 8th Oct. 2010**). :

S/no	Description	Qty	Unit	Rate	Amount ₦
1	Casing pipes pvc 8"x12 bar	28	Pieces	15,900	445,200
2	Antisol drilling chemical	3	Bags	32,000	96,000
3	Bentonite drilling chemical	15	Bags	6,400	96,000
4	2" Risers pvc pipe	30	Pieces	1,800	55,500
5	Marine Rope 14mm	5	Rolls	10,000	50,000
6	Gum	10	Tins	18,300	91,500
7	Electric cable 2.5mm	5	Rolls	18,300	91,500
8	Water for drilling	20	Tanks	12,000	240,000
9	Gravel	1	Trip	34,000	34,000
10	Joint kit	3	-	8,000	24,000
11	Socket nipple plugs & access		-	Lump	19,500
12	Security well head	1	-	10,000	10,000
13	Installation tapes	2	Packets	750	1,500
14	Grease oil fuel	-	-	20,000	20,000
15	Screen	5	Lengths	19,000	95,000
16	7.5 Hp submersible pump	1	-	275,000	275,000
17	Drilling and casing	88	Meters		440,000
18	Geophysical investigations*	-	-	Lump	80,000
19	Well logging	-	-	-	26,000
20	Well development	-	-	-	45,000
21	Cement	10	bags	2,000	20,000
22	Provision for sign post	-	-	-	20,000
23	Allowance for consulting services	-	%	10%	219,520
	Sub Total				**2,414,720**
	STANCHION AND TANK				
1	Detachable H. Channel 30ft high with 12ft wide with angle iron and other materials	-	-	Lump	750,000

2	Reinforced foundation with bolts and nuts	1	-	lump	103,000
3	20,000 gallons metallic storage tank capacity	1	gallon	Lump	730,000
4	Anti-rust protection and painting			Lump	200,000
5	Transport and logistics			lump	250,000
	Sub-Total				**2,041,000**
	GENERATOR SET AND GEN HOUSE				
1	Cement	25	Bags	2,000	50,000
2	Sharp sand	2	Trip	12,000	24,000
3	Plastering Sand	1	Trip	Trip	15,000
4	Roof sheet (zinc)	2	bundles	12,000	32,000
5	Nails	Assorted		5,000	5,000
6	Roofing planks and ties	Assorted		58,000	58,000
7	Doors (metallic)	1	piece	30,000	30,000
8	Coarse aggregate	1	Trip	32,000	32,000
9	Painting/finishing	2	Drums	4,000	8,000
10	Labour and logistics			lump	68,000
11	Gen set diesel operated	1	15KVA	430,000	430,000
12	Installation accessories			lump	113,000
	Sub-Total				**865,000**
	Reticulation/plumbing/four fetching outlets within the water borehole site.			lump	320,000
	Sub-Total				**320,000**
	Grand Total **Euro Equivalent**				**₦5,640,720** **€29,482.71**

The cost of providing solar panel to power a 7.5Hp (Horse Power) submersible pump borehole is ₦ 7,000,000 (which is €36,587).

Advantages

1. Management of this project will be effect as the project will be sustained through better and committed involvement of the community from the project conception to maintenance. A community water committee (CAC) shall be established comprising mainly of women and youth group with sub-committees attached. Under the supervision of CAC will exist the following sub-committees:

A. Community Project Committee (CPC).

B. Community Finance Committee (CFC).

The community project committee will be involved from project design to execution. While Community Finance Committee will be solely responsible with raising of the fund as counterpart fund and for maintenance. They will generate the collection of agreed tolls or levies from various households and report same to the community water committee which shall have account with the community microfinance bank. These committees will undertake an orientation course from the consulting firm involved.

2. Water availability is assured.

3. Quality of water is known and determined (as the community is the sole owner).

4. Health, Economic and Social effects that affect the community as a result of inadequate water supply are reduced to the bearable minimum if not eradicated.

5. Sustainable development of the community is well guaranteed.

6. The security of the project is assured by the Community Project Committee (CPC)

7. The safety of the villages with respect to the water scheme is assured by the CPC.

Disadvantages

1. Unaccountability of the monies collected for the maintenance of the project may occur hence Corruption may arise as a result of this which may lead to none maintenance of the borehole water scheme.
2. The Project is the first point of destruction should communal crisis occur. Hence, leading to economic waste.
3. Election or selection of various members of the committees could lead to crisis in the community if not well managed and this may lead to the close down of the water project.

4.1.4 ***Design of a Concrete water tank at Umuezeokoha Community***

The design of the concrete water tank at umuezeokoha is very vital as we consider different sources of water supply for the community. The designed tank will be able to take the quantity of water supply that we finalized. However, i also took into consideration the present population of **8,750** and the increasing population in years ahead (10 or 50 years forecast). Based on this, I consider the present population and future population forecast:
* Present Population is **8,750 PE**

* 10 years population forecast gives us $8,750 \times 1.07^{10}$ **= 17,212.57 PE**
* 50 years population forecast gives us $8,750 \times 1.07^{50}$ = **257,748.97 PE**

This number (for 50 years forecast) is more than 25 times the present population. This would imply the urbanization of a vast area and the hydraulic infrastructures should be planned as it should be done on a wider basis for an organized urban development of the Community into a large town. This is matter for urban planners.

At present i would rather limit the works to cope with the present emergency (present population) which I consider as ***PHASE A*** and **PHASE B** (which covers future population forecast of 10 - 50 years), so that i can:

- check the actual development rate of the community
- check if the provision of water enhances its growth dynamics
- check whether the system is acceptable or if planners should move towards more advanced water supply systems.

PHASE A

I will consider the present population (emergency), financial involvement and inadequate detailed information from existing wells in the study area which will enable me to have sufficient information of the well characteristics. Hence, it will be appropriate to follow two steps:

*** Drilling two wells now (two wells at the beginning, which will serve as exploratory wells);**

*** The remaining three wells will follow later.**

As I am short of detailed information from the existing wells in that area, the two wells will provide me with the following detailed information such as:

1. **Hydraulic Conductivity;**
2. **Stratigraphy;**
3. **Porosity of the shale's (measured inside the well);**
4. **Fractures (amount of fractures of the shale's);**
5. **Pumping test (through pumping test carried out in the well, we can achieve hydraulic conductivity, transmitivity (this gives us the potentiality of amount of water to extract) etc.**
6. **Ground water balance estimation (how much ground water that we have);**
7. **Chemical, Physical and Microbiological Quality Analysis.**

These information above gives us the extent of capacity of the well. As we don't know the detailed characteristics of the existing wells, it will be nice to have two wells in the beginning to enable us acquire further information for later wells best performance. These two wells will be placed at the village civic center that is owned by the community and the wells will be 30 – 40meters apart from each other. If we drill many wells (of about 15 or 30 now), this can lead to over exploiting the aquifer which can lead to the drying of the wells within two years leading to financial loss and catastrophic situation in the village (as they will return back to the initial stage even worst situation).

Calculations:

PHASE A:

8,750 PE (Present Population):

8,750 PE x 50 L/PE/d = **437,500L/d**

437,500L/d (Daily Consumption: **Dc** or daily volume V_d **). 437.52m^3/d.**
437,500L/d /24h/d = 18229L/h = 18.23m^3/h.

From data taken from local experts, we can assume that a well can give 2L/s. If we limit the operation to 12 hours per day (to avoid over exploitation of the well), the water that can be safely provided by a well can be calculated as follows:

Well yield = Wy = 2L/s x 60 s/min x 60 min/h x 12h/d = **86,400L/d**

Number of wells = **Dc\Wy** ≈ **5 wells**

PHASE B

If all the information collected from the drilled wells in Phase A which can be achieved within one year is good from the point of view of the Geological, Geophysical, Environmental, Social, Health etc. then, the PHASE B can start the following year. Should the information and drilled wells not performing, another favorable technical solution may be considered. But if all goes well, the phase B will be implemented bearing in mind the current developmental trend.

PHASE B:

$8{,}750 \times 1.07^{10}$ **= 17,212.57 PE** (10 years forecast) (Future Population):

17,212.57 PE x 50 L/PE/d = **860,625L/d**

860,625L/d (Daily Consumption: **Dc** or daily volume V_d **)**

From data taken from local experts, we can assume also that a well can give 2L/s. If we limit the operation to two hours per day (to avoid over exploitation of the well), the water that can be safely provided by a well can be calculated as follows:

Well yield = Wy = 2L/s x 60 s/min x 60 min/h x 2h/d = **14,400L/d**

Number of wells = **Dc\Wy** ≈ **60 wells**

So **60 wells** is needed to satisfy the population of **17,212.57** of water demand per day of **860,625** in the next decade.

In addition, to limit the financial burden, it would be preferable to start with half of the infrastructures and to postpone the remaining half within the next five years (this then implies that i have to drill 30 wells now (in the Phase B) and in the next five year i complete the remaining 30 wells. This also will allow adjusting the design of the third part of the works based on the experience drawn from the first years of operation of wells of PHASE A. This experience will be precious to improve the works to the actual needs of the Community. For example, i may not need to build 60 well, but extend the working hours from 12 to 24, if this will be proven possible.

And these 30 wells can be divided within the four villages as follows:

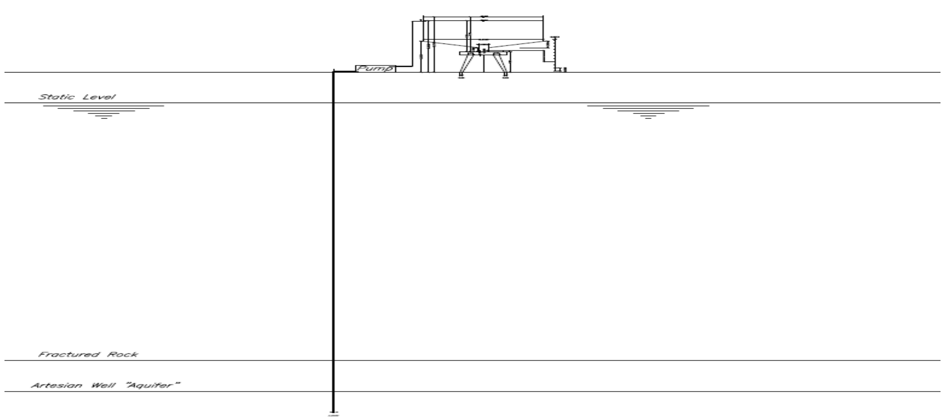
30/4 = 7.5 = rounded 8 wells per village**.** The village with the higher population takes 8 wells while the once with lower population takes 7 wells with one reservoir per village. As i planned 1 reservoir per village, hence, 8 wells will be connected to each reservoir as shown in **Figure 5** below.

2 wells is needed now (at the beginning)

Considering the 2 wells that are needed now and the number of villages which is 4, i plan to build the two wells at the center of the village (at the village civic center) which is owned by the community. These two wells will serve one reservoir (the reservoir is placed at the right end of the two wells). The planned wells (the two wells) will be placed at the civic center of the community and these two wells will be connected to the reservoir as shown in **Figure 4.4** below.

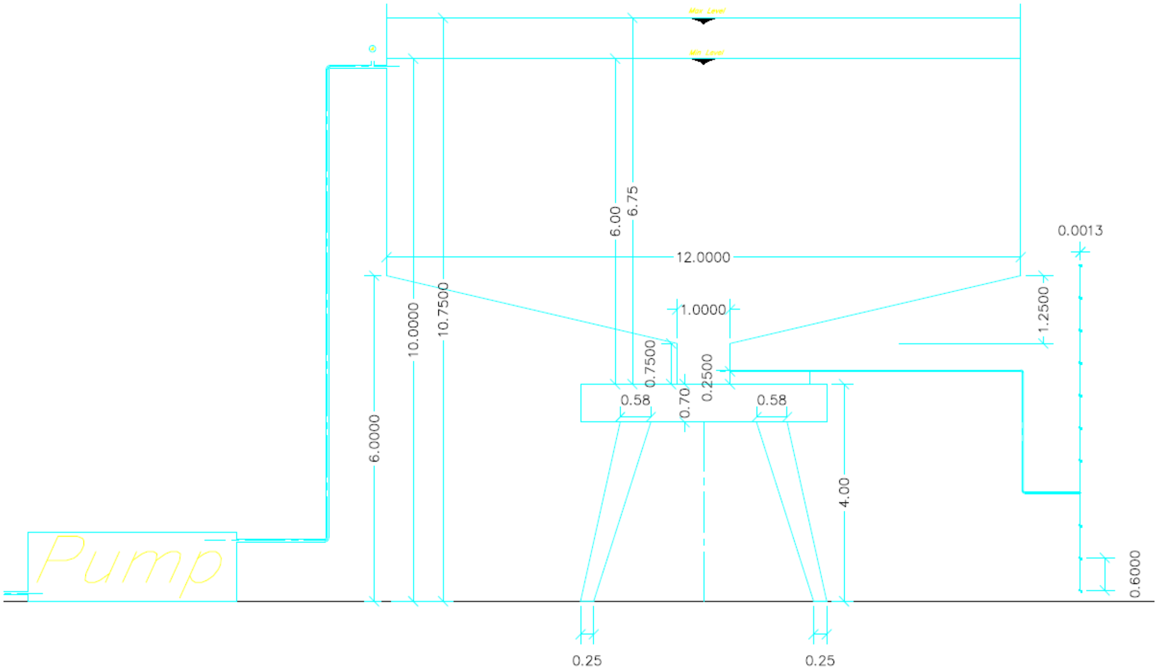
SCHEMATIC DESIGN OF WELLS AND A RESERVOIR

Below design shows the phases which the number of wells that has to be implemented in the community to enable the required safe quantity of water to be supplied to them:



One single well connected to a reservoir. Disinfection is carried-out at **a point A** that is at the very end of the pipe that runs from the well to the reservoir**. One Way Valve** is placed at the

bend joint to the disinfection point. This one way valve prevents the disinfectant from going in to the well even at a lower pressure of the well.



Clearer view of one single well connected to a reservoir.

PHASE A

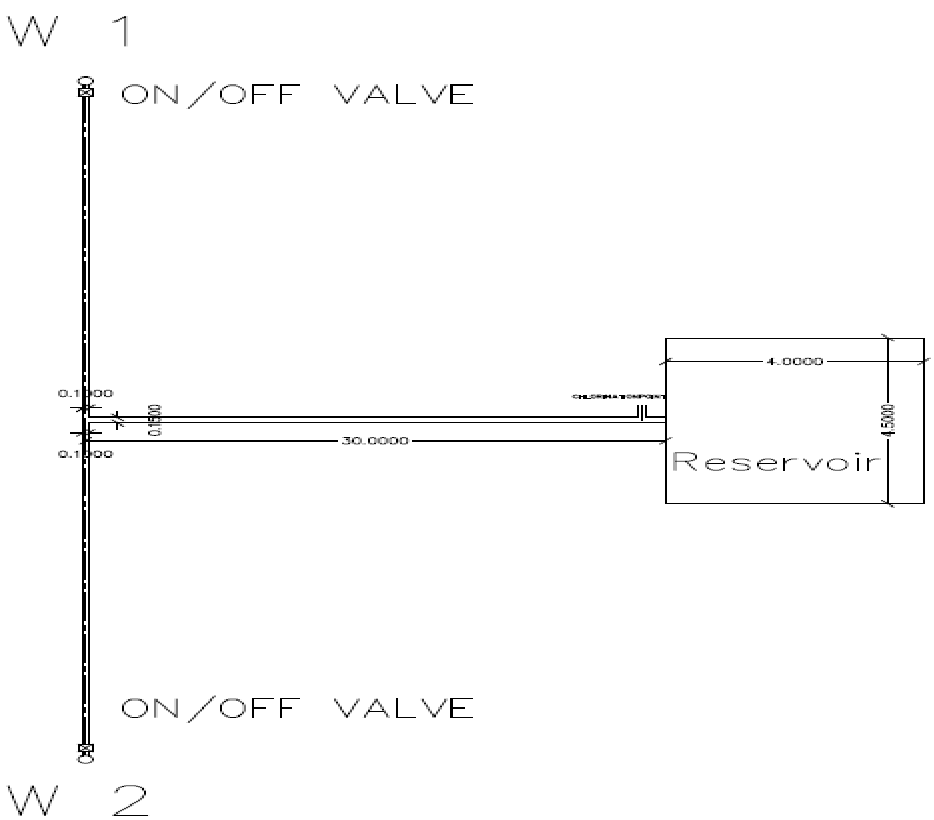
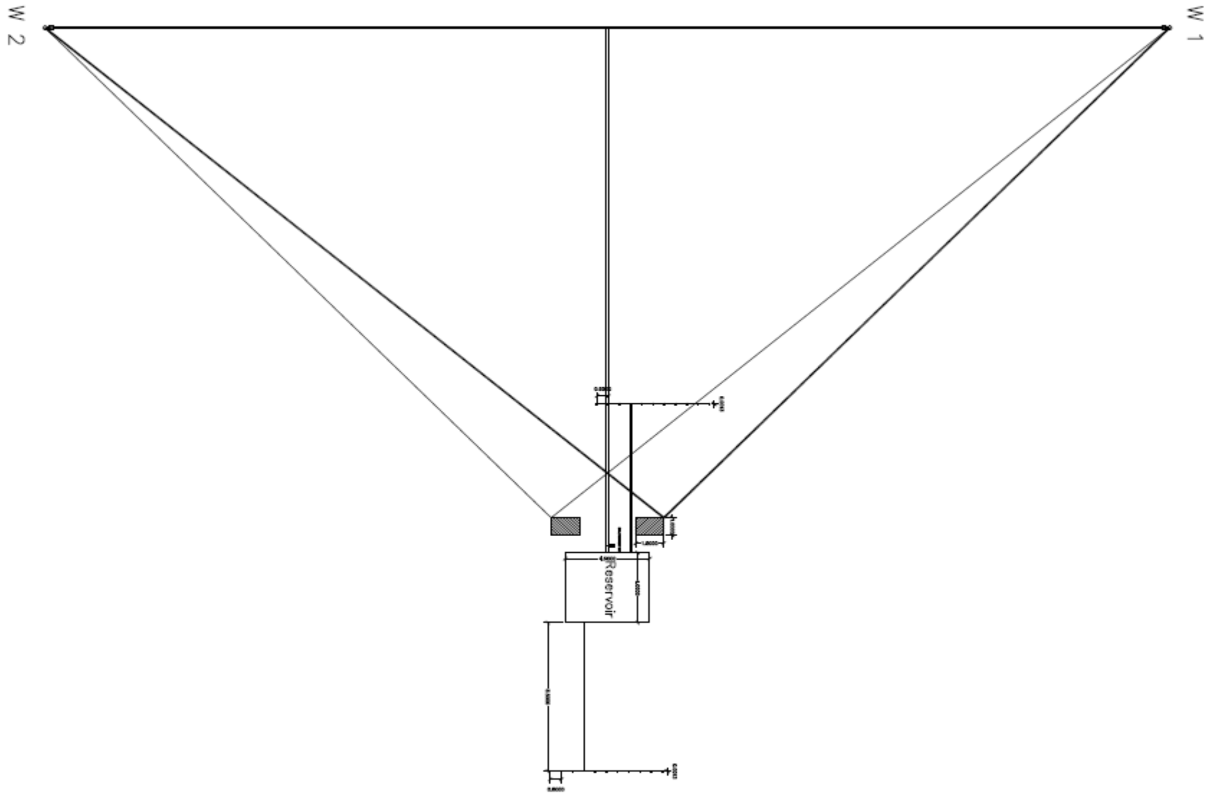


Figure 4.4: Top view of Two (2) wells connected to a single reservoir.



Clearer view of two (2) wells connected to a reservoir, with two public fountains (each fountain with 10 taps) and the two fuel generators connected to the wells

PHASE B

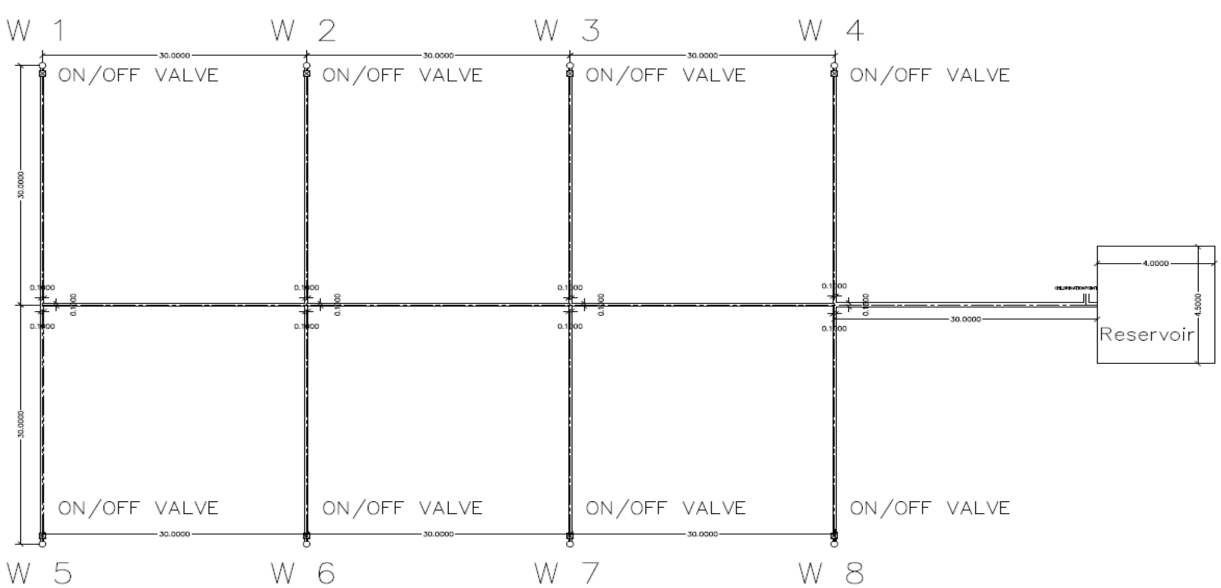
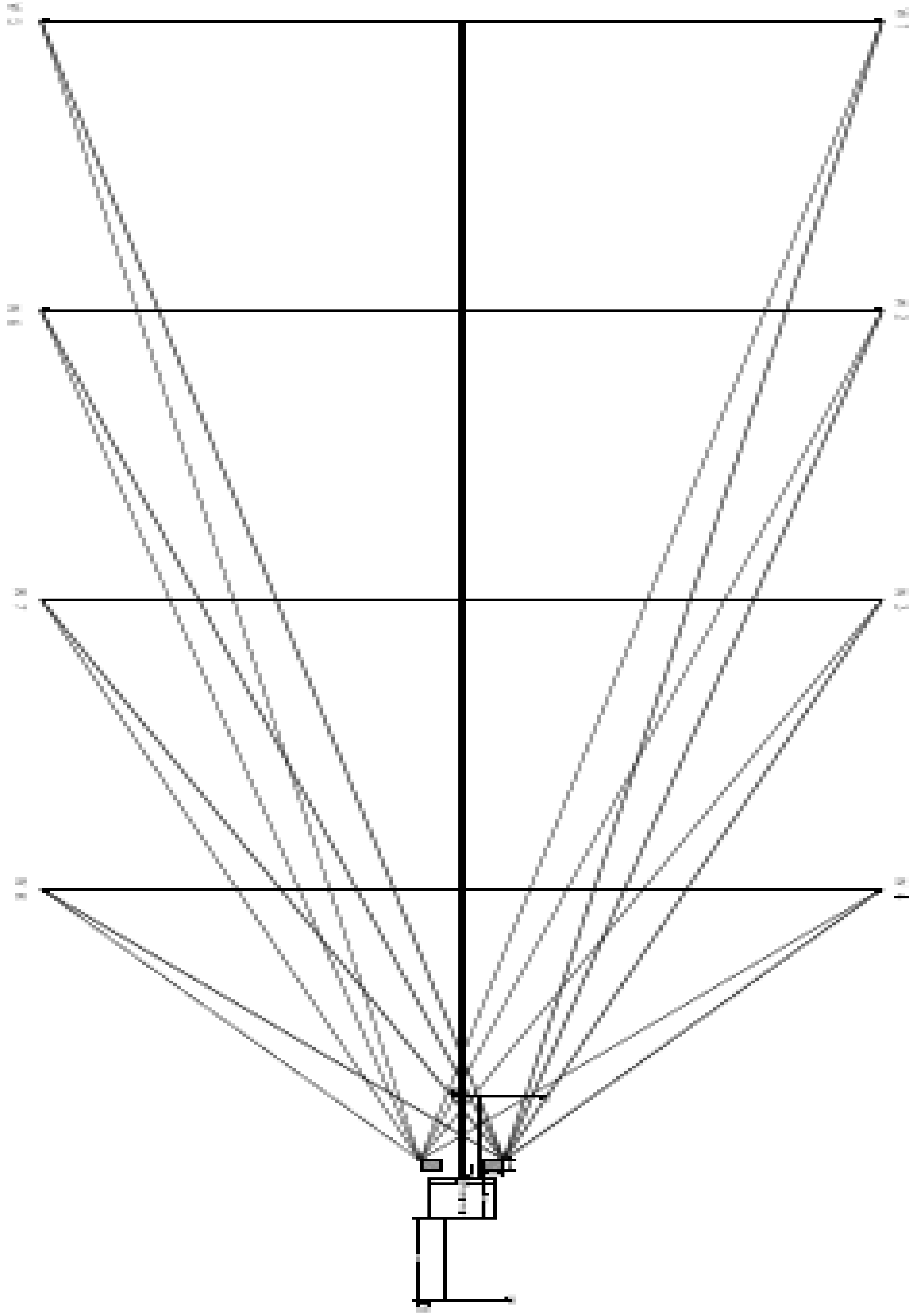


Figure 4.5: Top view of the Eight (8) wells connected to a reservoir.



Clearer view of eight (8) wells connected to a reservoir, with two public fountains (each fountain with 10 taps) and the two fuel generators connected to the wells

Cost of the design of a Concrete water tank shown above of **860.625 m^3** for the community is:
Design dimensions of a Rectangular Tank: **864m^3** = 6m (H) x 12m (L) x 12m (W) = **864m^3** including the free-board. Surface area is equal to **576m^2 [**That is**: 2(LW+LH+WH)].**

S/no	Description	Qty	Unit	Rate	Amount ₦
1	Concreting and reinforcement.	576	**m^2**	3,200	1,843,200
2	Fetching, Plumbing and Accessories			Lump	450,000
3	Sub-total				**2,293,200**
4	**Total for the 4 villages**				**2,293,200 x 4 = 9,172,800**
	Amount in Euro				**€47,944.05**

For **PHASE A**, two electric generators (fuel powered) will be provided to produce energy for the pumps (submersible pump of 7.5Hp).

Then the generator will work for 12 hours/day, serving each pump for six hours per day for each generator.
As I cannot provide running water in each dwelling, the reservoir will feed two "public fountains", each with 10 taps (need to avoid people queuing for hours waiting for their turn to fill their jerrycan or bucket), where people can go and collect water in jerrycans or bucket.

I consider that one tap can give 0,1 l/s and that a person that would like to fill his/her jerrycan or bucket to get 50 L/day will take not less than **10 minutes** (which is: 50 L / 0,1 L/s * 60 s/min = 8.33 min, plus some additional "dead" time of 2mins = 10 minutes).
I also excluded that people is queuing at night in the dark (6:30 PM to 5:30 AM) or in the burning sun (1 PM to 3 PM), so that only 24 - 11 - 2 = **11 hours are available to get water.**

This will also be extended to PHASE B with time changes, working hours of the generator and people's attitude will be put into consideration in PHASE B (using all information from PHASE A).

4.2 *Water Sanitation Improvement through Disinfection by Chlorination*

Disinfection is a process designed to reduce the number of pathogenic microorganisms below a threshold limit which varies according to the water usage. These limits are particularly strict when potable water has to be distributed to the population. While other water treatment processes, such as filtration or coagulation-flocculation-sedimentation, may achieve pathogen reduction, this is not generally their primary goal. A variety of chemicals or physical agents may be used to carry out disinfection. The concept of disinfection preceded the recognition of bacteria as the causative agent of disease.

Disinfection is an important step in ensuring that water is safe to drink. Water systems add disinfectants to destroy microorganisms that can cause disease in humans. When water is taken from surface sources such as lakes, streams, or groundwater sources under the influence of surface water, disinfection should be always performed, as bacterial contamination may arise form contact with faecal matter, or, in general, with organic matter which undergoes biological decomposition.

Natural environment contains numerous microorganisms. Most of these present no concerns. However, some protozoans (e.g.: Giardia lamblia), worms (or Helminths) various viruses and bacteria, can be present in water supplies, can cause severe diseases in humans. These disease-causing organisms are known as pathogens. Because pathogens can be present in drinking water supplies, disinfection is very important—the EPA requires it for surface water and groundwater under the influence of surface water.

Disinfection treatment methods include:

chemical disinfection, which is obtained by dosing chemicals, such as chlorine gas or hypochlorites, chlorine dioxide, ozone, peroxiacetic acid (also named peracetic acid)

physical methods, such as ultraviolet light irradiation.

When combined with conventional treatment, such as coagulation, flocculation, sedimentation, and filtration, good results have been obtained. Direct filtration, slow sand filtration, and diatomaceous earth filtration, along with disinfection, have been just as successful. Helminth eggs and protozoans can successfully be removed by rapid sand filtration, rather than wit simple disinfection, as they are big enough to be retained within the sand bed.

Groundwater which contains iron and manganese has to be treated with oxidising agents to remove these metals by forming insoluble oxides, which can then be flocculated and removed by filtration. In fact, insoluble oxides form when chlorine, chlorine dioxide, or ozone are added to these systems. Both ozonation and chlorination may cause flocculation of dissolved organics, thus increasing turbidity and necessitating filtration. The effectiveness of disinfection is judged by analyzing for an indicator organism (e.g.: total coliform bacteria). These organisms are considered harmless, but their presence indicates that pathogens may also have survived.

Purpose of Water Chlorination

Just as water is close to being a universal solvent, so chlorine has nearly become in the last century a universal water treatment chemical. The primary objective of water supply chlorination is disinfection. Because of chlorine's oxidizing powers, it has been found to serve other useful purposes in water treatment, such as taste and odor control, prevention of algal growths, maintaining clean filter media, removal of iron and manganese, destruction of hydrogen sulfide, color removal by bleaching of certain organic colors, maintenance of distribution system water quality by controlling slime growths, restoration and preservation of pipeline capacity, restoration of well capacity, main sterilization, and improved coagulation by activated silica. None of the alternatives to chlorine have been able to compete with its versatility and relative ease of use.

Bacteria and other microorganisms may live by degrading organic matter. Therefore, whenever biodegradable organic matter is found in water, then there is an actual risk of microbial contamination. However, iron, manganese, and sulfur compounds may be present in groundwater and provide autotrophic organisms with the necessary energy for life. As these organisms die, they produce degradable organic matter, which, in turn, leads to further microbial contamination. Chemical treatment is always required for the removal of these compounds and associated organisms. Normally, the microbial content of the water extracted from a well is negligible when these compounds are absent. This is why special treatment with chlorine is usually required whenever groundwater and surface water are mixed in a distribution system. All the municipal water supplies today that are being chemically disinfected, at least 99 percent use chlorine. In 1881, the German bacteriologist Koch demonstrated under controlled laboratory conditions that pure cultures of bacteria could be destroyed by hypochlorite.

When a community water supply was changed from bad to excellent by adequate treatment, for every person saved from death by any waterborne diseases three other persons would be saved from death by causes, many of which were probably never thought to have any connection with, or to be especially affected or influenced by the quality of the public water supply. This change in death rate observation was known as Hazen theorem. Therefore, disinfection of public water supplies goes further than just the control of waterborne diseases (such as Typhoid Fever, Cholera, Amoebic Dysentery, Bacterial Gastroenterities, Toxigenic E.coli, etc). Bearing in mind that the sole purpose of disinfection of potable water is to destroy pathogenic organisms and thereby eliminate and prevent waterborne diseases.

The World Health Organization (WHO, 2006) believes that 80 percent of all intestinal illnesses in Third World countries is due to lack of sanitation and proper hygiene. The highest disease rate and death is from diarrhea, whose pathogen is commonly waterborne. The causative agent is most likely enterotoxigenic E. coli. Death from diarrhea is thought to be as a result of dehydration. Other symptoms produced by this coliform pathogen include but not limited to abdominal cramps, nausea, headache, vomiting, and fever. In all cases investigated, the primary cause is either poor or no sanitation, absence of disinfection, malfunction of equipment, or improper design.

In the USA, many safe drinking water practices today follow the Safe Drinking Water Act of December 1974 which resulted in improved surveillance of drinking water supplies. The provisions of this act apply to all water systems serving 15 connections or at least 25 individuals for a minimum duration of 60 days. This act was followed by the National Interim Primary Drinking Water Regulations created by EPA in 1975 and implemented in 1977. These regulations established maximum contaminant levels for specified microbiological and chemical contamination, as well as turbidity limits and monitoring frequency.

Chlorine Reaction

Chlorine gas (Cl_2) is dissolved either directly in water by a solution-feed chlorinator to form hypochlorous acid, or by a specially controlled process in a solution containing caustic to yield a hypochlorite bleach solution. The exception to these systems occurs when a direct gas feed chlorinator or Water Champ (it’s unique because it’s the only device on the market that pulls the chlorine gas directly from the chlorinator and into the process stream without the necessity for using an auxiliary injector at the point of application) is used. In these cases, chlorine gas is dispersed directly into the stream.

Hydrolysis of Chlorine Gas

Dissolution of chlorine gas into water produces an oxidizing agent HOCl (hypochlorous acid).When chlorine reacts with water, a special type of oxidation-reduction reaction takes place and also chlorine gas is dissolved in water, it hydrolyzes rapidly according to the following equation:

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

The rapidity of this reaction has been studied by many investigators. Complete hydrolysis occur in a few tenths of seconds at 18°C; and at 0°C, only a few seconds are needed. At atmospheric pressure and T = 20°C, the maximum solubility of chlorine is about 7395mg/L. However, if the solution is subject to a negative relative pressure (i.e. an absolute pressure below 1 atmosphere) chlorine gas solubility drops. Therefore, all systems that are not closed should be designed to avoid negative relative pressure conditions in the chlorinator solution lines. This prevents off-gassing at the point of application where a diffuser assembly is installed; otherwise, serious corrosion in the surrounding area could occur, as well as offensive chlorine odors.

Table 4-1 illustrate what happens in the chlorine solution discharge from a chlorinator ranging in feed rates to produce concentrations varying from 500 to 3500mg/L, at 15°C. It also demonstrates the necessity for maintaining a constant high concentration of chlorine (e.g., 1500-2000mg/L at a low pH in the generation of chlorine dioxide).

Table 4-1 Percent molecular chlorine and hypochlorous acid in a water solution buffered from pH 1 to 6 at 15°C at atmospheric pressure (Clifford White, 1999).

	Solution Concentration (mg/liter)									
	500		1000		1500		2000		3500	
pH	Cl_2	HOCl	Cl_2	HOCl	Cl_2	HOCl	Cl_2	HOCl	Cl_2	HOCl
1	54.30	45.65	64.67	35.25	69.94	29.95	73.29	26.57	78.91	20.89
2	17.66	82.31	27.41	72.52	33.95	65.93	38.78	61.05	49.70	49.97
3	2.48	97.51	4.73	95.25	6.79	93.17	8.68	91.26	13.57	86.28
4	0.26	99.72	0.52	99.46	0.77	99.20	1.02	98.45	1.76	98.19
5	0.026	99.74	0.05	99.71	0.078	99.68	0.104	99.66	0.181	99.58
6	0.000	97.68	0.005	97.67	0.008	97.67	0.010	99.67	0.018	97.66

Effect of pH

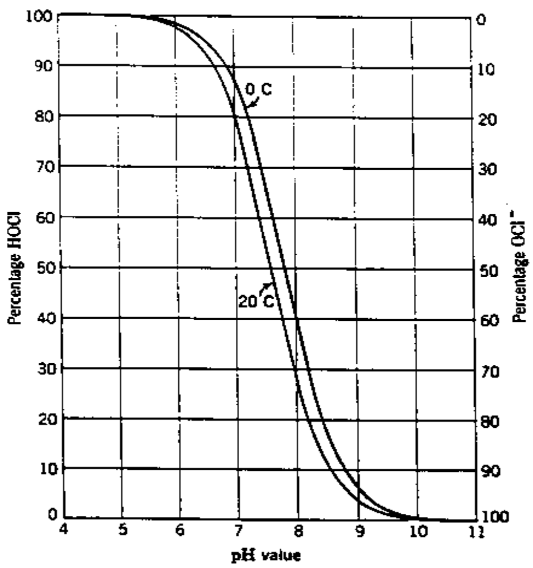
The most important reaction in chlorination of an aqueous solution is the formation of hypochlorous acid. This species of chlorine is the most germicidal of all chlorine compounds with the possible exception of chlorine dioxde.

Hypochlorous acid is a "weak" acid which means that it tends to undergo partial dissociation as follows:

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

to produce a hydrogen ion and a hypochlorite ion. In waters at pH between 6.5 and 8.5 the reaction is incomplete, and both species are present to some degree.

Figure 4.1 and Table 4-4 show the percent undissociated HOCl species for the various temperatures and pH values. The percent OCl^- ion is the difference between these numbers and 100. The percent distribution of the OCl^- ion (hypochlorite ion) and undissociated hypochlorous acid can be calculated for various pH values as follows:



$$\frac{(HOCl)}{(HOCl) + (OCl^-)} = \frac{1}{1 + \dfrac{(OCl^-)}{(HOCl)}} = \frac{1}{1 + \dfrac{K_i}{[H^+]}}$$

Figure 4.1: Dissociation of hypochlorous acid at variable pH at 0 and 20°C. (http://www.cepis.org.pe/bvsair/e/repindex/repi55_56/disdrink/dis.html)

Table 4-4 - Dissociation of hypochlorous acid at pH between 5 and 11.7 at variable temperature (0 - 30°C). (Clifford White, 1999)

	Percent HOCl						
pH	*0°C*	*5°C*	*10°C*	*15°C*	*20°C*	*25°C*	*30°C*
5.0	99.85	99.82	99.80	99.79	99.74	99.71	99.68
5.5	99.53	99.45	99.36	99.27	99.18	99.09	99.00
6.0	98.53	98.28	98.00	97.73	97.45	97.18	96.92
6.1	98.16	97.84	97.50	97.16	96.82	96.48	96.15
6.2	97.69	97.29	96.88	96.45	96.02	95.60	95.20
6.3	97.11	96.62	96.10	95.57	95.05	94.53	94.04
6.4	96.39	95.78	95.14	94.49	93.84	93.21	92.61
6.5	95.50	94.75	93.96	93.16	92.37	91.60	90.87
6.6	94.40	93.47	92.51	91.54	90.58	89.65	88.78
6.7	93.05	91.92	90.75	89.58	88.43	87.32	86.27
6.8	91.41	90.03	88.63	87.23	85.85	84.54	83.31
6.9	89.42	87.77	86.10	84.43	82.82	81.29	79.86
7.0	87.04	85.08	83.10	81.16	79.29	77.53	75.90
7.1	84.22	81.92	79.63	77.39	75.26	73.27	71.44
7.2	80.91	78.25	75.64	73.11	70.73	68.52	66.52
7.3	77.10	74.08	71.15	68.35	65.75	63.36	61.22
7.4	72.78	69.42	66.20	63.18	60.39	57.87	55.63
7.5	67.99	64.33	60.88	57.68	54.77	52.18	49.90
7.6	62.79	58.89	55.27	51.98	49.03	46.43	44.17
7.7	57.27	53.23	49.54	46.23	43.32	40.77	38.59
7.8	51.57	47.48	43.81	40.58	37.77	35.35	33.30
7.9	45.82	41.79	38.25	35.17	32.53	30.28	28.39
8.0	40.18	36.32	32.98	30.12	27.69	25.65	23.95
8.1	34.79	31.18	28.10	25.50	23.32	21.51	20.01
8.2	29.77	26.46	23.69	21.38	19.46	17.88	16.58
8.3	25.19	22.23	19.78	17.76	16.10	14.74	13.63
8.4	21.10	18.50	16.38	14.64	13.23	12.07	11.14
8.5	17.52	15.28	13.46	11.99	10.80	9.84	9.06
8.6	14.44	12.53	11.00	9.77	8.77	7.97	7.33
8.7	11.82	10.22	8.94	7.92	7.10	6.44	5.91
8.8	9.62	8.29	7.23	6.39	5.72	5.18	4.75
8.9	7.80	6.70	5.83	5.15	4.60	4.16	3.81
9.0	6.29	5.39	4.69	4.13	3.69	3.33	3.05
9.5	2.08	1.77	1.53	1.34	1.19	1.08	0.98
10.0	0.67	0.57	0.49	0.43	0.38	0.34	0.31
10.5	0.21	0.18	0.15	0.14	0.12	0.11	0.10
11.0	0.07	0.06	0.05	0.04	0.04	0.03	0.03
11.5	0.02	0.02	0.015	0.013	0.012	0.01	0.01
11.7	0.01	0.01	0.01	0.01	0.007	0.007	0.006

As the disinfecting agent is the undissociated acid, it can be concluded that the higher the pH, the higher the disinfecting action of chlorine. If the water that has to be treated did not contain nitrogenous compounds, the chlorination of water would be much simpler. Though nitrogen appears in most water natural waters and in varying amounts as either organic or inorganic. These nitrogen compounds and their relationship to chlorination will be considered in the general grouping as follows:

- Inorganic Nitrogen: Ammonia, Nitrite, Nitrate;
- Organic Nitrogen Amino Acids, Proteins.

The chemical state of any nitrogen compound found in nature is a function of time in the overall life processes of all plants and animals. The amounts of these various forms of nitrogen relates directly to the sanitary quality of the water to be treated. The reaction of chlorine with any compound containing the nitrogen atom with one or more hydrogen atoms attached will form a compound broadly classified as an N-chloro compound, or, more commonly, as chloramine. There are two distinct classes of chloramines —organic and inorganic. The inorganic chloramines are formed by the reaction of chlorine in an aqueous solution with ammonia N naturally occurring in the potable water or waste water being treated. When organic N is present in a drinking (potable) water system, it will react instantaneously with the free chlorine (HOCl), to form a non-germicidal organo-chloramine.

Chlorine residual

The goal of dosage testing is to determine how much sodium hypochlorite solution to add to water that will be used for drinking to maintain free chlorine residual in the water for the average time of local storage of water (typically 24 hours). This goal differs from the goal of infrastructure-based (piped) water treatment systems, whose aim is effective disinfection at the endpoints (i.e., water taps) of the system. The WHO (2006) recommends "a residual concentration of free chlorine of greater than or equal to 0.5 mg/L after at least 30 minutes contact time at pH less than 8.0." This definition is only appropriate for users who obtain water directly from a flowing tap. A free chlorine level of 0.5 mg/L can maintain the quality of water through a distribution network, but is not optimal to maintain the quality of the water when it is stored in the home in a bucket or jerry can for 24 hours.

Recommendations:

1. At 1 hour after the addition of sodium hypochlorite solution to water there should be no more than 2.0 mg/L of free chlorine residual present (this ensures the water does not have an unpleasant taste or odor).

2. At 24 hours after the addition of sodium hypochlorite to water in containers that are used by families for water storage there should be a minimum of 0.2 mg/L of free chlorine residual present (this ensures microbiologically clean water).

This methodology is approved by the WHO (2006), and is graphically depicted below (Figure 4.2). The maximum allowable WHO value for free chlorine residual in drinking water is 5 mg/L. The minimum recommended WHO value for free chlorine residual in treated drinking water is 0.2 mg/L. Center for Disease Control (CDC) recommends not exceeding 2.0 mg/L due to taste concerns, and chlorine residual decays over time in stored water.

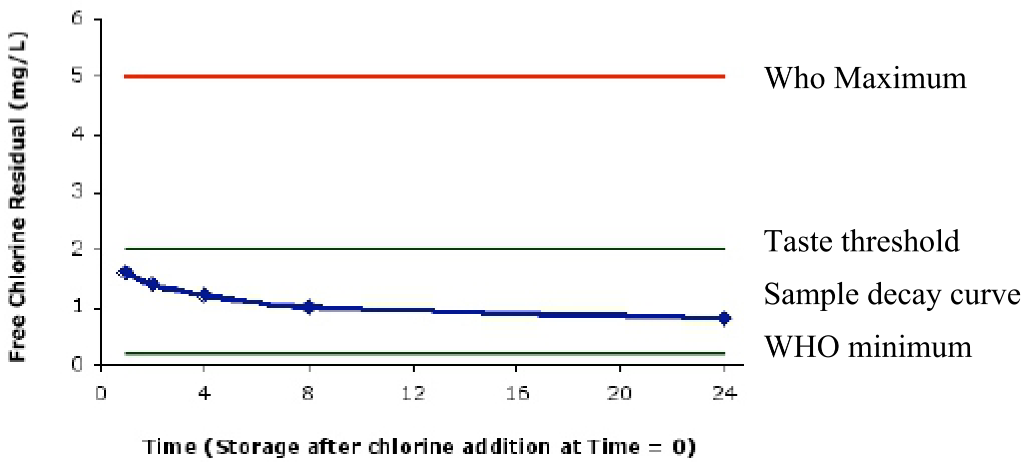


Figure 4.2: Sample chlorine decay curve with time (in hours)

Determination of chlorine residuals in water

When chlorine compound were first introduced, about 1902, as a means of water disinfection, the only method available for testing residual chlorine was the starch –iodide one. Until about 1930 the use of chlorine in water treatment was increasing at a tremendous rate. This inspired more and more studies of the various phenomena of controlling the application of chlorine. The most important development in the method of measuring chlorine residual was the amperometric method, first introduced for measuring chlorine residuals in 1942.

The amperometric test was refined to give a better discovery of the breakpoint phenomenon of chlorine residual. This breakpoint phenomenon revealed that there was more than one kind of chlorine residual. The types were identified as Free available and Combined chlorine residuals.

Figure 4.3 below illustrates the amount of titrable free chlorine residual required to produce 1.0mg/L HOCl. At pH 8.5mg/L titrable free residual is required to produce 1mg/L undissociated HOCl. If the pH were 7.5, only 2mg/L of titrable free chlorine residual would be required to yield 1mg/L HOCl, etc. The effects of the pH on the free residual process affects the selection of chlorine dosage, as can be seen from the following example. It is generally conceded that a free chlorine residual is the most reliable for the destruction. It is generally assumed that it takes about 0.3mg/L of undissociated HOCl residual to inactivate Coxsackie A2 virus and chronic bacterial infections after 20 min contact time. At the City of Phoenix Municipal Water System, water quality data are the following: pH, 7.8-8.6; hardness as CaC03, 150-200mg/L; turbidity, 5-30 NTU; and seven-day THM formation potential, 0.20-0.25mg/L. Disinfection of this Municipal water is: 2.5-4.0mg/L of chlorine to produce a free residual in the settled water and additional chlorine can be applied to either the settled or filtered water so that a free residual of 0.8-1.2mg/L is carried into the distribution system.

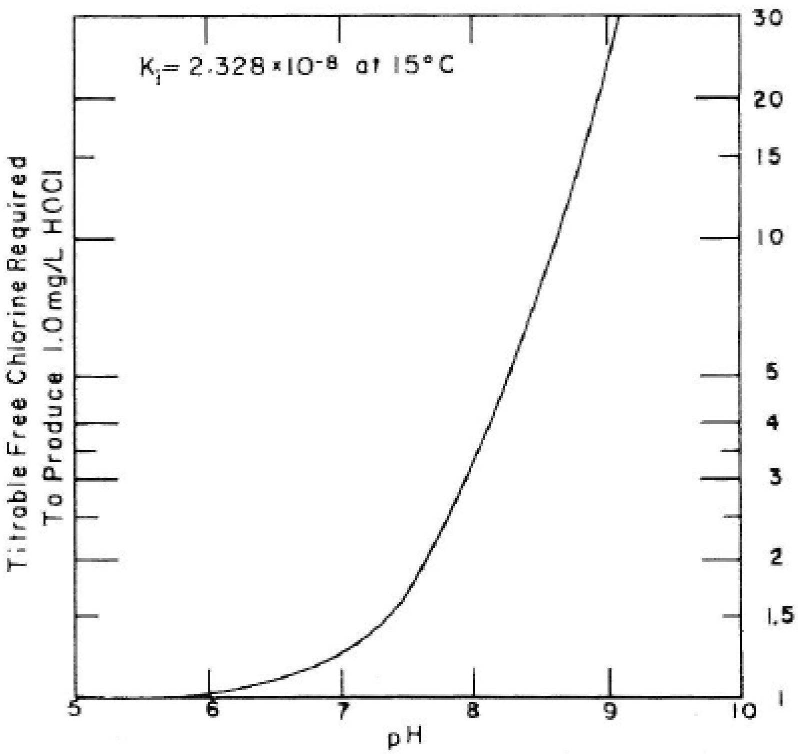


Figure 4.3: Effect of pH on the formation of hypochlorous acid (Clifford White, 1999).

If the pH of the water to be treated is 8.5, then 10mg/L of titrable chlorine is required to produce 1.0mg/L undissociated HOCl (Figure 4.3). The free chlorine residual required at this pH level will be 10 × 0.3 or 3 mg/L. This then is the minimum dose that will be required to provide 0.3 mg/L of 100 percent undissociated HOCl at the end of 20 min.

The presence of free chlorine residual in drinking water indicates that: 1) a sufficient amount of chlorine was added to the water to inactivate most of the bacteria and viruses that cause diarrheal disease; and, 2) the water is protected from recontamination during transport and storage. Because the presence of free residual chlorine in drinking water indicates the likely absence of disease-causing organisms, it is used as one measure of the portability of drinking water (source: http://iwawaterwiki.org/xwiki/bin/view/Articles/ChlorineResiduals)

Testing free chlorine is recommended in the following circumstances:

- To conduct dosage testing in project areas
- To monitor and evaluate projects by testing stored drinking water in households

Role of inorganic and organic Nitrogen

If ammonia nitrogen is present in the water, chlorine reacts rapidly with it to form mono and dichloramine. These compounds will appear in the combined residual. Depending upon the factors of concentration and ration of chlorine to ammonia nitrogen, NCl3 (nitrogen trichloride) may form, which causes an offensive odor at the tap. The speed of reaction between chlorine and ammonia nitrogen to produce a free residual varies from water to water because this reaction is not only temperature and pH dependent, but is grossly affected by the concentrations of both chlorine and ammonia N. In the free residual process, sufficient chlorine must be added to destroy the ammonia nitrogen, which occurs when the ratio of chlorine to ammonia nitrogen (as N) is about 10:1 by weight. However, the stoichiometric ratio (theoretical) is 7.6:1. In practice it is known to vary from 8.5:1 to 11:1.

Organic nitrogen in concentrations as low as 0.3 mg/L (Figure 4.4) will seriously interfere with the chlorination process, and looms as a formidable obstacle in producing an acceptable water. Organic nitrogen in a potable water is a direct result of wastewater contamination. However, there is thought to be a significant amount entering surface supplies due to natural runoff that leaches and dissolves organic compounds from industrial waste dump sites. The source of most organic nitrogen compounds is proteinaceous matter and urine, both of which are present in copious quantities in all domestic wastewater discharges. Urine contains substances that react with chlorine to form extremely stable N-chloro compounds that titrate as dischloramine by either the amerometric method or the DPD method of residual analysis, but are nongermicidal.

A minimum free chlorine residual of 0.2 mg/L should be sufficient to maintain disinfection, provided that enough contact time (at least 30 min) has been allowed in the disinfection tank. Chlorine residual over 1.0 mg/L may lead to bad taste. Also, higher concentrations of chlorine in water can cause health-related problems. The concentration of free chlorine is usually in the range of 0.2 mg/L (e.g. EU regulations for drinking water) up to 2 mg/L in US cities (http://www.speclab.com/elements/chlorine.htm). Higher free chlorine residual require an expensive de-chlorination treatment with the dosage of a reducing agent such as sulfur dioxide or sulfurous salts. The WHO drinking water standards states that 2-3mg/L chlorine should be added to water in order to gain satisfactory disinfection and residual concentration. The maximum amount of chlorine one can use is 5mg/L. For a more effective disinfection the residual amount of free chlorine should exceed 0.5mg/L after at least 30 minutes of contact time at a pH value of 8 or less (WHO, 2006).

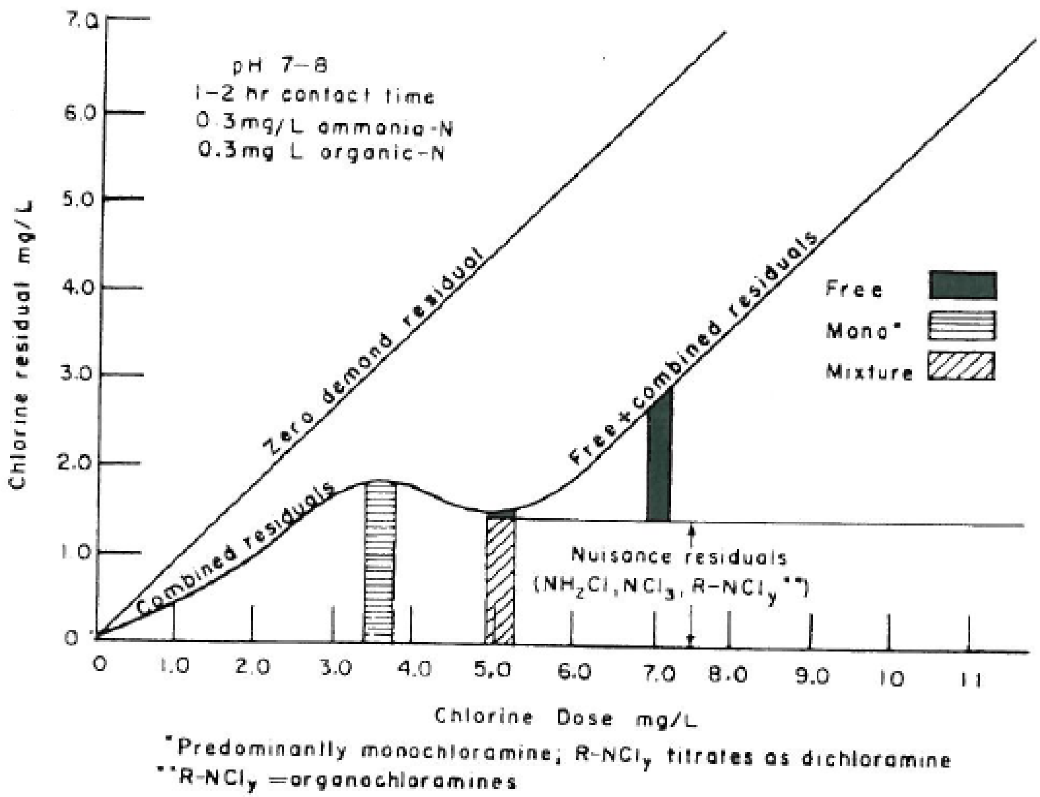


Figure 4.4: Chlorination of water containing organic N and ammonia N (Clifford White, 1999).

Another consideration of the free residual process is the effect of sunlight on HOCl. While it is a relatively stable compound in that it resists loss due to aeration, losses due to bright sunlight have been reported as high as 2mg/L HOCl in 4 hours. Chloramines act in reverse fashion; they do not suffer appreciable loss due to sunlight but are subject to losses as high as 15 percent of the residual by aeration. If nitrogen trichloride is present, all of it is quickly lost because of either sunlight or aeration or both.

Maximum Trihalomethane Potential

The potential for the formation of Trihalomethanes (THMs) is directly related to the chlorine demand. Trihalomethanes are formed by the reactions between natural organic compounds (humic and fulvic acids) in the environment, naturally occurring bromides, and chlorine used in the water treatment processes. One of the techniques to determine the potential THM formation is a procedure long known as the “chlorine demand” of water. In case of THM formation the recommended procedure is to add sufficient chlorine to the sample so that a measurable free chlorine residual will persist for at least seven days.

The total trihalomethane (TTHM) concentration is measured at daily intervals. These concentration are plotted to generate a TTHM curve. When the curve reaches a plateau, that is the maximum THM potential (MTP, micrograms per liter). Each water supply will react differently to the chlorine demand test. Chlorine dosages to provide a measurable free chlorine residual to produce a plateau will vary from 2 to 20mg/L, and the reaction time may be from 5 to 15 days. These variations will be a function of the water quality and the nature of the concentration of the precursors. THM potential is in measured in micrograms per liter. Today, THM formation has been reduced by either ozone or any other improvement in the pretreatment processes, so that the overall chlorine demand can be greatly reduced.

Methods to Test Free Chlorine in the Field in Developing Countries.

There are four main methods to test free and total chlorine residual in drinking water in the field in developing countries:

1) Pool test kits;

2) Color-change test tubes;

3) Color-wheel test kits; and,

4) Digital colorimeters.

All four methods depend on a color change to identify the presence of chlorine, and a measurement of the intensity of that color to determine how much chlorine is present. This article does not consider commercial test strips for chlorine residual testing, because of their relatively higher cost (0.15-1.00 USD) per test. When only a small number of tests are needed it is possible that commercial test strips could be a viable, cost-effective option.

1. Pool test kits. The first option for chlorine residual testing uses the liquid chemical OTO (othotolidine) that, when added to water with total chlorine in it, causes a color change to yellow. To complete the test, users simply fill a tube with water, add 1-5 drops of the solution, and look for the color change to yellow. These kits are sold in many stores as a way to test the concentration of total chlorine in swimming pool water. This method does not measure free chlorine.

Benefits of the pool test kits are:

- Low cost
- Very easy to use
- Easily purchasable

Drawbacks of the pool test kits are:

- Degradation of the OTO solution can cause inaccurate readings over time
- Generally not reliable quantitative results
- Lack of calibration and standardization
- Measurement of total chlorine, not free chlorine

Cost and Ordering Information. Pool test kits can be obtained from many home supply and pool stores at a cost of approximately $5-20 each.

2. Test-tube DPD color comparator. The Lamotte Company developed a rapid presence/absence test kit for free chlorine residual in response to the 2004 Tsunami in Indonesia. The test tube color comparator uses DPD (N,N diethyl-p-phenylene diamine) tablets that causes a color change to pink in the presence of chlorine. To use the kit, users add 5 mL of water to the test tube, add one rapidly dissolving DPD-1R tablet, and compare the results to a color chart. This kit combines the simplicity of the pool test kits, with the benefit of testing for free chlorine residual instead of total chlorine residual. To use this kit to measure total chlorine, a DPD-4R tablet can be added instead of the DPD-1R tablet to the water sample, or a DPD-3R tablet can be added to the sample water after the DPD-1R tablet has been added and the free chlorine residual has been read. The test kit is not available as a package, but the individual components (test tube, DPD tablets, and color chart) can be ordered individually. Test kit instructions and part numbers can be found at: http://www.lamotte.com/pages/common/pdf/instruct/3529.pdf.

Benefits of the test tube kit are:

- Low cost
- Very easy to use
- Measurement of free chlorine

Drawbacks of the test tube kit are:

- Generally not reliable quantitative results
- Lack of calibration and standardization

Cost and Ordering Information. The kit parts are available from the Lamotte Company (www.lamotte.com) for a cost of approximately US$5 for both the test tube and color comparator chart, and approximately US$70 for 1,000 DPD tablets.

3. Color wheel test kits.

Color wheel test kits also use DPD tablets or powder that, when added to water with free or total chlorine present in it, cause a color change to pink. The color wheel test kits are more accurate than the pool test kits / test tube DPD color comparators and simpler and less expensive than digital meters. This is because users measure the intensity of the color change, as compared with a sample of water to which no DPD has been added, using a color wheel to visually match the color change to a numerical reading. The test kit can be used to measure either free chlorine or total chlorine, or both, generally within a range of 0-3.5 mg/L, equivalent to 0-3.5 ppm (parts per million). Please note that DPD tablets and powders are company specific, and that using one company's test kit with another company's DPD tablets is not recommended. Also note that although all DPD-1 tablets measure free chlorine, there is variation between companies as to whether the total chlorine tablet is added to the same sample water the free chlorine is tested in or whether it is added to fresh sample water.

Benefits of the color-wheel test kits are:

• Accurate quantitative readings if used correctly

• Low cost

Drawbacks of the color-wheel test kits are:

• Potential for user error

• Lack of calibration and standardization

Cost Information. Color wheel test kits costs are in the range of US$44 – 55.

Additional DPD tablets or powders can be ordered as well, at a cost of approximately US$70 per 1,000 tablets or sachets.

4. Digital Colorimeters - Digital colorimeters are the most accurate way to measure free chlorine and/or total chlorine residual in the field in developing countries. To use the colorimeters:

1) a DPD-1 (free chlorine) or DPD-3 (total chlorine) tablet or powder is added to a vial of sample water that causes a color change to pink; and,

2) the vial is inserted into a meter that reads the intensity of the color change by emitting a wavelength of light and automatically determining and displaying the color intensity (the free or total chlorine residual) digitally.

The range of the meters is generally 0-4 mg/L, equivalent to 0-4 ppm (parts per million). Please note that DPD tablets and powders are company specific, and that using one company's test kit with another company's DPD tablets is not recommended.

Benefits of the digital colorimeters are:

• Highly accurate readings

• Fast results

• EPA approved

Drawbacks of the digital colorimeters are:

• Expensive

• Need calibration with standards

• Need for skilled operator

Cost information. Digital colorimeters may cost from US$70 to $350. Additional DPD tablets or powders can be ordered as well, at a cost of approximately $70 per 1,000 tablets or sachets.

The role of contact time

For the germicidal efficiency of chlorine both contact time and concentration of chlorine (free available chlorine residual or combined available chlorine residual) are very important. The required contact time can be determined by laboratory results by testing the micro-organisms that are still alive after exposure to a certain amount of free chlorine at different times. Most waterborne diseases are susceptible or extremely resistant to chlorination. Chlorination has been found to be effective at 1-2mg/L dosage level. Precise data for contact time and free residual are not available.

Institutions, hotels, and so on, should make it a practice to sterilize there water systems on a regular bases, similar to the recommended practice of main sterilization. This could be as frequently as once each six months. Water supply whose systems have large holding reservoirs should be aware that Legionellae can work in such environments. Another example is Giardia cysts are extremely resistant to chlorine (4 mg/L and 60 min contact time to kill all cysts in a chlorine-demand free solution at pH levels of 6, 7, 8 at 5°C).

As excessive chlorine concentration may have harmful effects on human health and on the environment and may cause bad taste and odors, worm eggs and protozoan cysts (like Giardia and Cryptosporidium cysts) should be removed by rapid sand filtration, so that chlorination will be reserved for bacterial and virus removal only. A typical example of a drinking water supply treatment train is depicted in Figure 4.5. The example shown in Figure 4.5 can be applied to water taken from surface water bodies, where filtration is always needed. When water is taken from wells and it is already clear (low turbidity, no suspended solids), clari-flocculation and filtration sections are not needed.

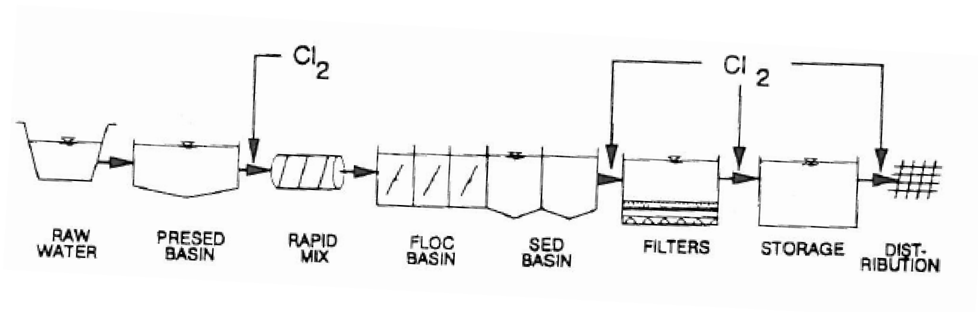


Figure 4.5: Example of surface water treatment train for the production of drinking water, Phoenix Municipal Water system (Clifford White, 1999)

Chlorination Equipment

If sodium hypochlorite is used instead of chlorine gas, the storage and dosing system is safer, cheaper and simpler. Where sodium hypochlorite can be easily supplied, then, a fiberglass reinforced plastic (FRP) storage tank and a timer-driven dosing pump are the only equipment needed.

Where the supply of sodium hypochlorite is difficult, then it may be produced onsite and the raw material that is needed is salt. Electrochlorination is a simple and proven technology to convert ordinary salt water (or brine or seawater) into Sodium Hypochlorite by means of Electrolysis. It is produced and applied on-site. The device which uses this technology is named as Electrochlorinator or Onsite Hypo Generator. Of course an energy source is needed to supply the electrolyser cell (Figure 4.6). Electrochlorinators find application where Chlorine is not readily available or where operation with chlorine is not acceptable. Electrochlorinators therefore, find application in Drinking Water Treatment, Cooling Water Treatment, Waste Water Treatment, Bleaching, Pharmaceutical formulations and other industrial applications.

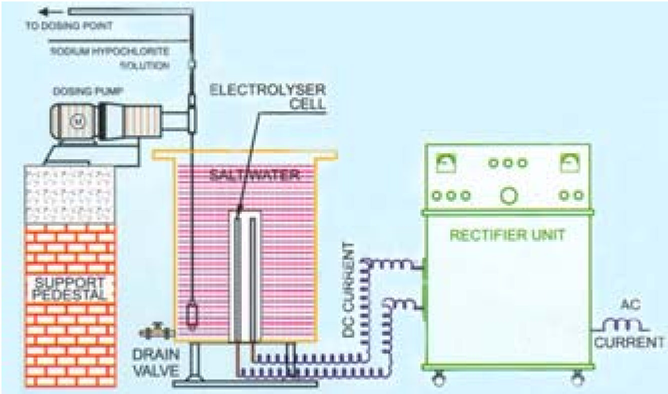


Figure 4.6: An Electrochlorination system
(source: http://www.perfectchloro.com/electrochlorine.htm)

Depending upon the mode of operation, electrochlorinators are classified into two types namely Batch Production Electrochlorinators with capacity from 15 g/h to 500 g/h and Continuous Production Electrochlorinators with capacity ranging from 15 g/h to 15 kg/h.

Description. Batch production electrochlorinators are designed for small capacities and are available from 15 g/h to capacity of 500 g/h chlorine equivalent, using our unique Multimetallic Oxides Titanium Nobel Anodes and Electrochemical process. Production of Sodium hypochlorite is completed in a batch of every 8 hours, to concentration of around 6-8 g/L.

Basic System Components: Electrolyser cell, alternate/continuous current rectifier, storage tank and dosing pump.
Operation: A metered amount of water is mixed with common salt to form brine of required concentration [or Seawater is used]. This is the electrolyte used in the process. Electrolyser cells are dipped in this measured quantity of Brine Solution, contained in a FRP tank, internally lined with an epoxy-resin (Bisphenol Resin). These cells are connected to a rectifier, which converts Alternate current to Direct current. When DC Current passes through these Titanium Anodes with MMO Coating, Sodium Hypochlorite evolves instantaneously with negligible quantities of hydrogen rising up to the surface, which is vented out. This process is based on the chemistry of Electrolysis of Sodium Chloride. The Sodium Hypochlorite thus generated is collected in a storage Tank and applied directly or pumped to the point of application.

Water Quality in the Study Area

Water analysis was carried-out at **Abakiliki University** and **Isiagu Community** (all in Ebonyi State of Nigeria) to determine the suitability of the borehole water for human consumption. The results of the analytical campaign are shown below:

Abakiliki University

Results of test carried-out on 23rd March 2010 at Ebonyi State University Abakaliki. This result was needed by the governing council of the University for the purpose of drinking water provision in the university.

RESULT OF CHEMICAL ANALYSIS:

Parameter	Well Water	Stream Water	Borehole Water	WHO 1993	EU 1998
pH	6.40	7.04	7.41	6.5 – 9.5	6-9
Hardness (mg/l)	4.79	4.78	2.43	NG	NM
Sulphate (mg/l)	0.78	12.98	0.79	500	250
Nitrate (mg/l)	3.74	5.56	3.65	50	50
DO (mg/L)	4.98	5.97	3.99	NG	NM
BOD (mg/l)	20.00	8.00	12.00	NG	NM
Conductivity (µS/cm)	18.0	16.00	16.00	250	250
Chloride(mg Cl/l)	14.90	17.70	10.71	250	250
Arsenic (mg As/l)	0.002	0.0021	0.001	0.05	0.50
Cadmium (ug Cd/l)	0.25	1.02	0.63	5.0	5.00
Calcium (mg Ca/l)	0.22	0.10	0.01	200	200.0
Fluorides (mg F/l)	0.005	0.034	0.0023	1.5	1.5
Iron Total (mg Fe/l)	0.003	0.005	0.001	0.3	3.00
Lead (mg Pb/l)	0.0003	0.004	0.0001	0.01	0.50
Sodium (mg Na/l)	0.59	9.22	0.67	200	200.0

RESULT OF MICROBILOGICAL QUALITY ANALYSIS:

Parameter	Well Water	Stream Water	Borehole Water	WHO 1993	EU 1998
Total Heterotrophic count (cfu/ml)	1.14×10^4	2.06×10^4	6.4×10^3	NM	NM
***Clostridium perfringens* spore (cfu/100mL)**	0	0	0	NM	NM
Faecal coliform (cfu/100ml)	15/100 ml	25/100 ml	0	NM	0 in 100ml
***Salmonela* (cfu/ml)**	0	0	0	NM	NM
***E. Coli* (cfu/ml)**	0	4.0×10^1	0	NM	0 in 250ml
***Vibrio* (cfu/ml)**	0	0	0	NM	NM

RESULT OF PHYSICAL/ORGANOLEPTIC ANALYSIS:

Parameter	Well Water	Stream Water	Borehole Water	WHO 1993	EU 1998
Colour (TCU)	0	0	0	15	15
Odour	0	0	0	Unobjectionable	Unobjectionable
Taste	0	0	0	Unobjectionable	Unobjectionable
Temperature ^{0}C	-16.666 (2F)	55 (131F)	-12.222 (10F)	Ambient	Ambient
Turbidity (NTU)	0	2	0	5	NM

NM = Not Mentioned

NG = No Guideline

NTU = Nephelometric Turbidity Units

Isiagu Community

Anason Laboratory Services EBONYI STATE NIGERIA

Results of test carried-out on 21st July 2010 at Isiagu community in Ebonyi State of Nigeria. The result of this test was needed by Chie Joseph Nwaodika (a professional politician) for soio-economic development of the community.

RESULT OF CHEMICAL ANALYSIS:

Parameter	Well Water	Stream Water	Borehole Water	WHO 1993	EU 1998
pH	7.44	7.45	7.42	6.5 – 9.5	6-9
Hardness (mg/l)	5.09	5.58	2.30	NG	NM
Sulphate (mg/l)	1.78	10.13	1.32	500	250
Nitrate (mg/l)	2.54	4.51	2.15	50	50
DO (mg/L)	3.90	3.37	3.09	NG	NM
BOD (mg/l)	20.21	8.92	12.18	NG	NM
Conductivity (µS/cm)	17.16	15.11	10.11	250	250
Chloride(mg Cl/l)	12.18	16.90	11.74	250	250
Arsenic (mg As/l)	0.045	0.0026	0.005	0.05	0.50
Cadmium (ug Cd/l)	0.25	1.02	0.63	5.0	5.00
Calcium (mg Ca/l)	0.25	0.12	0.009	200	200.0
Fluorides (mg F/l)	0.046	0.026	0.0030	1.5	1.5
Iron Total (mg Fe/l)	0.02	0.044	0.021	0.3	3.00
Lead (mg Pb/l)	0.0022	0.040	0.0001	0.01	0.50
Sodium (mg Na/l)	0.25	7.23	0.50	200	200.0

RESULT OF PHYSICAL/ORGANOLEPTIC ANALYSIS:

Parameter	Well Water	Stream Water	Borehole Water	WHO 1993	EU 1998
Colour (TCU)	0	0	0	15	15
Odour	0	0	0	Unobjectionable	Unobjectionable
Taste	0	0	0	Unobjectionable	Unobjectionable
Temperature ^{0}C	15	25	15	Ambient	Ambient
Turbidity (NTU)	0	6	0	5	NM

NM = Not Mentioned **NTU** = Nephelometric Turbidity Units **NG** = No Guideline

RESULT OF MICROBIOLOGICAL ANALYSIS

Parameter	Well Water	Stream Water	Borehole Water	WHO 1993	EU 1998
Total Heterotrophic count (cfu/ml)	2.79×10^4	3.00×10^4	5.5×10^3	NM	NM
***Clostridium perfringens* spore (cfu/100mL)**	2.20×10^2	2.10×10^4	0	NM	NM
Faecal coliform (cfu/100ml)	17/100 ml	22/100 ml	0	NM	0 in 100ml
***Salmonela* (cfu/ml)**	0	4.20×10^2	0	NM	NM
***E. Coli* (cfu/ml)**	0	3.61×10^4	0	NM	0 in 250ml
***Vibrio* (cfu/ml)**	0	0	0	NM	NM

From the water analysis shown above, it can be seen that the average **pH is 7.4** at an average **temperature of 20°C** and the average turbidity value is 0.7 NTU, which means that borehole water is very clear .

However, a high number of heterotrophic bacteria such as ***Faecal Coliforms*** are present and, moreover, **BOD** (i.e. the concentration of biodegradable matter expressed as Biochemical Oxygen Demand) is very high for both the well and the stream waters. Also, the presence of ***Salmonella*** and ***Clostridium perfringens*** in the Isiagu water confirms the presence of pathogenic microorganisms.

As BOD is high in the borehole water, it can cause severe bacterial growth downstream of the well, in the storage reservoir and in the pipes, creating favorable conditions for the growth of pathogens.

Also, if biodegradable organic matter (expressed as BOD) and heterotrophic bacteria are both present, this means that contamination is derived from biodegradable organic matter in the area where the borehole water is originated. This may also suggest that wastewater and organic wastes are not properly managed and that biodegradation and putrefaction may affect the areas where water infiltrates in the aquifer.

Disinfection is therefore necessary, but it should be coupled with improved sanitation to further reduce the risk of waterborne diseases.

CHLORINATION

Following the considerations reported above, the appropriate disinfection to be carried out is Chlorination.

Chlorination is highly needed to eliminate any potential waterborne diseases that may occur as a result of the presence of the Faecal Coliforms and the BOD (Total Heterotrophic count).

And also considering the nature of our study area (literacy level, life style, poverty etc), the usage of Chlorination becomes paramount to other disinfection methods as chlorine is readily available (as in gas, liquid or powder), its cheap, widely available, effective, its easy to apply due to relatively high solubility (7000mg/L), It leaves a residual in solution, which will not be harmful to man (as it provides protection in the distribution system) and its toxic to most microorganisms that are interfering with metabolic activities as its very effective even at a low dose.

Though other disinfection methods (such as Ultraviolet, Ozone, Peracetic acid, chlorine dioxide) can as well be used, but in this study area (area characterized with the high rate of gastrointestinal diseases, compounded by the poor living conditions of the population, deficient in hygiene and sanitation, with high scanty economic resources and very low educational standards), it will be very expensive to used **ultraviolet or ozone** and also these methods does not have any disinfection residual that is very vital to keep the water safe in the distribution network and also these two methods does not have a technical database on how well these system perform for various water quality conditions. **For peracetic acid**, its has a high cost (though this has been attributed to limited production capacity worldwide), there is increase of organic content in the effluent due to acetic acid (AA) and thus in the potential microbial re-growth (acetic acid is already present in the mixture and is also formed after peracetic acid decomposition). **For chlorine dioxide**, its 5-10 time more expensive than chlorine (the cost depends on the chemicals that are used to produce chlorine dioxide), and also chlorine dioxide is generally effective for the deactivation of pathogenic microorganisms but less effective for the deactivation of rotaviruses and E.coli bacteria and also chlorine dioxide and its disinfection by products chlorate and chlorite creates problems for the dialysis of patients. Peracetic acid and Chlorine dioxide can effective deactivate viruses and bacteria at a high dose which if not effectively applied can create mutilple health dialysis problem to patients.

Water is the principal vehicle for the transmission of gastrointestinal diseases, mainly typhoid and paratyphoid fever, salmonella, dysentery, and cholera. The best way to prevent these infections is by water disinfection, and the most economic means is the use of chlorine.

Sodium hypochlorite solution or Solid calcium hypochlorite (Chlorination) dosage is required for the disinfection of water for the community consumption.

Proper dosage will be achieved by measurement of free residual chlorine as explained in the previous section.

For the disinfection to take place, the following initial investigation has to be taken:

Ammonia N and Organic N. The concentration of these two items are the first to be analyzed. Their values will be of great help in deciding if they may be causing any interference in the analytical measurements of the Chlorine residuals.

Chlorine Demand. This value is most important for the system operator to obtain. It is vital to the final determination of the problem, if any. First, use the following list of dosages; 1, 2, 3, 4, and 5mg/L. Then analyze the residuals of these dosages at the end of 10, 20, 30, and 60 min. by either the complete forward amperometric titration method or the DPD method.

If there is 0.1mg/L or less of ammonia N, 0.1mg/L monochloramine in the residual, and any dichloramine residual, this indicates that the dichloramine residual is really a nongermicidal organochloramine, owing to the organic N content in the water sample.

All the above serves to orient the operator in the proper way to handle the chlorination system.

The Chlorine Demand x Contact Time = Ct Factor

This is the most important variable for determining or predicting the germicidal efficiency of any disinfectant. It has been used most successfully by the wastewater dischargers in California since the 1979s. The chlorine demand (C) of the water or wastewater to be examined is the most important part of this factor. The lab technician should determine the C demand for a variety of contact (t) times to evaluate which will be the most suitable for the particular water being tested, as shown above.

Potable water may be contaminated by variety of pathogenic organisms. These include, but are not limited to enteric viruses, protozoans, and cysts that could be responsible for waterborne diseases outbreaks. Owing to this dilemma, it is extremely difficult to choose a “consensus’’ organism. Such an organism would have to be easily identifiable, and its inactivation rate would have to be similar or equal to that of the most resistant organism that causes a waterborne disease outbreak.

Currently the EPA has developed Ct values for Giardia cysts, enteric viruses and faecal coliforms. Given that a Ct values has been established for a series of organisms known to cause waterborne outbreaks, there are other factors that affect the Ct factor, as follows:

1. **The chlorine species to be found in the residual C is important**. There is a great deal of difference between the disinfecting power of free chlorine and that of monochloramine. Therefore, the Ct value has to be determined on the basis of a given species. If organic N is present in the raw water, then the nongermicidal organochloramine residual must be accounted for.
2. **The contact time, t, is as important as C**. The method of determining contact that provides the greatest factor of safety is to use a **tracer.** Apply the tracer at the proposed point of disinfectant application, and record the time required for the first appearance of the tracer at the end of the contact chamber. This is in full practice in California for wastewater dischargers. The tracer used is **Rhodamine B dye**. Another common method is to provide a **chlorine spike** at the point of application, and time the appearance of the spike at the analyzer sampling the discharge from the contact chamber.
3. **Water temperature has a significant effect on the inactivation of these organisms**. The lower the temperature is, the lower the disinfection efficiency.
4. **pH is a consideration**. When free chlorine is required, it is essential to maintain the water being disinfected at a reasonably steady pH between 7.0 and 7.5. In potable water treatment this range has been found to be the most effective for disinfection by free chlorine.
5. **The effect of sunlight is a factor**. When free chlorine is required, and if the contact chamber is exposed to sunlight, there will be a significant loss of chlorine residual from the sunlight (UV rays). This phenomenon varies with both latitude and altitude as well as cloud cover. Therefore, residual control is imperative. There also has to be a programmed dosage change to account for the lack of UV rays after sundown.
6. **The contact chamber design is very important**. If the contact chamber is going to be an open channel type, it must be designed to achieve 85-90 percent plug flow conditions. This minimizes short-circuiting. The preferred design, particularly when free residual chlorination is being practiced, is a closed conduit with a slight surcharge. Closed pipes flowing full can easily achieve 97 percent plug flow conditions and, at the same time, eliminate loss of residual to sunlight.

7. **Adequate mixing at the point of chlorine application is as desirable as plug flow conditions in the contact chamber**.

If this concentration of Free chlorine stated above is present in the waters (Abakiliki and Isiagu waters etc) with the specified contact time, the water will be well disinfected, and well enough for human consumption.

Disinfection Measures

Problems and failures in chlorination need to be avoided by taking proper actions (**Figure 4.7**; see for example: Lazcano, 1998 and Vargas Garcia, 1998).

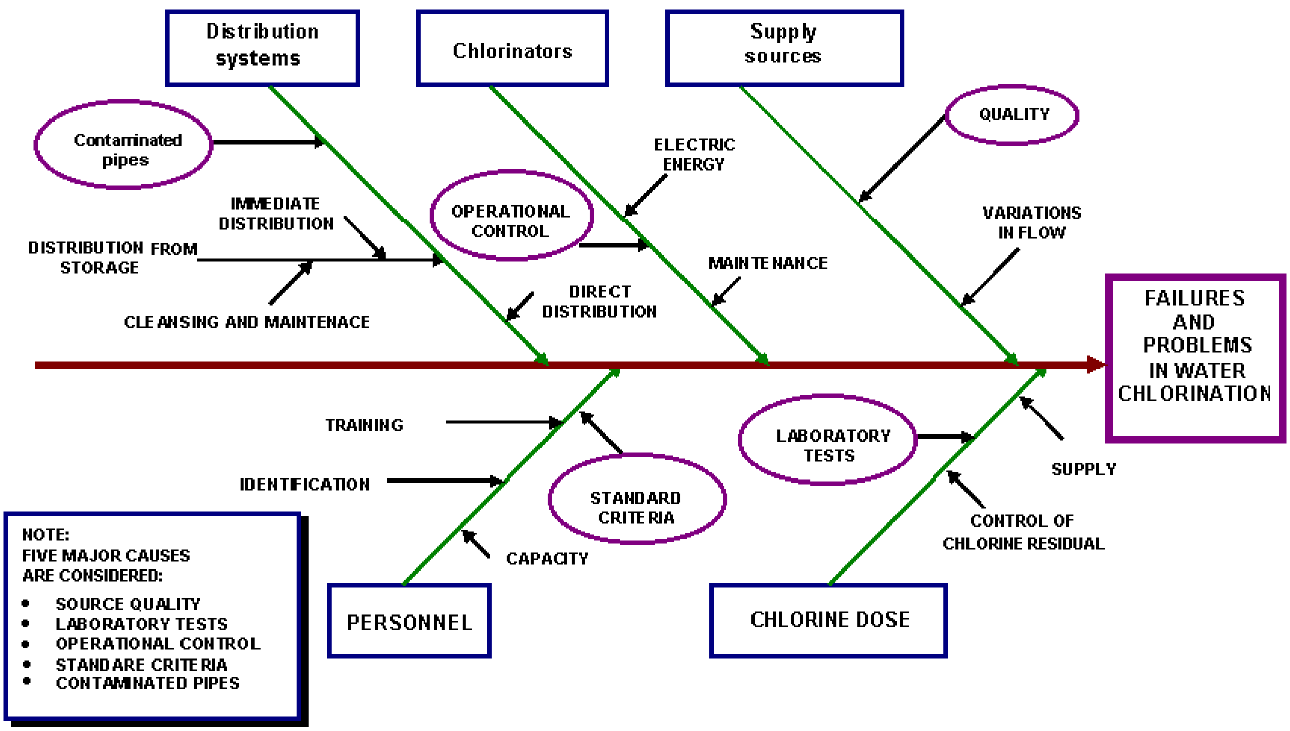


Figure 4.7: Causes of problems and failures in Urban Chlorination (Lazcano, 1998)

The measures are:

***SUPPLY SOURCE**: The supply source of water should be free from contamination as this will help to reduce the concentration of living organisms that reach the water treatment plant, including pathogens that get to the reservoir were the chlorination takes place. The community should ensure that the wells (pipes as well) that supply water to the reservoir where the chlorination takes place should be devoid of contamination. The community should have laws to protect water sources as this water is mainly for human consumption. However, as some contamination can be endemic and no other sources may be availbale at acceptable costs, and as some contamination from external sources can occur in the well, disinfection will be mandatory.

* **DOSE OF CHLORINE APPLIED**: In our study area, we proposed direct application of chlorine for effective result. Direct application is the most commonly used chlorination method. This method brings about effective disinfection as its results to a chlorine dose above the **breakpoint** (breakpoint chlorination consists of a continual addition of chlorine to the water upto the point where the chlorine enquiry is met and all present ammonia is oxidized, so that only free chlorine remains) with free chlorine residuals and this is achieved by carry out **chlorine demand tests** (as shown in the dosing calculation below) or **organic nitrogen analyses**. The chlorine application with a dose of 2 mg/L (higher than this value creates bad test) eliminates the total and thermo-tolerant Coliforms (Faecal) in an order of magnitude of 3-4 logarithms. The doses applied during chlorination must also be above the breakpoint and must be standardized to ensure a free chlorine residual of no less than 0.5 mg/L at any point of the system, especially if the systems are very old and there is a risk of cross-contamination with sewers. The breakpoint of chlorination has other benefits, such as smell and taste control.

* **COMMITTEE**: The community should set up a committee with its sole aim will be on the operation and management of the chlorination processes. The members of this committee responsible for running the chlorination are key factors in the chlorination results, because of the difficulties involved in ensuring proper control of the dose of chlorine. These difficulties are mainly due to the following situations:

- Operation of the dosing is usually manual.
- Proper timing and dissolution of the calcium hypochlorite makes it difficult to effect precise dosing and reading.
- Application does not correspond properly to the volume and quality of the water to be chlorinated
- There are no dosification control records in many cases.
- Personnel are not properly trained to manage the chlorination system.

However, chlorination can be made more accurate by training the personnel to handle, control, operate and maintain the equipment, and by raising their awareness of the importance of their work, as this will ensure that the difficulties are well checked. The personnel also must be properly trained to follow all the chlorination protocols, so that the applied doses will comply with laboratory recommendations.

* **DISTRIBUTION SYSTEM:** After chlorination, some bacteria may still be evident in the distribution system/network. Such pollutant could be as a result of cross-contamination or of old pipes in a bad state of conservation. Cross-contamination is mainly due to damaged pipes through which contaminants from the soil or from sewerage pipes reach the water. Normally the flow conditions are under considerable positive pressure. However, siphon-type suction can occur in the distribution system if the water pressure drops and there are defective connections or fractures in the pipes. Polluting organisms can thus be absorbed into the water pipe. Problems of this nature occur more frequently when the drinking water pipe is laid too close to the sewage collector (laying of pipes close to sewage collector has to be avoided). It is very difficult to predict the quantity of chlorine that will be needed to neutralize this type of pollution. However, it's very vital that the chlorine residual in the distribution systems should not be less than 0.5 mg/L at any point of the system in order to eliminate any bacterial pollutants still present in the distribution network.

* **MAINTENANCE OF PIPES**: It's very important that regular maintenance of pipes is being carried-out to ensure that there is no broken, cracked or rusted pipe. This will ensure that cross-contamination will not occur in the flow system due to damaged pipes or re-introduction of other contaminants due to rusted pipe. Hence, general maintenance of the whole water system (from the pumping well to the distribution) is very vital. Preventive maintenance of the chlorination must be scheduled for reservoirs in order to prevent unforeseen stops that would interrupt the chlorination process.

*To avoid a situation where the disinfection process may be stopped or delayed as a result of fault in the equipment or theft, stand-by equipment should always be present; spare parts should be always kept safely stored (to avoid thieves from stealing the spare parts), repair should be agreed on a contract base within a certain amount of time (e.g.: 1 week), late intervention should be fined severely etc.
The committee should enforce strict rules on the whole processes to achieve proper water management.

* The application of a 2 mg/L dose of chlorine above the raw water demand determined by chlorine-demand tests with a contact time of no less than 60 minutes, eliminates faecal coliforms in an order of magnitude of 4 log. as well as all the enteropathogen bacteria. A control of the formation of chlorination by-products needs to be carried out.

* Chlorine residual controls must be carried out at strategic points at the outlet of the reservoirs and distribution systems. It is important that these controls be effected by technicians specialized in taking appropriate corrective measures.

* To reduce the use of chlorine in pipes with a high demand, cleaning by means of venting and/or superchlorination must be scheduled to eliminate all the slime and free-living organisms inside. Piping that is very old or in a bad condition must be changed.

* The chlorination process must be considered essential. Chlorination should not be stopped or reduced because of the assumption that by-products are formed from the chlorination. The long-term effects of the trihalomethanes in inducing some forms of cancer caused by water consumption have not been verified. However, waterborne infections are more frequent and have a high rate of morbidity and mortality in the study area. Prevention is better than cure!!

Chlorine Dosing

The amount of chlorine need for dosing the water for Umuezeokoha community is calculated in order to ensure that the needed chlorine free residual is present at the distribution system for making the water safe for human consumption. Therefore it is vital that the dose is continuously maintained to avoid unsafe water distribution and, consequently, the outbreaks of waterborne diseases.

At present it is very unlikely that at the Umuezeokoha community sodium hypochlorite solution at 12% Chlorine can be supplied continuosly, stored in a proper vessel (sheltered from solar light) and fed by dosing pumps reliably and continuously. Therefore, as a first step, dosing of a powdered chlorine compound should provide the following short-term advantages:

- supply of bags is simpler than supply of liquid reagents;
- handling of powdered chlorine compounds is simpler and reasonably safe, provided that safety measures are accomplished (see "precautions" section below);
- no machinery is needed for dosing, as dosage can be performed manually.

Plastic tanks for storing NaCLO solution and electrically driven dosing devices can be considered as a possible option only

1) after the local population has got familiar with disinfection and has recognized its beneficial effects on human health and

2) if a reliable electric energy supply can be provided and reliably operated.

Then, manual operation for dosing powdered chlorine chemicals can be still used under emergency conditions, e.g.: to provide safe water while waiting for maintenance and repair of damaged units. Trichloroisocyanuric Acid (TCCA) was chosen as it is more stable than Calcium Hypochlorite $Ca(ClO_2)$ and can be easily supplied as powdered bags, or tablets.

To determine the necessary amount to be dosed, the following calculations were performed.

Trichloroisocyanuric Acid (TCCA, formula $C_3O_3N_3Cl_3$), Molecular Weight (MW) = 220 g/mol

As TCCA purity is between 80 and 90%, the percentage of chlorine in commercially available TCCA is:

3 x 35 / 220 x 0.8 = 0.382 (38,2%), as it can be assumed a conservative figure of 80% purity. Otherwise, at 90% purity the weight fraction of Chlorine would be 42,9%.

The present emergency (present population) and the future population was considered for the design of wells, reservoirs and pipes, and a water daily consumption per capita has been defined as the minimum advised by WHO (50 Liters per capita and day). Therefore:

PHASE A:

8,750 PE (Present Population):

8,750 PE x 50 L/PE/d = **437,500L/d**

437,500L/d (Daily Consumption: **Dc** or daily volume V_d **). 437.52m^3/d.**
437,500L/d /24h/d = 18229L/h = 18.23m^3/h.

Q consumed = **437,500L/d**

Dose (D) = 2mg Cl/L (higher than this will produce a bad taste)

Total chlorine needed (W_{Cl}) = Q x D = 437,500L/d x 2 mg Cl/L : 10^6 mg/kg = **0.9 kg Cl/d**;

Volume of the reservoirs (V) = 864 m^3

Hydraulic Retention Time (HRT) = V_{tank}/Q = 864m^3 : 860.625 m^3/d = about 1 day retention time

Therefore, each day about **0.9 kg** of Chlorine should be added in the tank. This corresponds to a quantity of TCCA of 0.9/ 0.382 = 2.36 kg TCCA per day = rounded **2.4 kg/d**.

PHASE B:

$8{,}750 \times 1.07^{10}$ **= 17,212.57 PE** (Future Population):

17,212.57 PE x 50 L/PE/d = **860,625 L/d**

860,625L/d / 24 h/d = **35 859 L/h** (Daily Consumption: **Dc** or daily volume V_d **)**

Q consumed = **860,625 L/d**

Dose (D) = 2mg Cl/L (higher than this will produce a bad taste)

Total chlorine needed (W_{Cl}) = Q x D = 860,625L/d x 2 mg Cl/L : 10^6 mg/kg = **1.7 kg Cl/d**;

Volume of the reservoirs (V) = 864 m³

Hydraulic Retention Time (HRT) = V_{tank}/Q = 864m³: 860.625 m^3/d = about 1 day retention time

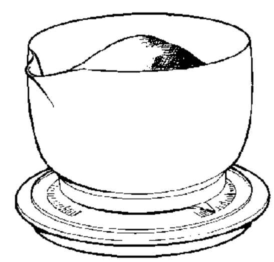
Therefore, each day about **1.7 kg** of Chlorine should be added in the tank. This corresponds to a quantity of TCCA of 1.7 / 0.382 = 4.45 kg TCCA per day = rounded **4.5 kg/d.**

Therefore the daily amount of TCCA to be dosed today in the **PHASE A** volume reservoir will be about **2.4 kg**, in order to ensure the required dose while in the **PHASE B** will be **4.5 kg/d.**

Doses are approximates as they are only estimations to achieve a first approximation of the quantity that are needed daily and, also, to estimate the costs. Effective, actual doses will be determined after specific analyses will be performed on site, aimed at determining the actual decay of free Chlorine with time, and to know whether the actual trend is similar or not to that shown in figure 4.2 above.

Procedure for Determining Chlorine Disinfection Dose:

PHASE A:



1) Weigh 300 g of TCCA powder by an add-and-weigh facility (see example in the figure on the right: www.fao.org/wairdocs/x5434e/x5434e0j.htm)
2) Dissolve the 300 g powder in a bucket with 10 liters of water and mix very carefully, avoiding any splashing, until you get a homogeneous suspension.
3) Carefully add the suspension into the reservoir (water tank) of **864**m³ (as the case is in our study area).
4) Repeat the operation 9 times a day (as 300 x 9 = 2400 g = **2.4kg**), ***possibly adding the TCCA + water suspension in different points of the reservoir***; the timing of each operation should be decided according to the usage (e.g.: if all people come to get the water in the morning, it is better to dose all the 2.4 kg powder the night before).
5) After adding the last bucket, wait for 30 minutes and measure Free Residual Content (FRC) in the reservoir and also in the distribution network. A simple and cheap method of measuring chlorine and pH is by using a pool tester kit (as used for swimming pool water).
6) Ensure that the FRC present meets the recommended range of not less than 0.5mg cl. Should the value fall below 0.5 mg Cl/L, you have to carefully add more TCCA still the required

concentration is achieved (this has to be carefully carried out in order to avoid over-doses in the water).

PHASE B:

The same procedure followed in PHASE A will be applied in PHASE B bearing in mind that 4.5 kg/d of TCCA is required to achieve 1.7 kg of Chlorine that is needed in the PHASE B. Hence:

1). Weigh 500g of TCCA powder

2) Dissolve the 500 g powder in a bucket with 10 liters of water and mix very carefully, avoiding any splashing, until you get a homogeneous suspension.

3) Carefully add the suspension into the reservoir (water tank) of **864**m^3 (as the case is in our study area).

4) Repeat the operation 9 times a day (as 500 x 9 = 4500 g = **4.5kg**), ***possibly adding the TCCA + water suspension in different points of the reservoir***; the timing of each operation should be decided according to the usage (e.g.: if all people come to get the water in the morning, it is better to dose all the 4.5 kg powder the night before).

5) After adding the last bucket, wait for 30 minutes and measure Free Residual Content (FRC) in the reservoir and also in the distribution network. A simple and cheap method of measuring chlorine and pH is by using a pool tester kit (as used for swimming pool water).

6) Ensure that the FRC present meets the recommended range of not less than 0.5mg cl. Should the value fall below 0.5 mg Cl/L, you have to carefully add more TCCA still the required concentration is achieved (this has to be carefully carried out in order to avoid over-doses in the water).

Effect of pH

The optimum range for chlorine disinfection is between 5.5 and 7.5 (effective of chlorine disinfection can reduce by a factor of between 3 and 6 when the pH rises from 6 up to 9). Chlorine disinfection is not reliable when the pH is above 9.

If pH is above 7.5 then the:

• pH can be adjusted, which is not very practical for the specific situation.

• Chlorine dose can be increased: aim for higher FRC at the end of the contact time (0.5mg/L from pH 7- 8, and 0.6 mg/L from pH 8 – 9).

Effect of Temperature

At 18 – 20°C and above, a contact time of 30 minutes is adequate. For every 10°C drop in the temperature, the efficiency of disinfection reduces by 50 – 60% (at close to 0°C disinfection efficiency is very poor).

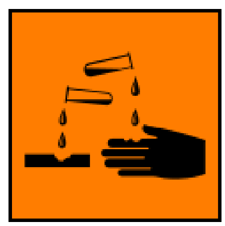
- Double the contact time if temperature falls to 10°C;
- At least quadruple contact time if temperature is approaching zero.

Since our study area is a poor rural community where all the householders take there water from a single source it is fairly straightforward to sample a number of filters and determine an appropriate chlorine dose. Contact time should be quite constant as the reservoir is filled

Precautions when Handling Chlorine Products

Chlorine is an aggressive and corrosive chemical and certain precautions must be taken.

- Protect the eyes and skin when handling chlorine powder, granules and solutions. Therefore always wear long-sleeve shurts, long pants, protection gloves and glasses.
- A big, clear sign indicated corrosion and toxicity danger should be placed where the TCCA powder bags are stored (examples are shown here below):



- Inside the building where plastic bags of TCCA are stored, a sign should clearly state the following message:
  CAUTION: always wear protective gloves and safety glasses when handling the TCCA powder
- The pH of the powder when suspended in water is very acid (pH < 3); therefore, if any drop enters in contact with the skin or eyes, wash them thoroughly with much clean water – for this purpose, always keep a 10-L bucket of clean water near the operator and NEVER use this bucket to dissolve TCCA.
- Prepare chlorine solutions in a well- ventilated area, preferably in an open air space, which should be fenced to avoid children and unauthorized person can access the area;
- Use plastic equipment and containers to prepare and store chlorine solutions;
- Pregnant women should be away from the place of preparation of chlorine solution;

• Asthmatic or related patient should be away from the preparation area.

Storage

Chlorine products and solutions lose strength rapidly with exposure to air, sunlight, and heat:

• Store products (and solutions) in plastic or plastic lined containers, and keep closed;

• Store products and solutions in a cool (at least well aerated), shaded (ideally dark) area.

The storage and preparation area should be fenced to avoid access to children, unauthorized persons and animals.

To ensure that the chlorine content is close to the design strength, verify that the product is not older than three months and that it has been transported and stored properly.

5. THE DEFINITION OF THE FEASIBILITY STUDY FOR ENSURING A RELIABLE AND SUFFICIENT WATER SUPPLY AT UMUEZEOKOHA COMMUNITY: PCM

After identifying the potential technical solutions to improve access and quality of water resources, the second step was to develop a full feasibility study, provides the definitions of different phases to implement the entire project in Umuezeokoha Community.

These steps are based on the logic of the project cycle.

5.1 Project Cycle Management Introduction:

Since the 1950s the development agenda has been characterized by projects and programs aimed at improving the quality of life of beneficiary communities, be it in physical or qualitative terms. Despite significant inputs of human and financial resources, many fell short of expectations. Projects failed to meet the priority needs of communities; stated outputs were not achieved or, if achieved, not sustained; target groups did not benefit in the manner intended; project costs escalated and implementation dates slipped; and adverse outcomes were not anticipated.

These failures were attributed in part to poor project management, such as inadequate opportunities for potential beneficiaries to participate in project identification, weak financial management, inadequate monitoring during implementation, poor linkages between project activities and project purpose, and insufficient attention to the external environment during project design. It was also recognized that projects were more likely to succeed when account was taken of the socio-economic context in which they operated.

The rationale for addressing socio-economic and gender issues in project cycle management is the wish to achieve sustainable development. Projects should identify and understand the different roles and entitlements between women and men in target communities, and the special challenges faced by disadvantaged groups.

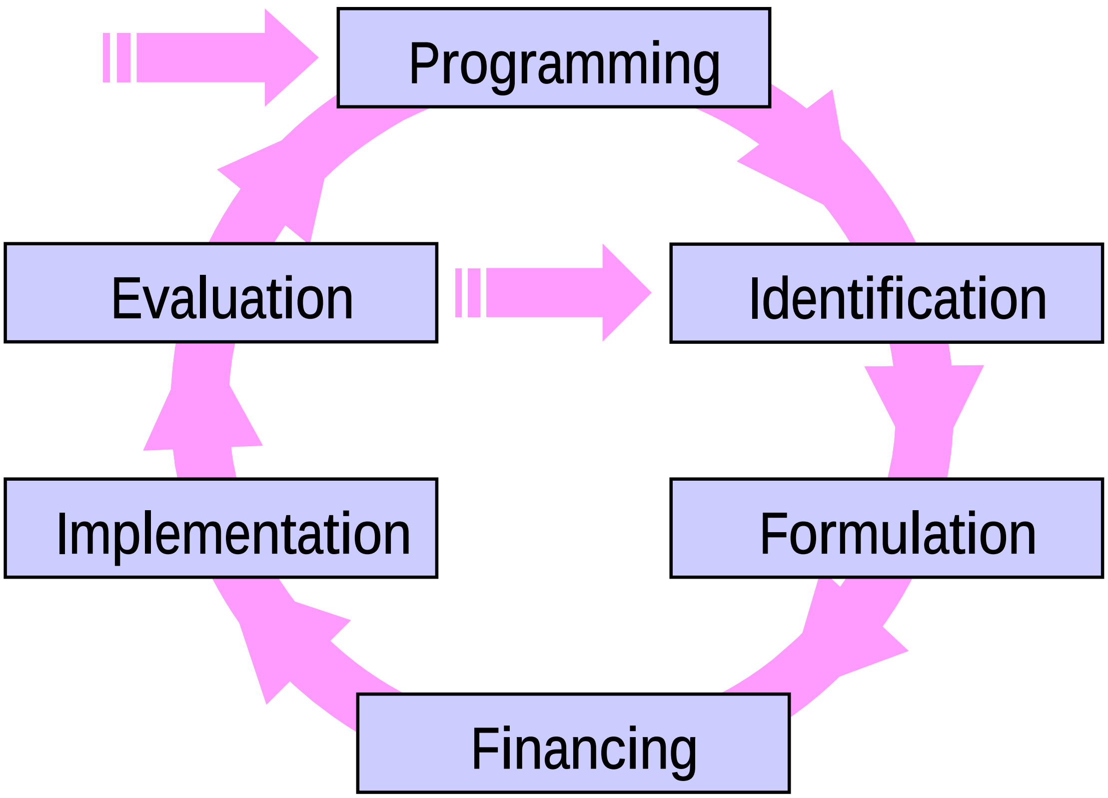
During recent decades, many tools have been developed to strengthen the management of projects, such as project cycle management, the logical framework and rapid appraisal techniques. *(Project Cycle Management Technical Guide SEAGA Socio-Economic and Gender Analysis Programme, Food and Agriculture Organization of the United Nations (FAO 2002).*

Indeed the **Project Cycle** follows the life of a project from the initial idea to its completion. It provides a structure to ensure that stakeholders are consulted, and it defines the key decisions, information requirements and responsibilities at each phase, so that informed decisions can be made at each phase in the project life.

It draws on evaluation to build the lessons of experience into the design of future program and projects.

The Project Cycle Management give a methodology for the preparation, implementation and evaluation of projects and program based on the principles of the Logical Framework Approach (LFA). Also it describes management activities and decision-making procedures used during a project's life-span (including key tasks, roles and responsibilities, key documents and decision options).

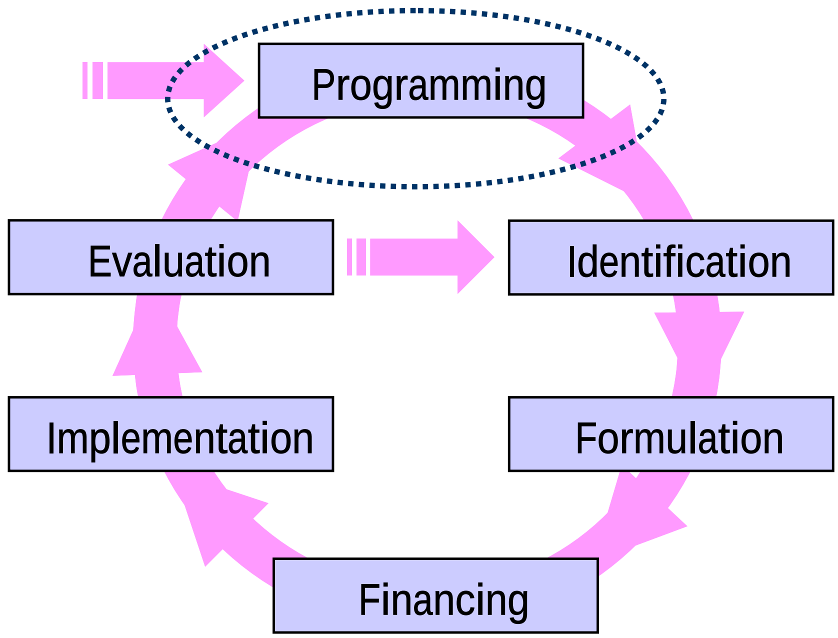
PROJECT CYCLE (using the European Union and World Bank pattern):



– The goal of project cycle management is to improve the management of external co-operation actions by taking better account of essential issues and framework conditions in both designing and implementing projects and programs.

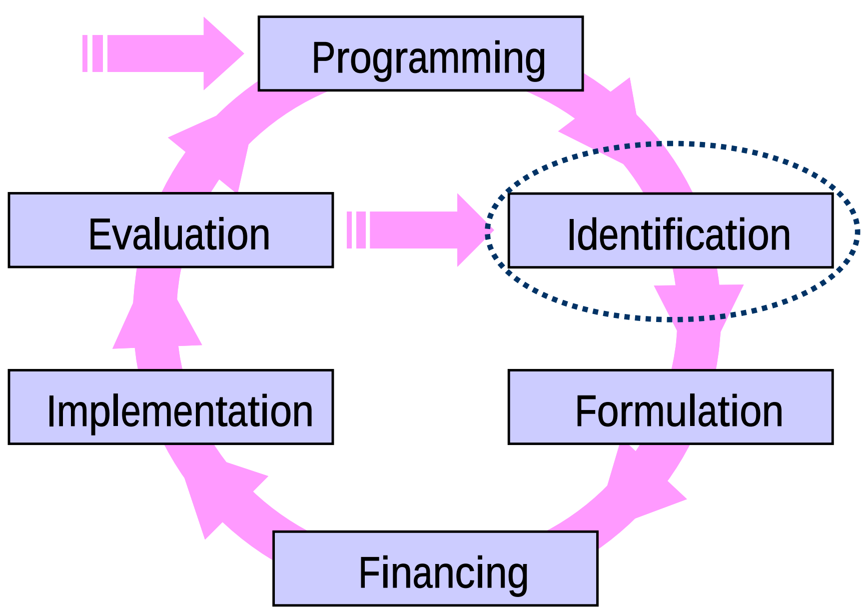
5.1.1 Programming

In programming, priorities are defined by different points of view:



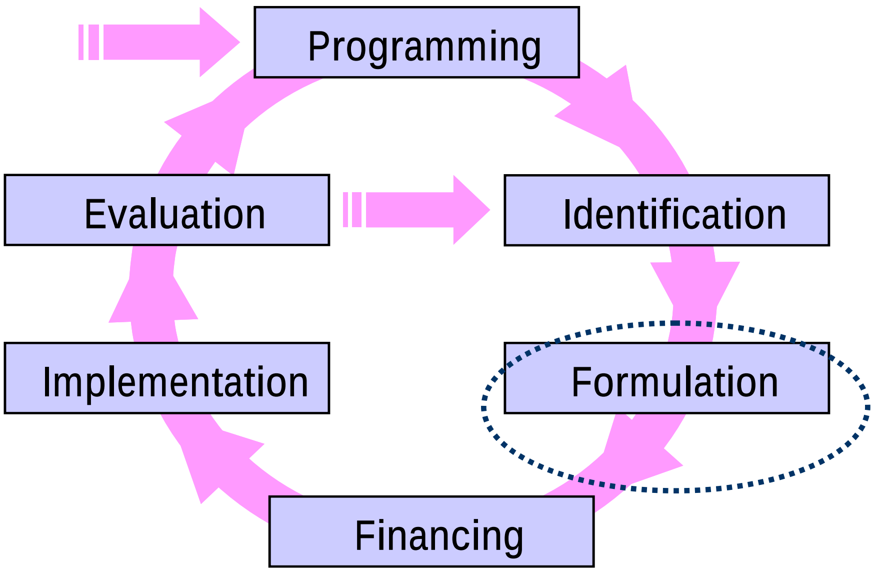
- **By nature of the intervention** (development, reconstruction, humanitarian aid)
- **Geographic** (which countries)
- **Sectoral** (social, health, education, production ...)
- **By type of local partners** (institutions, NGOs, private sector, movements ...)

5.1.2 Identification



It involves the **initial elaboration** of the **operation idea** in terms of **objectives, results and activities**, with a view to determining whether or not to go ahead with a feasibility study. This involves consultation with the intended **beneficiaries of each action**, an analysis of the problems they face, and the identification of options to address these problems. Project Initial elaboration is vital in Project Life Cycle and essentially involves starting up the project. You initiate a project by defining its purpose and scope, the justification for initiating it and the solution to be implemented.

5.1.3 Formulation



- Financing plan, cost-benefit analysis, risk management, monitoring etc
- Confirm the relevance and feasibility of the project idea as proposed in the identification.
- Prepare a detailed project design, including the activities, management and coordination arrangements.

6. THE PROGRAMMING STAGE

6.1 The nature of the intervention

The nature of intervention in umuezeokoha community is the provision of sustainable access to safe drinking water for the poor rural community. Its an intervention that will lead to the **sustainable development (Socio-economic development)** of the rural poor community of umuezeokoha in Ezza North of Ebonyi State of Nigeria.

The community at present has no access to clean, safe and permanently available freshwater sources and rainwater collection is performed in an open collection area situated in the centre of the village, where rainwater accumulates during the rainy season. The maximum storage capacity of this collection tank is approximately **$200m^3$.**

This volume does not last for more than four days after the end of rainy events and poses serious risks to human health as evidenced before. During the dry season water is supplied to the community by the government by truck which is not consistent on daily basics. The amount supplied by the local government to the community is about 23,000 liters per day, which is equivalent to 2.63 L per capita per day which is well below the water supply quantity recommended as the minimum vital by the World Health Organization (50 Liters per capita and day; WHO, 2003: "Domestic Water Quantity, Service Level and Health" [4]) At present, the people of this community have to walk about 2.5 km (or by bicycle, as the road is very poor and inaccessible) to another community to have access to water during the dry season.

6.2 The partners

For the project to be successfully carried-out at the community for sustainable development, we thought it is very vital to have partners such as Prof.Benard Odoh, Mr Ahamefule Utom, Department of Geological Sciences, and Faculty of Natural Sciences Nnamdi Azikiwe University Awaka Nigeria, Umuezeokoha Community Development Union, Umuezeokoha Youth Movement, Umezeokoha Women Association, Ebonyi State, Ebonyi State Water Board Authority, Federal Ministry of Agriculture & Water Resources Nigeria, Federal Ministry of

[4] www.who.int/water_sanitation_health/diseases/WSH03.02.pdf

Works, Housing & Urban Development Nigeria and Ministry of Women Affairs, Better Life for Rural Development Nigeria.

The role of the partner is that they provide the local information that is very necessary towards the objective of this work and as well the work with the people of this community towards understanding the true situation of the community (cultural, customs and beliefs) and ensuring that the objective of this work is successfully implemented for the sustainable development of this community and the state at large.

6.2.1 The local Authorities

The local authorities that are ground with respect to this project are Umuezeokoha Community Development Union, Government of Ebonyi State, Ebonyi State Water Board Authority, Federal Ministry of Environment Nigeria, Federal Ministry of Agriculture & Water Resources Nigeria, Federal Ministry of Works, Housing & Urban Development Nigeria, Federal Ministry of Youth Development Nigeria, Federal Ministry of Youth Development and Ministry of Women Affairs.

6.2.2 The Non-governmental Organizations

At the moment, i don't have any NGO's but i am very willing to work with any NGO's such as Veolia Water, Veolia Environment, Oxfam, HELP, Save Children, CARE, Caritas, UN-Charta, UN-System etc this will enable me to effectively and efficiently carried-out this strategic intervention for the socio-economic development of the community.

7. THE IDENTIFICATION STAGE

7.1 The collection of the existing information

For the intervention to be successfully carried-out, collection of existing information concerning what has to be done towards actualizing the objective is was very vital. This information enables us to look at the possible solutions that have to be investigation for the intervention.

Construction of borehole water on site at the community was considered as one of the possible solution to be investigated and so, there is need to collect of both existing and non-existing (I have to run models to get the non-existing information) information concerning the geology and geophysical of the study area. This will enable us to know if there is possibility of groundwater in sufficient quantity in the area. Analyzing the geological and geophysical data's was very vital for this intervention.

Construction of an Aqueduct (Laying of pipeline) from either Abakiliki, Amuzu, or Isiagu to the community was as well considered as another possible solution of intervention that has to be investigated and so there is need as well to collect existing formation to actualize this purpose. These information will enable us to know if this particularly intervention is feasible or not for the community. Looking at the terrain where the pipeline will pass (slopes, altitude etc) distance that the pipe will be layed, depth/lengths of the pipes, dimension of pipes, pumps, security of the pipeline etc is very important for this vital intervention.

Water tankering as a possible solution was also taken into consideration. And collection of information that has to do with the tankering processes, the state of the truck, management, time from when the tank gets the water to its arrival to the community, the distance that the driver of the truck has to cover, the cost of the processes etc was very helpful for decision taken. These collected information was needed to make a concrete decision if the could be taken as a solution.

With these collected existing and non-existing formation with also the advantages and disadvantages of the possible solution, I was able to come up with detailed feasibility study on the best strategic intervention that will alleviate the poverty situation of this community that finally creates socio-economic development of the poor rural community from underdeveloped to developed community which will finally transform Ebonyi State and Nigeria at large.

7.2 The Definition of lack of Information

There are many cases where i was not able to get information that will really allow me to take a decision on a particular area of discussion; this is as result of lack or inadequate information/data. The current study area has not detailed information due to no one has very done any detailed work on that place as the place is at the very interior part of the state. Many geological, geophysical, hydrogeological etc information is not available for this community and the much that is available is not enough in taking a concrete decision concerning groundwater potential.

To make a detailed or understand the ground water situation in that area, I lot of geological and geophysical work was done by collaborating an already existing information concerning Abakiliki, Amuzu, and Isiagu which are few kilometers away from the community. And Abakiliki is at the moment where water supply is send to the community. So with the geological, geophysical, hydrogeological and hydrology data of work that is existing in Abakiliki, I was able to run models and make many correlations to arrive at a very detailed but good decision that groundwater potential in this community is very high and water borehole can be carried-out in the community. However, I strongly recommend for further studies (geological, geophysical and hydrogeological) to be carried-out in this community for better understanding and for future use.

There was also lack of information in other possible intervention, but I was able to ensure that with the information gotten I was able to make a vivid decision concerning the community. Those formation that are not available was mainly due to no study has been done in this area but with the existing information that i got, i was able to make a perfect conclusion on the very best solution for intervention in the community.

7.3 The Stakeholder Analysis

In the stakeholders analysis, I have to identifying & characterize potential major stakeholders; assessing their capacity. A basic premise behind stakeholder analysis is that different groups have different concerns, capacities and interests, and that these needs to be explicitly understood and recognized in the process of problem identification, objective setting and strategy selection. Any individuals, groups of people, institutions or

firms that may have a significant interest in the success or failure of a project either as implementers, facilitators, beneficiaries or adversaries.

The key questions asked by stakeholder analysis are:

- 'Whose problems or opportunities are we analyzing?
- 'Who will benefit or loose-out?

The ultimate aim is to help **maximize** the **social, economic and institutional benefits** of the project towards target groups and ultimate beneficiaries, and **minimize its potential negative impacts** (including stakeholder conflicts). **The purpose of stakeholder analysis is to improve the involvement of stakeholders in the participatory process**.

In this project, the potential major stakeholders here are the;

- Umuezeokoha Community Associations (both Men, Women and Youth);
- Ezza North Local Government Authority;
- Ebonyi State Government (Ebonyi State Water Resources);
- Federal Ministry of Works, Housing & Urban Development Nigeria;
- Federal Ministry of Agriculture & Water Resources Nigeria;
- Sponsoring Organization (NGO's, Companies, EU, UN, Country Government etc).

With the Potential major stakeholders, I will be able to:

- Identify the general development problem or opportunity being addressed/considered;
- Identify all those groups who have a significant interest in the (potential) project;
- Investigate their respective roles, different interests, relative power and capacity to participate (strengths and weaknesses);
- Identify the extent of cooperation or conflict in the relationships between stakeholders.

When the above information is actualized, i will be able to make Interpretation of my findings of the analysis and incorporate relevant information into the project design to help ensure that:

- **resources are appropriately** targeted to meet **distributional/equity** objectives and the needs of priority groups;
- **management and coordination** arrangements are appropriate to promote stakeholder ownership and participation;

- **Stakeholder's conflicts** are recognized and explicitly addressed into the project design.

7.4 The Problem Analysis

In Problem analysis, i intend to identifying the key problems, constraints & opportunities; determining cause & effect relationships. Problem analysis identifies the **negative aspects** of an existing situation and establishes the **'cause and effect'** relationships between the identified problems.

To enable me in the problem analysis, I have to:

- define the framework and subject of analysis;
- Identify the **major problems faced by target groups and beneficiaries** (What is/are the problem(s)? Whose problems?);
- Visualize the problems in form of a diagram, called a **"problem tree"** or "hierarchy of problems" to help analyze and clarify cause–effect relationships.

Creating a problem tree should ideally be undertaken as a participatory group event. It requires the use of individual pieces of paper or cards on which to write individual problem statements, which can then be sorted into cause and effect relationships on a visual display.

7.5 The Objective Analysis

The objective analysis is a methodological approach employed to:

- describe the situation in the future once identified problems have been remediated;
- verify the hierarchy of objectives;
- Illustrate the means-ends relationships in a diagram.

Note that, finally the 'negative situations' of the problem tree are converted into solutions, expressed as 'positive achievements'.

These positive achievements are in fact objectives, and are presented in a diagram of objectives showing a **means to ends hierarchy.** The diagram aims to provide a clear overview of the desired future situation. To achieve this, i have to follow these steps:

Step 1: Reformulate all negative situations of the problems analysis into positive situations that are:

• desirable;

• realistically achievable.

Step 2: Check the means-ends relationships to ensure validity and completeness of the hierarchy (cause-effect relationships are turned into means-ends linkages).

Step 3: If necessary:

• revise statements;

• add new objectives if these seem to be relevant and necessary to achieve the objective at the next higher level;

• delete objectives which do not seem suitable or necessary.

Once again the analysis of objectives should be undertaken through appropriate consultation with key stakeholder groups.

Information previously gained from undertaking stakeholder analysis
should also be taken into account.

This should help in terms of:

• Considering priorities;

• Assessing how realistic the achievement of some objectives might be;

• Identifying additional means that might be required to achieve desired ends.

Once complete, the objective tree provides a summary picture of the desired future situation, including the indicative means by which ends can be achieved very well.

7.6 The Strategy Analysis

In the strategy analysis, I intend to identifying different strategies to achieve solutions; and selecting the most appropriate strategy.

During the process of stakeholder analysis, problem analysis and the identification of the potential project objectives, the views on the potential merits or difficulties associated with addressing problems in different ways will have to be discussed. These issues discussed and options then need to be more fully scrutinized to help determine the likely scope of the project before more difficult design work is undertaken.

The type of questions that need to be asked and answered at this stage might include:

• Should all the **identified problems and/or objectives be tackled**, or a selected few?
• What are **the positive opportunities** that can be built on?
• What is **the combination of interventions** that are most likely to bring about the **desired results and promote sustainability of benefits**?
• How is **local ownership of the project best supported**, including development of the capacity of local institutions?
• What are the likely **capital and recurrent costs** implications of different possible interventions, and what can realistically be afforded?
• Which **strategy will impact most positively** on addressing **the needs of the poor and other identified vulnerable groups**?
• How can **potential negative environmental impacts best be mitigated** or avoided?

So in practice, a number of compromises often have to be made to balance different stakeholder interests, political demands and practical constraints such as the likely resource availability.

Key criteria for strategy selection could include:
• Expected contribution to key policy objectives, such as **poverty reduction** or **economic integration.**
• Benefits to target groups – including **women** and **men**, **young** and **old**, **disabled** and **able**, etc
• Complementarily with other ongoing or planned programs or projects
• Capital and operating cost implications, and local ability to meet recurrent costs
• Financial and economic cost-benefit
• Contribution to institutional capacity building
• Technical feasibility
• Environmental impact.

Using these criteria, it will be of good help to determine what can be included within the scope of the project, and what cannot be included.

8. THE FORMULATION STAGE

8.1 The identification of a preliminary framework of sustainable and viable solution

Provision of sustainable access to safe drinking water for the rural poor community is very essential for the socio-economic development of the community and its very vital to identify a preliminary framework solution which is sustainable and viable for the intervention. Looking the following identified possible preliminary framework solution that I think is sustainable and viable:

• Provide a local permanent water supply source by **drilling water well on site** (Groundwater development on site).

• Construction of **An Aqueduct** connection from any near by water source;

• Using trucks to supply water to the community on daily basis (**Water Tankering**).

Its very important for us to as well take into consideration the financing plan, cost-benefit analysis, risk management, monitoring etc and confirm the relevance and feasibility of the project idea as proposed in the identification stage and also prepare a detailed project design, including the activities, management an coordination arrangements.

8.2 The definition of specifications to perform the required further studies

The is need for further studies to be perform mostly on the data's that have been analyzed and for further geophysical, geological and hydrogeological survey to be carried-out to obtain more detailed information concerning this area of study. And on site project cycle management has to be performed to enable more data's to be obtained for the complete cycle analysis.

Further studies has to be performed in areas like the road network in the community to understand the potentials of pipeline network into and around the village for future application in terms of urbanization.

And also the rurality of the community has to be taken into consideration in further studies because effective rural developmental policies must be based on an accurate classification of the essential characteristics of the village types that make up the community. Such a frame work allows the identification of both needs and opportunities in the rural areas (Bogdanov et al. 2007). The consequences of lack of proper understanding of rurality on rural development are that the advantages associated with targeting policies to rural areas based on better understanding of the dynamics and sense of identity are not not harnessed (OECD 2005).

In Ebonyi State, the approach of targeting policies to rural areas on the basis of informed knowledge of rurality is still lacking and this to a large extent has been responsible for the poor and fragmented rural development in the state (Madu, 2008). Against this background, it becomes pertinent that the true picture of the rural situation in the state with a reflection on the communities can only be obtained by further analysis and mapping of the rural communities based on internationally recognized indicators and methodologies. This is very necessary because today, changes in rural areas are accompanied by growing requirements for comparability especially in statistics across local governments areas of the state reflecting the phenomenon of globalization (IWG. AgRI, 2005). Such comparative analysis can only be made when uniform approaches are used (Muula, 2007) for a vivid description of the communities.

9. CONCLUSION

A good clean water supply and adequate sanitation systems are considered to be the most important factors towards ensuring good health in any society. And improved water supply and sanitation systems were major element of the public health measures that drastically cut down death rate and improved health levels in industrialized countries. Sustainability access to safe drinking water is seen as a major factor for the development of any rural poor community as it's the case of Umuezeokoha community in Ebonyi State of Nigeria.

To achieve the objective purpose, possible solutions such as water availability through trucks (water tankering), water availability through aqueduct (pipe lying), and water availability through groundwater resources development on site (drilling a water borehole) where investigated thoroughly. Also, many other related vital factors where alongside taken into consideration with the possible solutions, such as: Geology, geophysical studies and hydrogeological studies, existing wells around the study area, cost of each solution, advantages and disadvantages, risk management (in terms of PCM), environmental safety and security concern were all put into consideration.

Groundwater Resources Development on site (drilling a water borehole in the community) was found to be the very best possible solution among all the above mentioned and investigated solutions towards ensuring a reliable, viable and sufficient water supply to Umuezeokoha Community in Ezza North Local Government Area of Ebonyi State of Nigeria. This solution presents greater possibilities towards sustainable access to safe drinking water for the community.

9.1 Recommendation

I recommend this thesis to be used by:

1. Ebonyi State water Resources Authority Nigeria.

2. Ebonyi State Government of Nigeria.

3. Federal Ministry of Agriculture & Water Resources Nigeria.

4. Federal Ministry of Works, Housing & Urban Development Nigeria.

5. Better Life for Rural Development Nigeria.

6. Government of other African Nations (with similar case of this Community; geological and otherwise).

7. Institutions, Organizations etc.

8. NGO’s, International NGO’S etc.

9. Other states of Nigeria.

This thesis could be adopted and used for the sustainable access to safe drinking water for rural development. Hence, imparting positively to the socio-economic development of such community, state and the country at large.

9.2 Future Research

Similar studies should be done with sufficient data in order to amend, correct or justify the analysis and findings done in this thesis work. And further geological, geophysical and hydrogeological surveys should be carried out in the community in order to also amend, correct or justify the analysis and findings done in this work.

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