UNIVERSITY OF PORT HARCOURT

ENGINEERING WITH A HUMAN FACE

An Inaugural Lecture

By

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INAUGURAL LECTURE SERIES

NO. 101

28 FEBRUARY, 2013

1. INTRODUCTION

The Vice-Chancellor, Deputy Vice-Chancellors, distinguished Professors and senior academics, all other academic colleagues, Great Students of a Unique University, distinguished ladies and gentlemen.

An Inaugural Lecture provides a scholar who has gained promotion to the professoriate the opportunity to effectively communicate to a diverse audience what exactly he or she professes. I am, therefore, glad to stand before you this afternoon to deliver my Inaugural Lecture entitled "***Engineering with a Human Face***."

Engineers are generally viewed as plastic and mechanical, with no attachment to our creations and as a people without soul. I am standing here today to show that the contrary is the truth. Our work is for human wellbeing.

I wish to use this opportunity to thank God and all those who stood by me during my time of trials. I can assure you that God is faithful. I am alive and here, today, by God's special interventions in my life.

1.1 TRIBUTES

Before I go on, I wish to show my appreciation to some of the people who have made a difference in my professional career. Among them are:

My PhD Team at Leeds University: ***Prof D.D. Mara & Prof Stentiford*** were both, my PhD supervisors at Leeds University, UK. Prof Mara's clarity of thinking and presentation can be matched by very few. He could see easily what others could not see. Professor E. I. Stentiford was excellent at putting things together. I also remember my project manager, Dr Pat Taylor, a motherly figure, who took pains at the daily running of the project. She assembled the data generated, and made sure I was comfortable. Mr Don was amazing at constructing any gadget I wanted. These people radically changed my approach to work and presentation.

The late **Prof Chi Ikokwu** was the first Dean of the Faculty of Engineering, University of Port Harcourt. He was accommodating, and opened the way for all to grow. He called me several times (and especially on one of our official journeys to Lagos) to particularly and specifically encourage and nudge me to press on. To some of us he was a towering fatherly figure in the Faculty of Engineering.

The late **Dr. N.O Umesi** of the Department of Chemical Engineering was one of my closest friends in the University of Port Harcourt. We worked on several striking projects. I will never forget on one of our sessions to put together a very creative document. He did not provide any seat for me in his office. He was comfortably seated on the only chair. I demanded a seat, and his reply was simple "***To get the best out of you, one must make you uncomfortable***" I did not realise until then, that I was that impossible. I hate people say to me "***let's just do it this way***". My friend was the only one I have worked with in Nigeria who avoided the phrase altogether, because he knew my hatred for it. Some of my most creative works were done in collaboration with him.

The late **Dr. P. Omotosho** was a brilliant young man I interacted first with in Newcastle University UK. From there he joined the Department of Civil Engineering and rose to the position of Head of Department. I remember when we were asked to provide data to fill a gap that was detected in the design for an integrated waste management centre for a company. It was a foreign company who had the job and we were contracted to provide the data. We were provided with their guideline for the execution of the project. Dr. Omotosho examined their proposals and said to me "***Let's teach these white folks Tropical Engineering***". He re-designed the layout for his component of the work and the result was stunning. The paper we published on this work attracted huge international interest (Leton & Omotosho, 2004). Definitely, Dr. Omotosho was a genius.

Engr. Deegbara Nwilene: He ensured that my early training in the university was supported with solid practical experience. He placed me with the Survey team, Soil & Materials Laboratory of the Ministry of

Works, Port Harcourt. This exposure placed me ahead in all courses related to these areas. He has never wavered in his support.

My Primary & Secondary Teachers: Mr Dumerenee and Mr R.U. Deekor were my primary school teachers whose encouragement I still treasure up till today. They had complete faith in me for the future. Mr Nkoyobe set me apart in my secondary school for special attention. He felt bad when I told him I will never be a teacher. I am happy to tell him today that I am not just a teacher but a professor.

Spiritual Mentors: Mr Kola Ejiwumi and Prof. J.U. Okoli took keen interest in my early spiritual life at the University of Nigeria, Nsukka. They nurtured me on spiritual values and they are still my spiritual supports.

My Family: My parents, Mr Benjamin Leton Akpayor and Mrs Neewa Leton were hard working, proud and contented parents. While my father was more of a philosopher, my mother was a super intelligent woman. She gave all for her children until she was burnt out. They taught us honesty, hard work, faith in God, and courage in the face of adversities. My eldest brother (the late Dr G.B. Leton) was a man who understood what life is about, a towering figure, on whose shoulders I grew up. My immediate elder brother (the late Engr. Deebi G. Leton) was a brother without reservations. They both nurtured and protected me while making sure I did not deviate from attaining a distinguished career. These two focused my attention on the future which is today.

My immediate family: My outstanding wife (Godae) and my three wonderful daughters (Neme, Mbara and Sisian) have been the guiding principle, inspiration and driving force behind my endeavours. How they manage to love and sustain a man whose attention is mostly on the computer is beyond my imagination. The love I have shared with these ones has been so deep and satisfying that I doubt if something better lies anywhere else. They have always urged me on. My second daughter, Mbara convinced me that I could have a go at the professoriate with the papers and other publications I had then. She single-handily assembled the documents, photocopied, updated my CV, and all I had to do was to help her carry the documents to the then Dean of Engineering, Prof D.P.S. Abam. Prof. Abam did not ask me any question but directed them all to her, and of course, she was the compiler and was up to it. That was early July 2007 and on 26th October that same year she left us from injuries she sustained from a ghastly motor accident on her way to NYSC camp, Ilorin. She was the centre of my family, a motivator, handled my academics and consultancy expertly. Mbara, what you so much wished and worked hard for, Daddy has accomplished. This is your day also. I can assuredly testify that we have made it to our goal. Of course, my granddaughter (Sisij) barely over a year old was helping me pull the hard copies of the lecture from my printer.

1.2 STEPPING STONES

Experiences that have shaped my thinking, career and my life

1.2.1 GS 101

Within the first three weeks of my arrival in University of Nigeria, Nsukka, I was asked to criticise a novel by the renowned author, Bernard Shore in GS 101 "Use of English" as my first assignment. This to me was a huge task beyond imagination, that I should criticise such a huge literary figure. I was encouraged by the lecturer and I believed I did something. This exercise opened for me a window into the world, and taught me that ***nobody is perfect***.

1.2.2 A USA Visiting Professor

I went to read in a classroom where a Soil Mechanics lecture had just ended. The Visiting Professor came in and saw the black board covered with heavy differential equations. He was terribly upset and asked me for the lecturer who had taught it. Unfortunately, the lecturer's office was nearby, and he went there to give the lecturer a thorough wash-down. He said, we were busy integrating to the moon and yet we could not supply water to the communities living up the hills surrounding the university. That revealed to me a loophole in our educational system– ***that of knowing only as compared to knowing and doing***. To prove that you have mastered something, you should be able to apply it to solve human problems, especially those at your door step. The hoe my grandparents used in planting yams is still the same today. This shows that training in engineering is not our major problem; its practical application to solve everyday problems is. Other disciplines should also reflect on these.

1.2.3 Lecturer 1

Civil Engineering Drawing was one of the most exciting and imaginative courses I did in my undergraduate days. I devised a method of projecting lines until the figure I was after just stands out. I lectured my fellow-students as an expert but when the exam came I failed. I told the lecturer that there was no way I could have failed the examination in that course. He looked at me and said "***but someone has to fail***". In this case that someone was me. I realised that he did not like my drawing approach because it was different from what he taught us. Other students used my method as a guide and then presented his method to him. From this experience ***I learnt that being correct and being right are not the same thing***. *It depends on the judge* - purely a personal perspective.

1.2.4 Lecturer 2

My lecturer in *Fluid Mechanics, Hydraulics and Public Health Engineering* could be described as my career lecturer. There was a one page derivation of a formula in hydraulics he taught us but I was able to derive the same expression in two steps using differential equation. I repeated the proof in an exam and he called me after grading my paper to ask who taught me the approach. I then asked him if the method was correct, and he said it was quite correct and I had an A in that course. ***Some people's minds are more open than others'***. This was certainly a reverse of my lecturer above. Well, some of us here like it that way – give it to me the way I dished out to you.

1.2.5 A course on Aesthetics & Beauty

One of the most revealing courses I took at my undergraduate level is "Aesthetics and Beauty". One important thing I learn here was that '*every object has a character.*' When you heard a Mercedes Benz horn in those days you knew it was a Mercedes Benz. Nowadays, a motorcycle can use a trailer-horn. Aesthetics and Beauty taught me to appreciate and connect aesthetics and beauty.

Fig 1 Development and the Environment

Civil Engineering has evolved with designs utilizing, or relying on, aesthetics and beauty. Our designs then, must be pleasing to the eye, blend perfectly with or into the environment, reflect human needs, stand out, and while at the same time remain functional.

1.2.6 Writing computer programs

One thing I learnt while I was writing computer programs for applications was that the first program you write is always the longest. You can always improve on it by shortening it or enhancing it with other aspects. That taught me that "***nothing is perfect, all things can be improved***". The Bible puts it this way: "As to the writing of books, there is no end." **(Ecclesiastes 12:12)**

1.2.7 Use of Mathematics

I am not good in Mathematics, I must admit. I believe, like many of us, I was poorly taught by people who did not understand Maths. This is a problem in Nigeria even today. Maths is the key to unlock so many things, not only in the field of Science, and Engineering but also of the Arts. We cannot be complacent about the teaching of such a building block for the future. It is absurd that Engineering students in this University still waste time studying Geometry and Algebra in the University instead of studying the building blocks of Mathematics. I have proposed to the Dean of Engineering that a realistic Mathematics programme be drawn for engineering students. Although I am not good in Maths as I confess, Maths saved me in my PhD programme and at other crucial times. ***What an Engineer I would be if I were good in Mathematics.***

1.2.8 Appropriate Technology

For me, appropriate technology is being mindful of what we are doing, and being aware of the consequences thereof.

The idea of appropriate technology is that local people, struggling on a daily basis with their needs, understand those needs better than anyone else, and should, therefore have a role in the technological innovations necessary to meet those needs.

One of the best-known early proponents of appropriate technology was the British economist E. F. Schumacher, who talked about 'intermediate technology' in his book ***Small is Beautiful: A Study of Economics as if People Mattered.*** He was principally concerned about development in low-income countries, and recommended a *technology that was aimed at helping the poor in these countries to do what they were already doing in a better way*.

The definition of "Appropriate Technology" is not stagnant; it is flexible and changes with each situation. For instance, it is not appropriate to install solar modules in a place with very little sun, and a wind generator in a place with little or no wind. What is appropriate in a large urban location is very different from what is appropriate in a remote, isolated environment. One quality that remains constant, however, is taking care of things.

Most of the work in appropriate technology took place in India, Brazil and some developed countries such the United States of America and

Britain. Conventional thinking in the areas of wastewater treatment and disposal, water treatment and supply, solid waste and building technology were challenged and replaced with simple and practical approach. Today the benefits are utilised in both developed and developing countries.

The people who pioneered appropriate technology were some of the most brilliant, and articulate minds I have known. Before one can go into appropriate technology, you must have a very high level of expertise and proficiency in the subject area. We should take advantage of appropriate technology in the quest for our development.

I was caught up in intermediate and appropriate technology concepts and these have pushed me in the direction I find myself in today. There is a huge data base and stack of articles covered under intermediate and appropriate technology that a developing country like Nigeria cannot overlook. Vice Chancellor sir, it is my humble opinion that a **Centre for Intermediate and Appropriate Technology (CIAT)** be established to cater for decimation of these knowledge and practical manpower training especially at the middle class. I will illustrate some of these areas in this lecture.

2. OVERVIEW

It is often desirable to set the framework within which one operates. For this purpose, I would ask then for your permission to define some key terms that may come up very often.

2.1 Pollution

Many professionals are involved in environmental pollution control, and as such, interpret pollution to suit their specific needs. It is difficult, therefore, to define environmental pollution to everyone's satisfaction, since everyone views it differently; neither is there any agreement on the short as well as the long-term effects of pollution.

A definition popular with the author is that "pollution is the introduction by man into the environment, substances or energy liable to cause:

- hazards to human health;
- harm to living resources and ecological systems;
- damage to structures or amenity; or
- interference with the legitimate uses of the environment".

It is implicit in the above definition that pollution is not simply the presence in the environment of an alien substance (i.e. contamination); there must be an unwanted effect. Almost all things are contaminated to an extent, even our well-washed white shirts, or treated water. The fundamental point is that ***only, unacceptable level of contamination becomes pollution***.

2.2 Environment

Man's *environment* is, considered as the surroundings in which he lives, works and plays. It encompasses:

- the air he breathes;
- the water he drinks, bathe;
- the food he consumes;
- the land he lives or/ and grows his food on; and
- the shelter he provides for his protection.

It also includes the pollutants, waste materials, and other detrimental environmental factors, which adversely affect his life and health. There is also the social dimension.

It is the aggregate of all those things and set of conditions, which directly or indirectly influence not only the organisms but also the communities at a particular place (Narayanan, 2011)

2.3 The Engineer

The word "engineer" has many meanings. We shall adopt the second definition as found in the Concise Oxford Dictionary – "*one who designs works of public utility*." Engineering comes from the Latin word, "***ingenium***", meaning "***cleverness or natural capacity***." I believe that we are still the sort of people the Romans envisaged. But from my HOD (*Late Prof Madu* of the University of Nigeria, Nsukka) definition – "an engineer should be able to do for 6k what others do for 10k". This implies that the engineer is knowledgeable as to the workings of his structures, the materials he uses and the environment in which it functions.

2.4 Civil Engineering

Civil Engineering is a professional engineering *discipline that deals with the design, construction, and maintenance of the physical and naturally built environment*, including works like roads, bridges, canals, dams, and buildings (Wikipedia).Civil engineering is the oldest engineering discipline after military engineering, and it was defined to distinguish non-military engineering from military engineering. It is traditionally broken into several sub-disciplines including:

Environmental Engineering - deals with the treatment of chemical, biological, and/or thermal waste, the purification of water and air, and the remediation of contaminated sites, due to prior waste disposal or accidental contamination. Among the topics covered by Environmental Engineering are pollutant transport, water purification, wastewater treatment, air pollution, solid-waste treatment, hazardous waste management, environmental noise and vibrations.

Environmental Engineering is the contemporary term for sanitary and public health engineering.

Geotechnical Engineering - is a branch of Civil Engineering concerned with the rock and soil that civil engineering systems are supported by.

Structural Engineering - is concerned with the structural design and structural analysis of buildings, bridges, towers, flyovers, tunnels, off-shore structures like oil and gas fields in the sea, aero-structure and other structures (Fig 2).

Fig 2 BurjKhalifa, the world's tallest building in Dubai

Transportation Engineering - is concerned with moving people and goods efficiently, safely, and in a manner conducive to a vibrant community. This involves specifying, designing, constructing, and maintaining transportation infrastructure which includes streets, canals, highways, rail systems, airports, ports, and mass transit.

Municipal or Urban Engineering - is concerned with municipal infrastructure. This involves specifying, designing, constructing, and maintaining streets, sidewalks, water supply networks, sewers, street lighting, municipal solid waste management and disposal, storage depots for various bulk materials used for maintenance and public works (salt, sand, etc.), public parks and bicycle paths.

Hydraulics Engineering - is concerned with the flow and conveyance of fluids, principally water. This area of Civil Engineering is intimately related to the design of pipelines, water supply network, drainage facilities (including bridges, dams, channels, culverts, levees, storm sewers), and canals

Water Resources Engineering - is concerned with the collection and management of water (as a natural resource).

Materials Engineering - deals with materials such as concrete, mix asphalt concrete, strong metals such as aluminium and steel, polymers and carbon fibres.

Coastal Engineering - is concerned with managing coastal areas.

Earthquake Engineering - covers ability of various structures to withstand hazardous earthquake exposures at the sites of their particular location.

Construction Engineering - Construction engineering involves planning and execution of designs from transportation, site development, hydraulic, environmental, structural and geotechnical engineers

Surveying - is the process by which a surveyor measures certain dimensions that generally occur on the surface of the Earth. *Although surveying is a distinct profession with separate qualifications and licensing arrangements, civil engineers are trained in the basics of surveying and mapping, as well as geographic information systems.* Surveyors lay out the routes of railways, tramway tracks, highways, roads, pipelines and streets as well as position other infrastructures, such as harbours, before construction.

*It must be made clear that **Land surveyors** are not considered to be engineers, and have their own professional associations and licensing requirements*.

Fig 3 Control systems play a critical role in space flight

Some non-traditional areas of Civil Engineering are:

Control Engineering or Control Systems Engineering - is the branch of Civil Engineering discipline that applies control theory to design systems with desired behaviours

(Fig 3).

Computational Science and Engineering (CSE) - deals with the development and application of computational models and simulations, often coupled with high-performance computing, to solve complex physical problems arising in engineering analysis and design (computational engineering) as well as natural phenomena (computational science)

Biomechanics - uses traditional engineering sciences to analyse biological systems. Biological systems are more

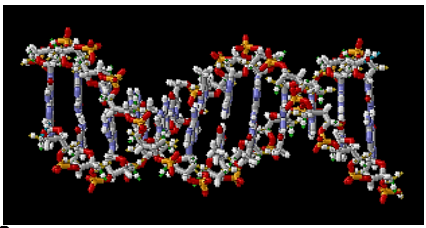


Fig 4 Microstructure of part of a DNA double helix biopolymer.

complex than man-built systems, as such numerical methods are applied in almost every biomechanical study.

Nanostructure - a nanostructure is an object of intermediate size between molecular and microscopic (micrometre-sized) structures (Fig 4)

Forensic Engineering- is the investigation of materials, products, structures or components that fail or do not operate or function as intended, causing personal injury or damage to property.

The foregoing is to demonstrate the vast field of Civil Engineering and its relevance to the society. Let us now focus on a small area of infrastructural development.

2.5 Development and the Civil Engineer

Whenever there is human development, the Civil Engineer is always the first to move in – *the first to know.* The Civil Engineer moves in first to:

The First to Move in

a. *conduct soil and water tests*
b. Construct roads and bridges to facilitate the movements of people, goods and services from one point to another.
c. Construct storm drains to drain way excess storm water;
d. Construct water lines for fresh water supplies;
e. Construct sewers to convey used wastewater from the environment;
f. Construct buildings to house human beings and human (industrial/ commercial) activities; and
g. Organizes the removal of solid wastes from the environment.

We are the first to be there and, as such, great responsibilities lie on our shoulders as to how the public view us and our creations. People may not usually see the one who creates or designs or constructs a structure, but the image created in their minds says a lot about the creator

Demolition

Closely linked to solid waste management is demolition exercise. When buildings become unfit or unsafe for human habitation, commercial or industrial activities, they must be demolished. Care is required during the demolition operation so as to reduce the impact of dust on the surrounding area, and on humans. The rubbles must be collected and transported to another site for reuse, or to disposal sites. *Once again, the civil engineer is the last to leave.*

The Last to Leave

The First to be there and the last to leave

We may, then, have to remember that Civil Engineers have an enormous responsibility on their shoulders as regards the health of people and protection of the environment. In most human development Civil Engineers shall always be "***the first to be there and the last to leave***."

2.5.1 The Civil Engineer and the Environment

The civil engineering activities listed above (though nor exhaustive), affect most facets of human life, and have great impact on our everyday living, and our environment. Great indeed are our responsibilities.

It must be said that lack of adequate town planning makes the task of water distribution, centralized sewerage and the collection of refuse an awesome task in our society today. We don't know where we are going; it might be worse in the future, as we are busy creating ghettos instead of planned cities

2.6 The Public Health Engineer (Environmental Health Engineering)

Some of you may already be confused by the various terms such as *Sanitary*, *Municipal, Environmental Health* and *Environmental* in addition to *Public Health Engineering* used in describing the profession. As a wide field of growing engineering activities, these names merely emphases or reflect the shifting interest within the profession. For example, in the developed countries, diseases caused by poor water quality and sanitation have been eradicated and the emphasis is now shifting to environmental pollution such as acid rain, radioactive decay levels, effects of chemicals such as herbicides etc. Thus, although Environmental Pollution Control is a subset of Public Health Engineering, in these countries, Public Health Engineering has been vastly replaced by **Environmental Health Engineering** or ***Environmental Engineering*** as an appropriate name to describe the activities of the profession.

What then is Public Health Engineering? A detailed answer to this question can be found in the definitions by Isaac (1981) and Pickford (1982).A short and up-to-date definition was given by Banks (1985) as "***Engineering serving the community and its environment for their mutual health and satisfaction***." Although our primary objective is to promote the health of man, it must be realised that a healthy environment contributes immensely to his health, implying that the man-environmental benefit is mutual. With this understanding, therefore, one can define Public Health Engineering simply as "***the application of engineering to serve people primarily for the purpose of promoting a healthy living***." Thus, it is a branch of engineering that is concerned with improving the living health standards of people. Consequently, it is a branch of engineering that is particularly important for the well-being of developing nations where high death rate, especially among infants, are attributed to diseases caused by poor water quality, improper disposal of excreta and other wastes (refuse dumps) etc.

2.6.1 Health Problems in Developing Nations

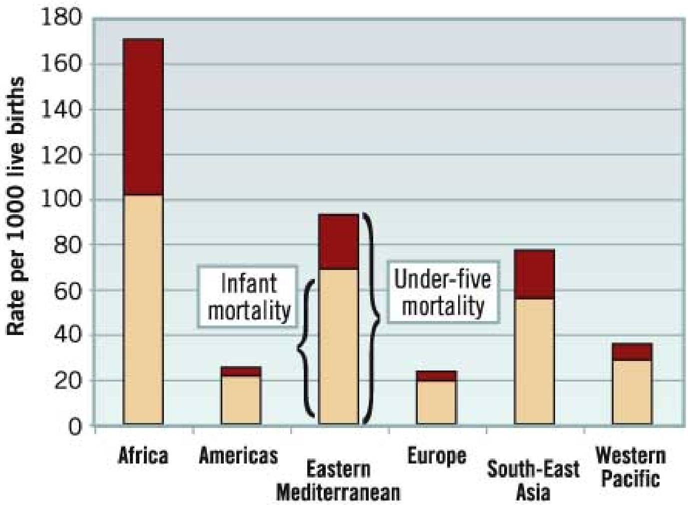
The World Health Organization estimates that 500 million diarrhoeal episodes occur each year in children under five in Asia, Africa, and Latin America (WHO, 1979). In Nigeria, and Rivers State in particular, several cases of juvenile gastroenteritis outbreak were reported in 1987, cholera, dysentery and diarrhoeal were very rampant. These illnesses are the result of poverty, ignorance, malnutrition, and poor environmental sanitation, particularly inadequate water supply and very poor excreta disposal systems.

Cholera, typhoid, and diarrhoeal diseases can be significantly reduced by adequate water supply and sanitation, as can many other diseases. The role of water in the improvement of health is not limited to those diseases transmitted through ingestion of water in food or drink. With adequate water supplies for bathing, washing of clothes and cooking utensils, food preparation, and other hygienic purposes, significant control of diseases of the eyes and skin, diseases transmitted by ecto-parasites (lice, scabies etc.), food – borne diseases and others, particularly those controllable by hand washing can be achieved.

2.7 World Update Reports

The picture painted by WHO/UNICEF (2003) update report as well as other World reports is not an encouraging one, especially for us in Nigeria (Fig 5). Most of the health related problems are associated with poor sanitation and inadequate water supply for washing and personal hygiene. Sub-Saharan Africa and, especially Nigeria, score badly as regards water supply, sanitation, open defecation etc. Other reports related to diseases present the same trend. Most of the people without access to improved sanitation and water supplies are poor and live in sub-Saharan Africa.

Fig 5 Under-five and infant mortality rates, by WHO Region, 2003



Some highlights from the WHO/UNICEF (2003) update on Millennium Development Goals (MDG) are listed below:

1. Sub-Sahara Africa including Nigeria are not on track to meet the MDG drinking water target;
2. Nigeria is not on track to meet the MDG sanitation target. coverage rate in 2010 was the same or lower than the rate in 1990; and
3. Open defecation is still practice by a majority of the rural population in 19 countries (Nigeria 26 – 50%)

Note that the MDG goals represent achievable levels if countries commit the resources and power to accomplish them. As noted in a recent Water Aid report, if the current rate of progress is not increased then Africa will meet the sanitation target not at the end of 2015 as originally set, but only by the end of 2084 (Water Aid, 2009).

Disease, Stunting and Cognitive Impairment

Poor water supplies and poor sanitation cause disease and death;malnutrition is the only greater risk factor (Evans & Mara, 2011). Some highlights from this publication, on *child mortality*, *stunting*, *cognitiveimpairments* and *personal dignity* are provided below:

Infant & Child Mortality and Life Expectancy at Birth

Infant mortality rate (IMR) is the number of babies who die before their first birthdays, expressed per 1000 live births ($^{0}/_{00}$).

Child mortality rate (U5MR) is the number of children who die before their 5th birthday.

Life expectancy at births (LEB) Is the number of year new born children would live if subject to the mortality risks prevailing for the cross section of the population at the time of birth. The data provided in Barbara Evans & Duncan Mara (2011) publication on the above subjects are summarised below

Category of countries	**IMR**	**U5MR**	**LEB**
Industrialised countries	5 %	6%	80 yrs.
Developing countries	48%	72%	67 yrs.
Least developed countries			57 yrs.
Nigeria			48 yrs.

The lower than expected value for LEB in Nigeria is attributed to AIDs related illnesses.

We know that many theories can be put forward as to why poor babies and children die at early age. The main reason however is that they are poor, have poor sanitation, poor water supplies and of course insufficient food. They are thus exposed to a high incidence of water- and excreta-related diseases.

Stunting

Stunting implies low height-for-age, and is mainly a manifestation of malnutrition. This is a common condition in developing countries (Fig 6) where it is exacerbated by diarrhoeal diseases and helminthiases (worm infections).

Cognition Impairment

Early childhood diarrhoeal diseases and helminthiases, most often in conjunction with malnutrition, result in a loss of cognition in older children. The area's most affected are verbal fluency, short-term memory and speed of information processing. These are precisely the area's most needed for people to be able to contribute to socio-economic development.

Personal Safety and Dignity

The lack of household-level sanitary facilities means that women and girls (particularly adolescent girls) are prone to assault and rape when they go out, especially at night, to a communal sanitary facility or to defecation in the open. This deeply affects the personal dignity of everyone, but especially women and adolescent girls.

Water is Life, Sanitation is Dignity –

So: no sanitation, no privacy, no dignity

Solutions to the Crisis

All hope is not lost; there exist appropriate, low-cost Public Health Engineering interventions to the sanitation and water-supply crisis. But for engineers to implement such interventions means that they must:

1. Understand and appreciate the environmental transmission pathways of water-and excreta-diseases; and
2. Design appropriate low-cost water-supply and sanitation systems in urban and rural areas.

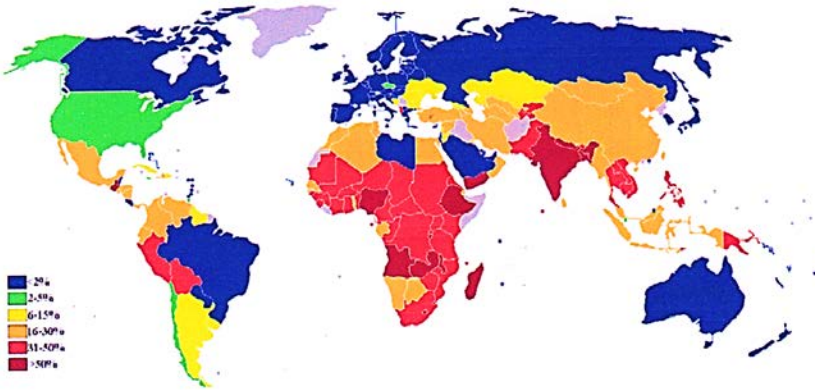


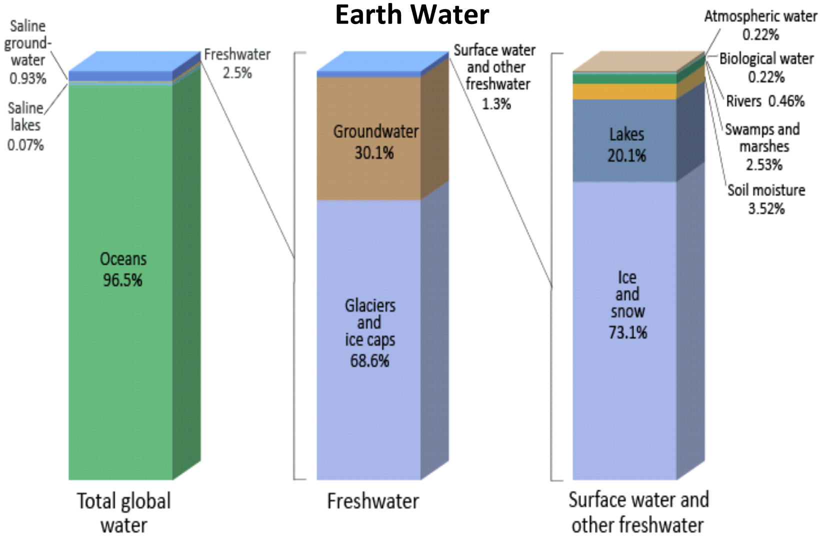
Fig 6 World map showing percentage of children under 5 with low height-for –age (WHO, 2008)

3. WATER ENGINEERING

One item of propaganda that is very popular with the politicians in Nigeria because it is easy to see its effect is water supply. Promises of water supply are often made, boreholes are drilled or water sourced from surface waters, overhead tanks erected, pumping stations installed and the water works are commissioned with funfair. After that, the scheme is often left on its own with virtually no support to run and maintain the water treatment facilities. The community in which these works are situated are then forced to contribute towards the running cost but with little maintenance. The trend of most of these water schemes are always downhill until everything crumbles.

It is interesting to note the number of potable water facilities in Nigeria that are practically non-operational due to lack of funds, operational and maintenance difficulties. Some of these plants can be made to work if attention is given to planning, design, future operation and maintenance. We shall now take a look at innovative key technical areas needed to design an effective water treatment system, using newly developed technologies for developing countries. Fig 7 provides a guide to the world's fresh water resources. Fresh water constitutes only 2.5% of the total global water resources.

Fig 7 Distribution of Earth Water



Source: Igor Shiklomanov's chapter "World fresh water resources" in Peter H. Gleick (editor), 1993, Water in Crisis: A Guide to the World's Fresh Water Resources.

3.1 Why Treat Water

The main objectives of water treatment are:

1. Removal of pathogens – bacteria, protozoa, viruses etc.;
2. Removal of toxic Chemicals - e.g. CN^-, Pb, $CHCl_3$;
3. Removal of undesirable effects – taste, odour, discoloration, solid materials; and
4. Removal of other effects for economic reasons - metal ions (corrosion), acidity.

The task facing the design engineer is to strike a balance between the *technological options* available to him in achieving these set objectives, the *financial implications* and the *benefits*.

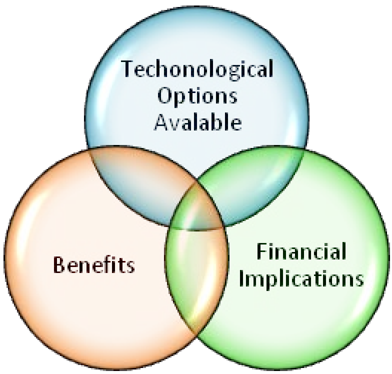


Fig 8 Task facing design engineer

It is, therefore, incumbent on the engineer in developing countries to design a treatment plant that is *low in initial cost; simple and economical to operate; contains a minimum of pumps, motors, and other equipment; and emphasizes the use of available labour*. It has been shown that an initial investment in plants based on the above principles in Latin America is between 3.5 to 10 times lower when compared to the North American conventional technology (Arbodela, 1983; Sank, 1979).Our survey of 23 water treatment plants in Nigeria (Leton & Oko, 2004) shows that most plants are working far below capacity and this could be attributed to failure by the planners/designers to consider the above principles at the design stages.

3.2 Source Selection

Water, in nature is, continuously circulating (Figure 9). From the hydrologic cycle, three sources of water are readily available to us, namely:

1. Rainfall intercepted before it reaches the ground;
2. Surface water in rivers, streams and lakes; and
3. Groundwater including springs

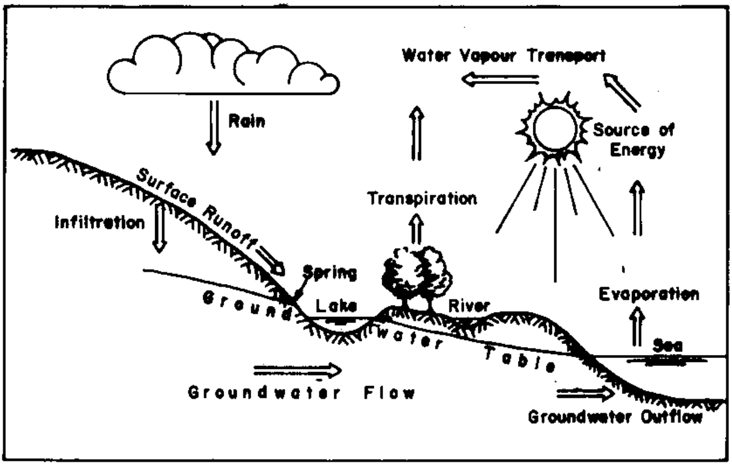


Fig 9 Hydrologic cycle

Although water for domestic use may be abstracted from the hydrologic cycle at various points, the order of preference in obtaining supplies based on criteria set by Thanh & Hettiaratchi (1982) should be:

1. Groundwater, requiring no treatment, recovered at various places at short distances from the consumer, e.g. deep and shallow wells;
2. Spring water, requiring no treatment recovered locally;
3. Groundwater, requiring simple treatment, recovered locally;

4. Spring water, requiring simple treatment and gravity supply;
5. Lake, pond, stream water, requiring simple treatment recovered at some distance and carried to the distribution area by a pump driven, piped supply.
6. Water from rivers, requiring extensive treatment and pumping to the supply area.

3.2.1 Water Quantity

In conditions of poverty and water shortage, according to Cairncross (1987), all the potentially water-borne diseases can pass from person to person in a host of different ways. Contaminated water is one such route, but contaminated fingers, plates and food can be just as common and even more dangerous, Fig 10.

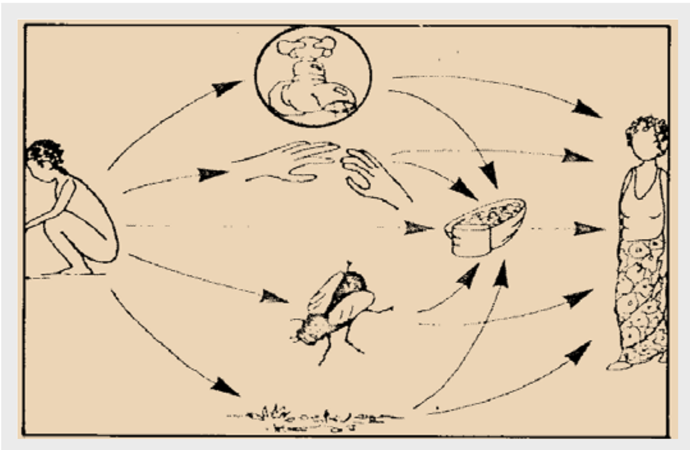


Figure 10 Faecal oral routes for diseases transmission

(Cairncross 1987)

For many in developing countries, the first health requirement may not be high quality water, but for more water of minimum acceptable quality to wash things and keep them clean. Ready availability of water in sufficient quantity also helps to control unpleasant skin infections such as scabies, and eye diseases such as trachoma which can be a common cause of blindness. The most effective way to increase a poor community's water consumption is to provide the water closer to their homes. Fig 11 illustrates that only when water is supplied in the house or the yard (journey time < 5 minutes) does consumption increase considerably. The per capita consumption can therefore be based on the criteria by Howard & Bartram, (2003); and WELL (1998).

3.2.2 Water Quality

The objective of water treatment is to provide water that is safe for human consumption and appealing to consumers. Although we use WHO Drinking Water Standards, for community water supply ***turbidity***, ***colour*** and ***coliform count*** should be the minimum guiding parameters.

The water treatment objective for rural communities therefore, is to supply water in sufficient quantity with regard to the most basic qualities.

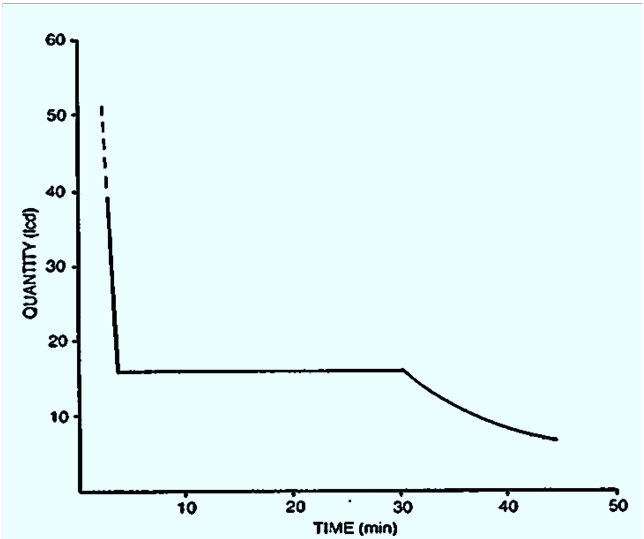


Figure 11 Graph relating domestic water consumption to collection time (Cairncross, 1987)

3.3 Design Philosophy

The design philosophy for community water supply treatment according to Monk et al (1984) should be to:

- Produce reliable plant;
- Ensure easy plant operation and maintenance;
- Minimize imported items;
- Reduce mechanization and instrumentation;
- Maximize local labour during construction and operation;
- Limit energy demands by taking advantage of gravity; and
- Use local materials whenever possible.

Adopting these fundamental principles above, in the design of a treatment plant results in the most effective and economical treatment process with the following properties (Wagner, 1983):

1. minimum size of plant and structures;
2. maximum reliance on gravity for chemical feed;
3. maximum use of hydraulic means for mixing, flocculation, and filter rate controls;
4. minimum loss of head through the plant; and
5. minimum use of equipment.

These design principles result in the most effective and economical treatment process. (Wagner, 1983).

3.4 Technological Options

3.4.1 Pre-Treatment

Pre-treatment removes larger settleable materials as water reaches the plant, thereby reducing the load on subsequent treatment units, leading to substantial savings in overall operating costs. Plain sedimentation or roughing filters (Fig 12) may be appropriate.

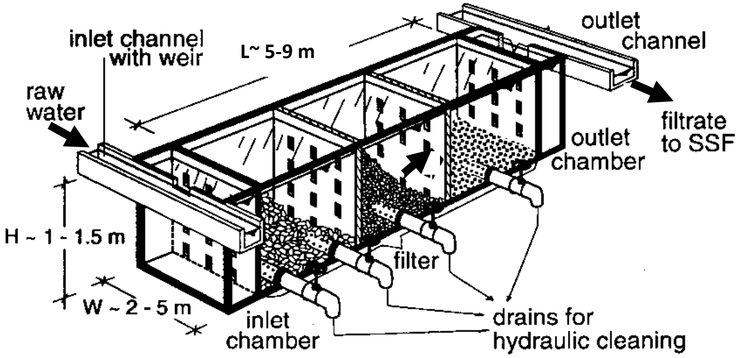


Figure 12: Horizontal flow roughing filter

3.4.2 Chemicals& Chemical Feeders

The chemicals commonly necessary in water treatment include (Table 1):

Table 1 Common chemicals used in water treatment

	Chemical	**Common type**	**Option**
1.	Coagulants	Alum generally	*Moringa Olefera* seed powder
2.	Disinfectants	Chlorine or hypochlorites generally	Ultra-violet (UV) radiation
3.	Alkalis for pH control	Lime	-

The use of local *Moringa Olefera* seed powder has been proposed as a suitable coagulant in place of alum, if it can be produced in commercial quantities (Matawal et al, (2006); Shulz and Okun,(1984).

Ultra-violet (UV) radiation can be used as an alternative to chlorination for small rural-friendly schemes but power cost should be considered (Matawal and Kulack; 2004)

Chemical feeders should be simple in design, and easy to operate. Hypochlorite and coagulant solution can be fed by locally constructed solution-type feeders.

3.4.3 Rapid Mixing

Rapid mixing should be provided by hydraulic rather than by mechanical means. Hydraulic jumps, flumes, or weirs (Fig 13) can achieve sufficient turbulence without mechanical equipment and are easily constructed, operated and maintained with local materials and personnel.

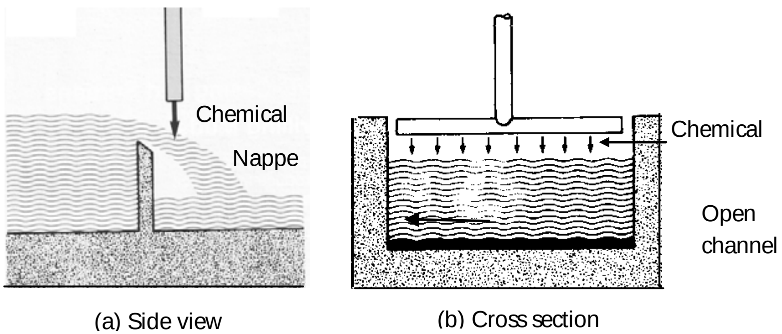


Figure 13: A simple and reliable rapid mix system using sharp

3.4.4 Flocculation

Flocculation can be achieved mechanically (using rotating paddles, blades etc.) or hydraulically, using the flow velocity of the water. Mechanical systems which allow some level of control over the waters' mixing intensity are generally used for large plants while hydraulic flocculators are used for small plants.

Hydraulic flocculators such as ***baffled-channel (Fig 14)***, ***gravel-bed***, and ***Alabama flocculators*** do not require mechanical equipment or a continuous power supply, and can be built largely of concrete, brick, masonry, or wood with local labour at low cost. Mixing is accomplished in Hydraulic flocculators with baffles (Figure 6) by reversing the flow of water. These channels can be designed with removable baffles to give more flexibility of operation.

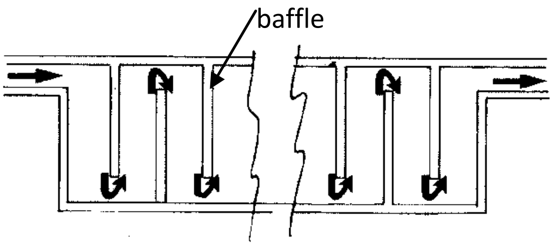


Figure 14 Baffled-channel flocculators

In addition, hydraulic flocculators produce almost plug-flow, while mechanical ones are prone to short-circuiting.

3.4.5 Settling

Horizontal-flow sedimentation tanks (Fig 15) with manual sludge removal require no imported equipment, and labour for cleaning is readily available. Plate settlers' sedimentation tank has overflow rates five to eight times those of conventional rectangular tanks and can reduce the size of such structures to a minimum. The tank Plate units (Figure 15a) can be built on the ground from locally produced plastics, or waterproof plywood. Plate settlers are now finding great popularity, not only in new plants but also where old plants are updated.

Plate settlers are preferred to conventional horizontal-flow sedimentation tanks because they are more economical to build, produce better effluent, and are more stable and reliable.

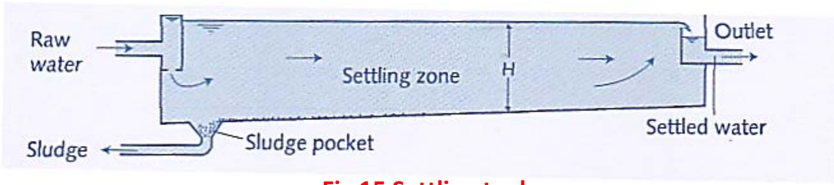


Fig 15 Settling tank

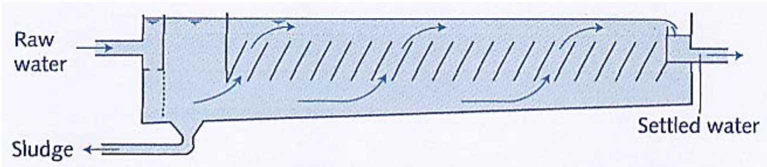


Fig 15a Tilted plate settling tank

For large tanks, quite sophisticated systems of trays or plates have been devised but in small installations flat or corrugated plates and upward flow of the water are frequentlythe most suitable. For any clarification duty, tilted plate settling tanks have the advantage of packing a large capacity in a small volume. The effective surface being large, the surface loading will be low, and the settling efficiency, therefore, high.

3.4.6 Filtration

Three types of filter that are often used by water treatment works are: **slow sand filter**, **rapid sand filter** and **pressure filter**.

Slow Sand Filters

The use of ***slow sand filters*** is experiencing a renaissance as more and more isolated/small water treatment plants are turning to this simple yet effective technology Wohanka (2002). SSF has received more recommendation as a single treatment step for surface water in developing countries than any other water treatment unit (Paramasivam et al., 1981; Lloyd et al., 1983). This is because it combines physical, chemical and biological actions to produce water of very high quality. Above all the filters can easily be constructed, operated, and maintained.

In order to be effective, a constant flow of water passing through a slow sand filter is essential for maintaining the bio-film responsible for much of the removal of disease-causing organisms. However, one recent significant advance in making the slow sand filter suitable for intermittent operation is attained by ***raising the under drain pipe back up above the sand level***, ensuring a foolproof method for maintaining the water level just above the sand.

Rapid Filters

Rapid filtration requires a larger proportion of equipment; it is regarded as the most costly and poses the greatest difficulty in design and construction of all water treatment processes. Fortunately, it is in rapid filters that the most drastic simplifications have occurred, namely:

- the use of a dual-media filter bed of sand and anthracite coal;
- the backwashing of a filter unit with the effluent from other units; and
- the use of declining-rate filtration.

Dual-media Filter Beds: - are preferred to sand alone because they allow filtration rates two to three times higher than conventional sand filters (around 285 m/d) and can consequently reduce the required filter surface area by the same factor.

Inter-filter-washing Units: - These filters (Fig 16), which are used to backwash a filter cell with the effluent from other cells, are easier to build, operate, and maintain than conventional filters that are washed with water from an overhead tank or with water that is pumped by large pumps. Thus the need for overhead tanks or pumps is avoided. Only two valves are needed for filter control.

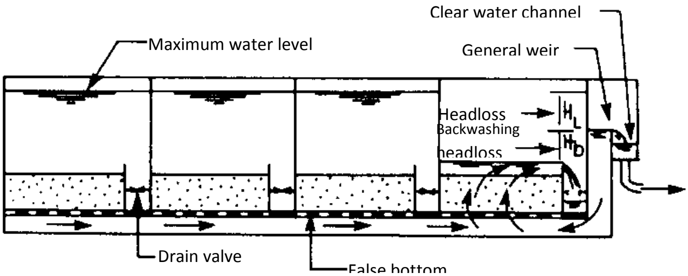


Fig 16 Inter-filter-washing filtration units

Declining-rate filtration: - The third simplifying feature is the omission of the flowrate controller, and the modification of the conventional design to allow declining rate flow in the filters. Excessive filtration rates are, thus avoided at the start of a run. This is achieved by maintaining sufficient head loss in the outlet by an orifice or control gate. Conventional rate controllers are complex to operate and maintain properly without skilled personnel and thus are not well suited for most developing countries.

By incorporating these three technologies in a single design, it is possible to eliminate most of the equipment used in conventional filter designs that would otherwise have to be imported in most developing countries. Moreover, construction costs for this kind of design can be reduced by as much as 60 per cent of the cost of conventional designs. Operation and maintenance costs are considerably reduced without any detrimental effects on filtrate quality.

Upflow-Downflow Filters

In this type of system, a battery of upflow roughing filters replaces the conventional arrangement of mixing, flocculation, and sedimentation used in rapid filtration plants (Fig 17). The downflow filter is a conventional rapid filter. This design can result in reduced construction and operations costs. The coagulant dosage is generally smaller than that required for conventional treatment.

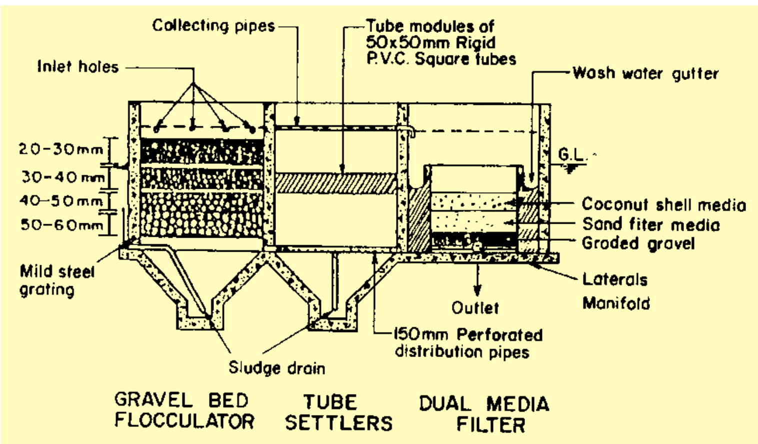


Figure 17: Flow diagram of upflow-downflow Plant (Schulz &Okun. 1984)

3.5 Status of Water Treatment in Nigeria

Water treatment had received more publicity but little attention in Nigeria since the early 70's. As such, there seem to be no coherent policy on the provision of potable water for the general public in the country. When elaborate water works are built, the designs are carried out without consultations with the indigenous professionals. Consequently, costly imported parts are used resulting in plants highly mechanised and hungry for expensive chemicals.

Some aspects of our studies (Leton & Oko, 2004) on the status of water treatment and supply in the southern part of Nigeria are outlined below.

Two major sources of potable water in use are borehole and surface water.

Most ***Borehole water*** sources are free from mineral contaminants, tasteless, odourless, and colourless and generally required minor treatment such as pH correction and chlorination. Traces of iron were observed in one or two borehole sources.

The plants that use ***surface water*** as their source of raw water make provision for elaborate treatment facilities. Data obtained indicated high turbidity and increased suspended solids concentrations after heavy rainfalls. The pH was found to be low in most cases and the water contained some fresh water micro-organisms.

3.6 Treatment units employed

The treatment (Fig 18) units used in the treatment of both boreholes and surface water sources in the plants visited are:

a. Pre-treatment
b. Pre-chlorination
c. Coagulation and flocculation
d. Sedimentation
e. Filtration
f. PH correction
g. Disinfection

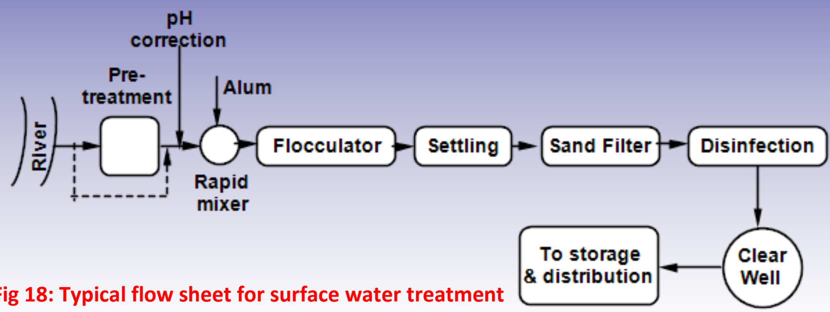


Fig 18: Typical flow sheet for surface water treatment

The use of new emerging technologies such as hydraulic mixers/flocculators and declining filtration etc. recommended for treating water in developing countries (Monk et al, 1984; Schulz & Okun, 1983; Thanh & and Hettiaratchi, 1982; Wagner, 1983), were not evident in these plants.

3.6.1 Pre-Treatment

The importance of pre-treatment is that it reduces the sediment load on the preceding treatment units and saves a lot on the operating cost and expenditure on chemicals.

Almost all surface water plants use ***pre-settling*** and ***plain sedimentation*** as pre-treatment to remove the larger-size and settleable materials before they get to the initial treatment units.

3.6.2 Pre-Chlorination

This involves the addition of chlorine at the initial stage of the treatment process. Few water treatment plants practiced pre-chlorination, and all use ***chlorine powder***.

3.6.3 Coagulation and Flocculation

All the treatment plants with surface sources of raw water included this treatment unit in their treatment processes. Only one plant using borehole included coagulation and flocculation treatment units, and this plant was observed to have iron problems. ***Alum*** is the only coagulant in use, and a few plants use coagulant aids such as ***polyelectrolyte***.

3.6.4 Sedimentation

This process, which follows chemical coagulation, involves solid - liquid separation. Most of the plants that use surface water as their source included sedimentation as treatment unit. As noted above a borehole-based plant with iron problems used sedimentation as a treatment unit. The type of sedimentation tank commonly in use is the ***horizontal flow tank,*** which employ manual cleaning.

3.6.5 Filtration

Filtration is used in water treatment as a separation process to remove fine inorganic and organic particles from water. All the treatment plants that use borehole as their source of raw water do not have filters except those that have the problems of iron and pH adjustment. These use ***pressure filters***. All the plants with surface water, as their source of raw water have filters and the type of filter widely used is the ***sand filters***.

3.6.6 pH Correction

In this treatment unit, pH of the water is adjusted to an acceptable range. This is done by the addition of an alkali - commonly ***hydrated lime***, because it is readily available in the market.

3.6.7 Disinfection

This involves the inactivation of pathogenic organisms still remaining in the water. This is normally the last treatment unit before the water is sent for distribution. The data shows that ***chlorine*** is the commonly used disinfectant in almost all the plants visited, except one plant that uses a variety termed ***tropical chloride of lime***. Some plants use chlorine in the liquid form while others use chlorine in form of ***powdered calcium hypochlorite***.

3.6.8 Cost of Chemicals

The cost of imported chemicals is one of the greatest obstacles that confront adequate treatment of potable water in Nigeria. The quantities and average cost of chemicals used in the various plants are shown in Table 2.

For chlorination, tropical chloride as used in one of the plants appears to be the cheapest, even at the dosage of 0.71 g/m^3 it still gives a cost of ₦60.00.

Table 2: Rate of chemical usage and cost

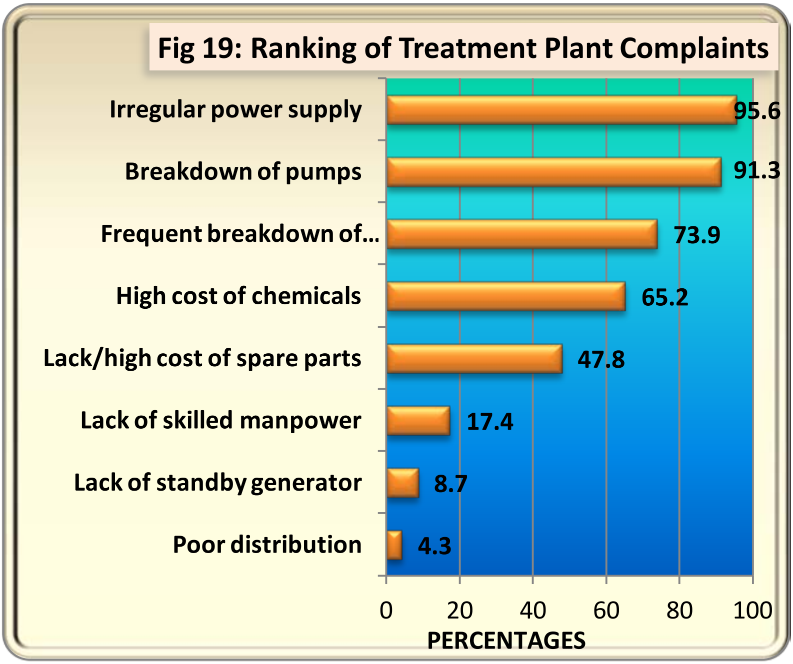
Process	Chemical	Usage (g/m^3)	Cost (₦/kg)
Pre-chlorination	Chlorine	0.71 – 1.4	160
Coagulation	Alum	0.04	15.5
Coagulation	Polyelectrolyte	-	3.4
pH correction	Hydrated lime	27 - 30	10.2
Disinfection	Chlorine	0.71	160
Disinfection	Tropical chloride	0.08	28

3.6.9 Treatment Unit with Frequent Breakdown

Some treatment units break down more often than others. These units include: ***chemical dosing units***, ***chlorine injectors***, ***metering pumps*** and ***air scour systems***.

3.6.10 Problems Encountered in the Treatment Process.

The problems encountered in the water treatment plants are listed and ranked in Fig 19. Almost ninety-five per cent of the plants visited complained about ***irregular power supply***.



Other major problems include: *frequent breakdown of pumps, frequent breakdown of power generating sets, high cost of chemicals, lack/high cost of spare parts and lack of skilled man power*.

A typical water treatment plant in Nigeria where some of these technologies have been implemented is that of Owerri Water Board. It is the authors' opinion that it is high time the Universities in Developing countries adjust their curriculum to reflect emphasis on these new trends.

3.7 Water Supply

Water supply lines are constructed to provide fresh water for human consumption, commercial and industrial uses. Unfortunately, most public taps are dry nowadays, and individuals have to make do with their own borehole water supply system. This is a setback in human, commercial and industrial development; the maintenance of public health and general cleanliness. With reference to open drains, it seems that there is no way we can construct water pipelines without crossing storm drains. The water pipes are thereby exposed to damage and become points of entry of pollutant into the water supply system. Of course, water pollution implies the spread of water related diseases.

3.7.1 Water Distribution

The purpose of a distributing system is to convey water from the point at which the trunk mains terminates to all the consumers. The pipe work of a distributing system comprises a number of sections serving different purposes (Leton, 2003), such as: *trunk mains, trunk distribution mains, secondary mains, service mains* and *service pipes*.

We have taken a detailed look at the water supply system in use in Nigeria and have observed the following wide range of pipe types used by the water industry in Nigeria:

1. asbestos-cement (AC);
2. polyvinyle chloride (PVC) including uPVC, MDPE and HDPE
3. galvanised iron (GI),
4. steel iron (SI),
5. ductile iron (DI) ;and
6. cast iron (CI) pipes.

The water engineer faces colossal problems in the design and preparation of specifications for water distribution pipes in the country. This is due to lack of uniformed standards in the specifications of pipe length, diameter, strength, rated pressure and cost. In addition, there is the problem of burst water mains as observed by Odjegba & Leton

(2004). These make design and cost estimates difficult or at best a guess-work.

Some of the revelations from our study are as follows:

Pipe usage: Fig 20 depicts the percentage usage of these pipes, with Asbestos-cement (AC) pipes having the highest usage of 93%, both PVC and galvanised iron (GI) have 75% usage each, SI has 28% usage, while DI and CI has 13% usage each. Thus, the most popular pipe in the water industry is the AC pipes followed by PVC and GI pipes respectively. The high percentage of AC pipe usage is a little surprising, due to the connection of asbestos dust/fibres with the cancer ***asbestosis***.

Pipe pressure: The rated pressure of most of the pipes in use are AC pipe, $10\times10^5 N/m^2$ (10 bar); PVC pipe (15 bar for Class E); GI pipe (10 – 60 bar); and DI pipe (60 bar).

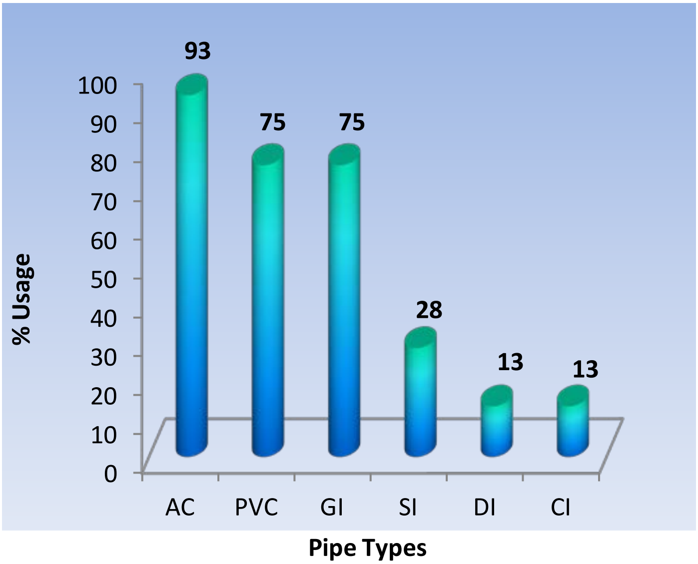


Fig 20 Water Pipes Usage Distribution

Causes of Pipe failures

Occasional failure of water pipelines was attributed to the following causes:

1. Water hammer due to rapid pressure variations;
2. Vandalism;
3. Improper tightening of joints;
4. Wearing of cement coating;
5. Poor workmanship;
6. Excessive load e.g. at road crossings;
7. High pressure;
8. Vibrations from vehicles; and
9. Fracture while laying pipes.

The major cause of pipe failure in Rivers State (UNIPORT) was attributed to the wearing off of cement coating due to the aggressiveness of the soil.

Failure Locations

Failure of pipes occurs mainly at road crossings, junctions and rail crossings. To increase protection for these pipes against excessive loads, the pipes should be protected by culverts or steel casing or any form of special casing..

Recommendations

The following recommendation can be made from the analysis of data gathered from the various states:

Service Pipes

Plastic (PVC) pipes are recommended for service lines (50<ø<150mm for the following reasons:

1. They are flexible, permitting easy deflections during installation;
2. They are resistant to corrosion, hence they have long service life;
3. They are relatively cheap;
4. They possess smooth interior surfaces, hence high flow capacity and low head loss.

Trunk Mains

Steel pipe is recommended for trunk mains for the following reasons:

1. They are strong and lightweight, thereby easy to handle, and transport without high tendencies of breakage, unlike AC pipes;
2. Their trenches can be dug to 2m deep or more without breakage due to backfill load, unlike the AC pipes;
3. If properly lined and polished, they are resistant to corrosion and exhibit high Hazen-Williams C value;
4. They are more suitable than other pipes for use at road crossings because they are strong to withstand traffic load vibrations; and there is little risk of breakage during installation.

3.8 Solar water Supply System for Rural Communities

We investigated the use of solar pumping for rural water supply to avert the problems of power disruptions (Leton & Yorkor, 2010). Solar water system requires no fuel, little technical knowledge, maintenance, and few repairs. These advantages make solar water systems more suitable for rural communities with no national grid. Various detailed design options were evaluated.

A ten-year economic analysis carried out showed that diesel system becomes economically unviable just after six years of operations, while solar system demonstrates a good viability even after ten years of operations.

4. WASTEWATER TREATMENT & DISPOSAL

To reduce the risk of water related diseases, waste water (used water) from buildings and industries are usually collected, isolated, treated on site or conveyed by sewers to treatment plants off-site. By isolating and treating wastewater prior to disposal, we reduce the impact of the pollutants on the environment. At present, there are no public waste water treatment facilities in Port Harcourt.

Wastewater refers to liquid wastes discharged from residential, commercial, or industrial premises. It is normally classified as domestic, industrial, or municipal.

When municipal wastewater is combined with storm waters (surface runoff), it is referred to as ***Combined Waste water***. Wastewater immediately after fouling is referred to as fresh wastewater as it still contains the dissolved oxygen present in the water supply. Wastewater in which dissolved oxygen has been completely exhausted and anaerobic decomposition has been established is referred to as ***septic*** wastewater.

4.1 Waste Water Characteristics

Domestic wastewater is made up of faeces, urine and sullage. Its analysis indicates that it contains about 99.9 per cent water and 0.1 per cent solids (Tebbutt, 1981). The solids are about 70% organic (mainly proteins, carbohydrates and fats) and about 30% inorganic (mainly grit, salts and metals) - See Fig 21.

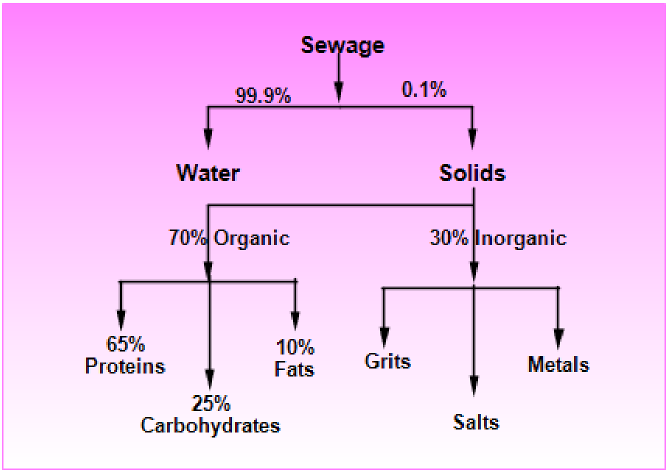


Fig 21 Composition of Sewage (Tebbutt, 1976)

In addition, municipal wastewater contains millions of intestinal bacteria some of which are able to cause human disease (pathogens) by producing toxic or poisonous compounds. They are excreted in the faeces of infected persons.

4.2 Major Pollutants

Pollutants of concern in the discharge of wastewater to surface waters are listed in Table 3.

Table 3 Major pollutants in the discharge of wastewater to surface waters

Types of pollutant	Typical measurement parameters	Environmental impact
Biodegradable organics	i. 5-day, 20˚C biochemical oxygen demand, BOD_5	Deoxygenate water and generate obnoxious odours

	ii. Chemical oxygen demand, COD	
Suspended materials	i. Total suspended solids, TSS ii. Volatile suspended solids, VSS	Cause turbidity in water and bottom deposits
Pathogenic micro-organisms	Faecal coliforms, MPN	Render water unsafe for drinking and recreation
Ammonia	Ammonium nitrogen, NH_4^+-N	Deoxygenates water , is toxic to aquatic organisms and may stimulate algal growth.
Phosphate	Orthophosphate phosphorus, PO_4^{3-}P	May stimulate algal growth
Toxic materials	As the specific toxic material	Hazardous to plants and animal life
Inorganic salts	Total dissolved solids, TDS	Limits the industrial and agricultural use of water.
Thermal energy	Temperature	Reduces the saturation concentration of oxygen in water and accelerates growth of aquatic organisms.
Hydrogen ions	pH	Potential hazard to aquatic organisms.

Effluent standards generally specified are limited to the first three and sometimes pH, e.g.

BOD_5, mg	< 20
SS, mg/1	< 30
Faecal coliform (MPN)	= 200
pH	= 6 - 9

4.3 Why Treat Wastewater

Municipal wastewater is objectionable in appearance and extremely hazardous in content, mainly due to the number of pathogenic organisms it contains. Under warm climatic conditions, it can lose its dissolved oxygen content early and become septic, with the associated highly offensive odour. In addition to these, a number of different chemicals ranging from detergent, pesticides to industrial chemicals are found in municipal wastewater. Thus before wastewater is discharged into the environment, it should be treated for the following reasons:

i. to reduce the spread of communicable diseases;
ii. to prevent the pollution of surface and ground waters; and
iii. to reduce the pollution load and its deteriorating impacts on the environment as a whole.

4.3.1 Treatment Philosophy

For practical purposes, the pollutants contained in a wastewater can be grouped into three categories:

- Materials in suspension;
- Materials in colloidal state; and
- Dissolved materials.

The underlying principle in wastewater treatment is to separate the suspended/colloidal particles and convert the soluble impurities into particulate bacteria, which can also be easily separated from the liquid. In the process, large quantities of solids (sludge) are produced. This sludge may contain many of the original pollutants – pathogens, and toxic chemicals in more concentrated form, thus requiring separate treatment and disposal.

To attain the above goals, the basic stages of wastewater treatment are as follows:

- Preliminary treatment
- Primary treatment
- Secondary treatment
- Tertiary treatment
- Sludge treatment.

A typical layout of a wastewater treatment plant incorporating biological treatment is shown in Figure 22.

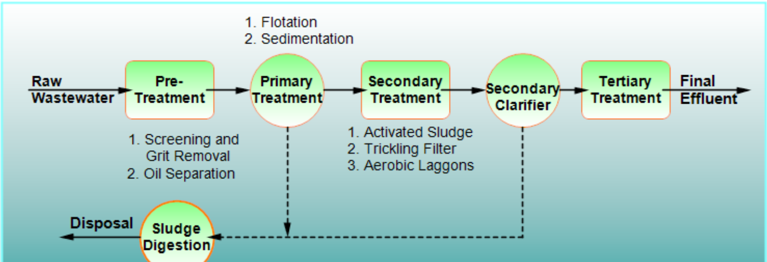


Fig 22 Typical wastewater treatment sequence

4.4 Conventional Biological Treatment Systems

The micro-organisms (usually present in the wastewater) on which the biodegradation relies may be used in two different ways:

1. Suspended growth (dispersed culture) systems
2. Attached growth (fixed film) systems.

Suspended Growth Systems

In this biological treatment system, both the biomass and the substrate are in suspension or in motion. Typical examples of this system are activated sludge (Fig 23), aerated lagoons, waste stabilization ponds.

Fig 23 Activated sludge

Attached Growth Systems

In this system, the population of active micro-organism is developed over a slid media or plastic. The attached growths of micro-organisms stabilises organic matter as the waster passes over them. Typical examples are trickling filters (Fig 24), rotating biological filters, anaerobic fluidised bed.

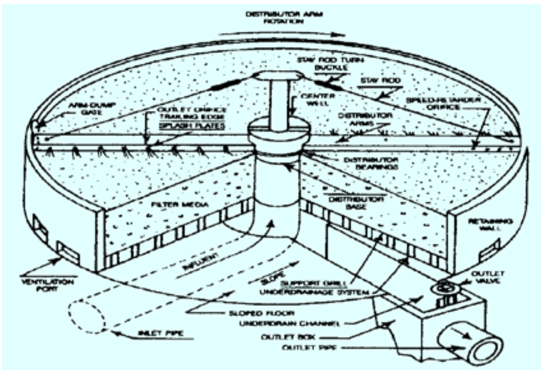


Fig 24 Section of a trickling filter (EPA)

Conventional biological treatment plants as outlined above are capable of removing 95 per cent of BOD and over 90 per cent of the suspended matter from the original wastewater.

It has to be pointed out that although biological treatment may remove more than 85 of BOD_5 and suspended solids, significant amounts of N_2, P, heavy metals, non-biodegradable organics, bacteria, and viruses are not removed. Tertiary treatment may be required to remove these pollutants where the effluent receiving waters are sensitive.

4.5 Tertiary Treatment

Tertiary or advanced treatment is the term used to describe those processes, which are used to improve the quality of effluents from conventional sewage treatment works; that is effluent that has received primary and secondary treatment.

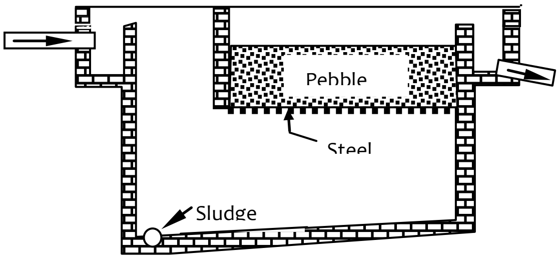


Fig 25 Pebble Bed Clarifier (Mara, 1978)

Tertiary treatment methods currently used to remove suspended solids are maturation ponds, flocculation and sedimentation or flotation, micro straining, sand filtration and clarification on a pebble bed (Fig 25). The pebble bed clarifier is shown below.

Maturation ponds are series of shallow basins, designed to:

1. achieve maximum faecal bacterial removal, and
2. further reduction in biodegradable organic materials (BOD_5).

4.6 Sludge Treatment and Disposal

The treatment of sewage produces large quantities of sludge and the hygienic disposal of this is essential. Sludge comprises grit, “primary” sludge deposited in the primary sedimentation tanks, and “secondary” sludge resulting from secondary treatment. These ‘solids’ have a considerable affinity for water being 94-99% water.

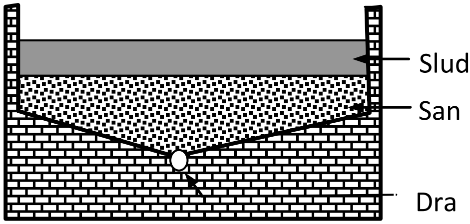


Fig 26: Sand drying bed

Local conditions are a very crucial factor in the choice of methods employed for sludge treatment and disposal. Sludge may be disposed in the liquid form, or it may be thickened or subjected to a process called digestion. Alternatively, some of the water may be removed by dewatering process before the sludge is disposed of in the form of a moist cake. Drying beds (Figure 26) are suitable in hot climates with scanty rainfall, or it can be covered in rainy areas.Finally, Sludge can be disposed of in landfill, sludge farming, ocean dumping, and composting.

4.7 Problems of Sewage Treatment in Hot Climates

Conventional sewage treatment relies heavily on electrical machinery – pumps, sludge scrapers, aerators and thus requires considerable skill in installation, operation and maintenance. This skill, particularly in maintenance, may not be readily available. The most common source of sewage plant failure in developing countries for a pertinent example has been associated with pumps. I have observed that in some plants visited.

In hot climates, sewage can soon become malodorous (Septic) if sufficient oxygen is not made available to prevent the onset of anaerobic conditions. A higher level of odour can thus be expected to come from primary sedimentation tanks, which are designed for quiescent settling, and not turbulent oxygenation. Primary settling tanks under tropical conditions would require frequent desludging, to avoid floating sludge, malodour and flies. As such, elimination of primary treatment facilities may be advantageous.

4.8 Options Available for Tropical Regions

The lines of action to be taken in tropical regions include:

1. Isolation of the wastewater from human, animal, insect access;
2. Conveyance of same to a safe location or unit where it can be treated;
3. Application of appropriate treatment processes applicable;
4. Disposal of effluent safely to the environment; and
5. Appropriate treatment and disposal of sludge (bio-solids).

We can separate wastewater treatment into two categories depending on their capacity as”

1. Centralised sewage works; and
2. Decentralised treatment plants.

4.8.1 CentralisedSewage Works

For centralised treatment works, the first two systems below are recommended, while the last two are listed because plants such as RBC have been used in the petrochemicals and refineries in Nigeria. The rest can be used if the setup calls for them e.g. bio-tower for the breweries.

1. Waste stabilisation ponds
2. Oxidation ditch
3. RBC
4. Bio-tower

Waste Stabilisation Ponds

It has been observed that retaining sewage in a series of shallow ponds under tropical conditions for two to three weeks provide an ideal environment for a significant reduction in the levels of both BOD and pathogens (Feachem et al. 1981). Warm climate, coupled with sunlight, promotes rapid growth of microorganisms, which are instrumental in the removal of BOD both aerobically and anaerobically.

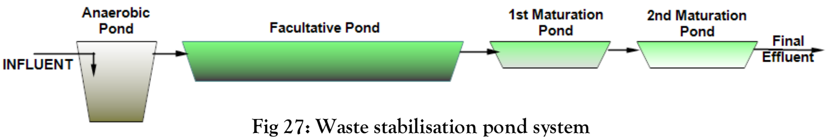


Fig 27: Waste stabilisation pond system

Waste Stabilisation Ponds (WSP) are large rectangular basins (Fig 27), arranged in a series of *anaerobic*, *facultative* and *maturation ponds*. As the wastewater enters and flows through the series, it is oxidized by heterotrophic bacteria utilizing oxygen produced by algae which grows profusely in facultative and maturation ponds.Worthy contributors to WSP design are Prof D.D. Mara of Leeds University, UK; Prof M.B. Pescod (New Castle Upon Tyne University, UK) and Gloyna, E.F.(WHO).

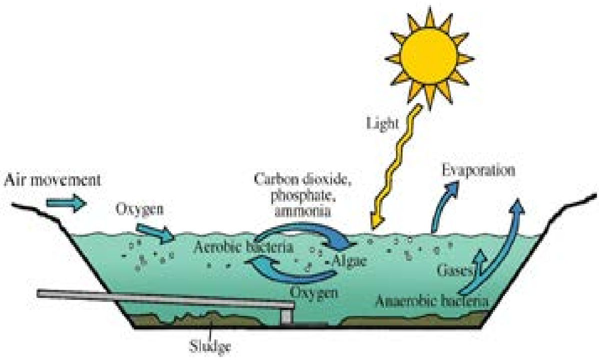


Fig 27a: Facultative pond

Advantages

1. Low capital cost
2. Simple operation
3. Sludge removal required at 10-20 year intervals

Disadvantages

1. Land-intensive
2. Prone to mosquito spread

Aerated Ponds System

This is an activated sludge system without sludge recycling. It is the treatment system that was designed for Port Harcourt by Balasha Jalon. It consists of a series of ***completely mixed***, ***partially mixed*** and ***polishing*** (maturation) ponds (Fig 28 & 28a). While this system can work efficiently in this environment, it requires a considerable amount of power. Sludge production is minimal.

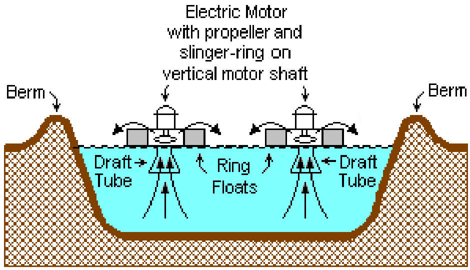


Fig 28: Completely mixed aerated pond

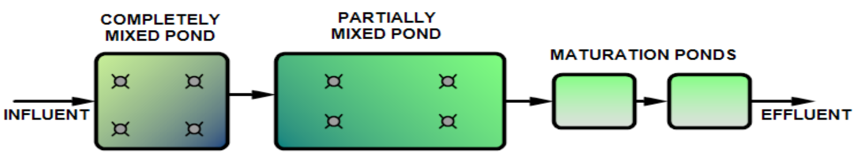


Fig 28a: Aerated ponds process train

Oxidation Ditch

Oxidation ditch (Fig 29) is an Extended Aeration Process operating in the endogenous respiration phase, i.e. low organic loadings and long aeration time. Process is based on providing sufficient aeration time for oxidising the biodegradable portion of the sludge synthesised.

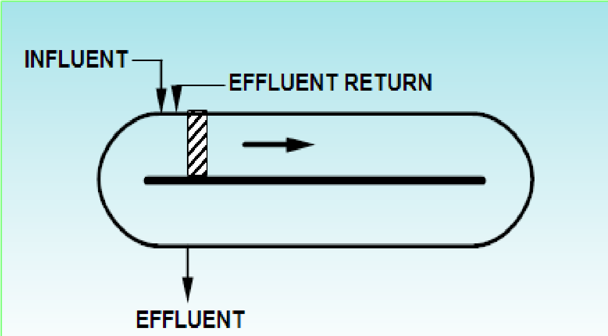


Fig 29 Schematic diagram of Oxidation ditch

The process produces less sludge and theoretically the excess sludge is only the non-biodegradable residues remaining after total oxidation. BOD removal efficiency = 75 – 95 %.

Rotating Biological Contactor (RBC)

A rotating biological contactor (RBC) is an attached growth, biological process. It consists of large diameters plastic media (or series of discs) mounted on a horizontal shaft, rotating slowly in the wastewater tank (see Fig 30). Micro-organisms naturally present in the wastewater adhere and grow on the partially-immersed media to form a biological active film. These micro-organisms in the active film consume the organic pollutants in the wastewater as it trickles over it. The rotation of the media contacts the active film with the wastewater and exposes it directly to air for absorption of oxygen, thereby promoting aerobic biological treatment. In addition, the rotation of the media through the wastewater allows for the mixing of the liquor, and also causes a portion of the excess microbial growth film to separate (slough) from the media surface, and can be removed from the process effluent. An RBC treatment system is made up of three main stages: (1) *preliminary* *treatment* (2) *biological treatment* using the rotating media and (3) *secondary settlement.*

Many RBC operating problems are caused by ***shaft failures***, ***disk breakage***, ***bearing failures***, and **organic overloading.** By adopting proper design, operation, and maintenance practices, wastewater treatment facilities can mitigate many of these problems.

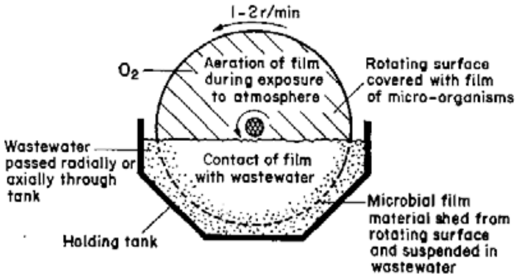


Fig 30 Principles of RBC

For example, many RBC systems are enclosed to eliminate disk *exposure to UV light*, reduce temperature effects, and protect the equipment. These facilities can control odour problems by reducing organic loading, or by increasing the oxygen supply using supplemental air diffusers in the tank. The problems noted above are the same as those affecting the RBC treatment plants visited in Port Harcourt and Warri.

Bio-Tower Systems

A bio-tower is simply a trickling filter having a greater depth. Usually, light weight pvc modular materials having large surface area and structural rigidity are used as filter media. These media provide a large filter volume in a relatively small tank. The bio-tower is used extensively for the treatment of wastewater in the beer industry.

We used a modification of the bio-tower filter system todesign of "Trickling Biological Periwinkle Shells Filter for Closed Recirculating Catfish Systems" (Uzukwu & Leton, 2010)

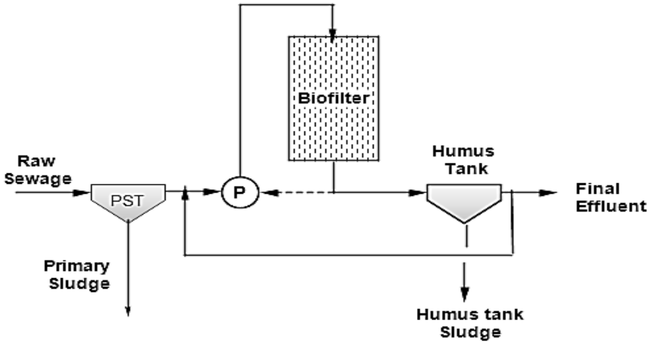


Fig 30a A Bio-tower filter systems

4.8.2 Decentralised Systems

Septic tank systems

For low to intermediate discharges, on-site systems are very feasible, starting from the humble septic tank systems (Fig 31) to the packaged treatment plants.

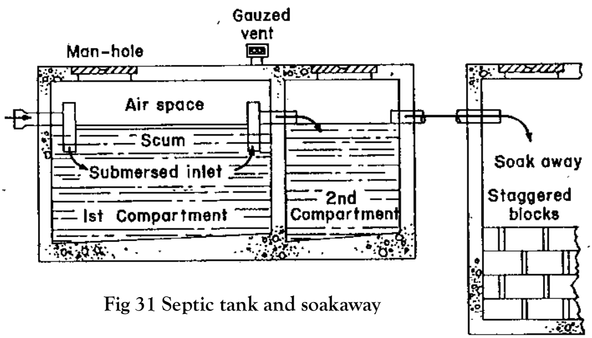


Fig 31 Septic tank and soakaway

Even the simple septic tank system requires a good grasp of its design philosophy, construction and an understanding of its operations and maintenance needs for it to work effectively. Generally, for example, in

Nigeria, Architects and Builders still use the British Standard Code of Practice (BSI, 1972) and, in some cases, the 1952 version. However, a septic tank is now viewed as a reactor and newer designs are more compact but require scheduled maintenance (Pickford, 1980; Mara et al 1986; Leton 2006, 2007).

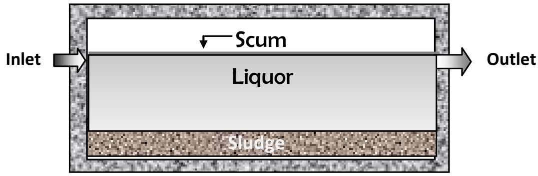


Fig 32 Schematics of a Septic Tank

The clarified liquor (Fig 32) needs further treatment and, in Nigeria, the soakaway is the only further treatment. Among soil absorption methods are:

1. Soakaway pits;
2. Soil absorption trench;
3. Soil absorption bed; and
4. Septic tank-mound system

Of all the systems listed above, the soakaway pits are the least desirable/efficient.There are other treatment systems that can be used to treat septic tank liquor, which are not based on soil absorption:

1. Anaerobic filter (Fig 33);
2. Baffled septic tank (Fig 34);
3. Intermittent sand filter
4. Constructed wetlands (35)

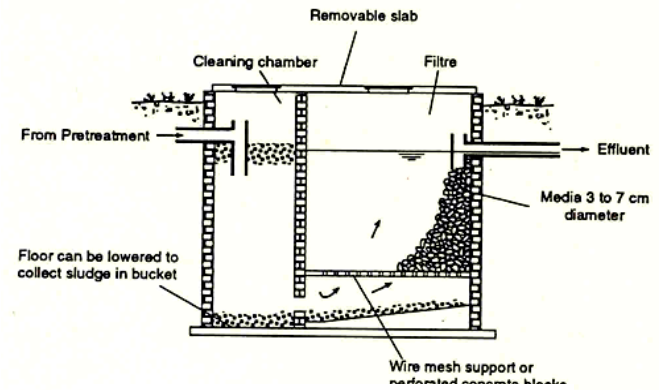


Fig 33: Anaerobic filter

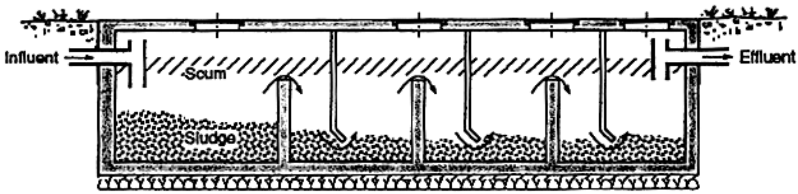


Fig 34: Baffled septic tank

Constructed Wetlands System (CWS)

Constructed wetlands are man-made wetlands built to remove various types of pollutants present in wastewater that flows through these systems. They are constructed to recreate the

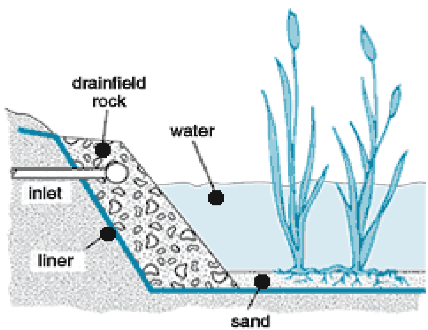


Figure 35a Open water SF wetland

structure and function of natural wetlands. They possess a rich microbial community to effect the biochemical transformation of pollutants, they are biologically productive and most important, self-sustaining.

Constructed wetlands "seem" very simple systems. Although these systems do not rely upon complicated and sophisticated technology, constructed wetlands need a proper design and a careful construction.

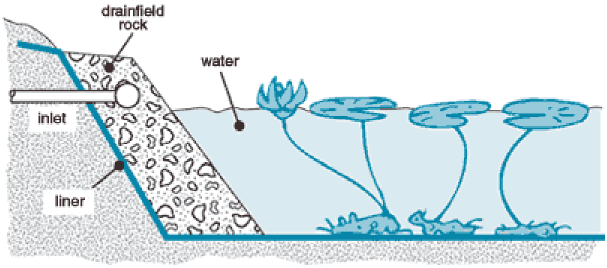
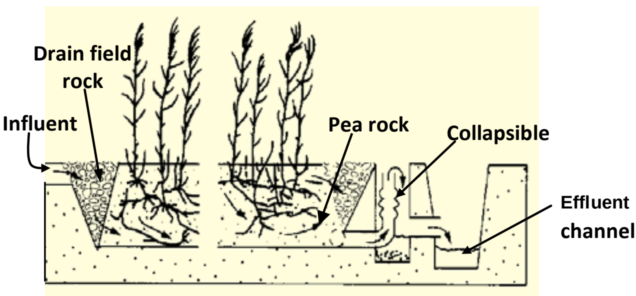


Figure 35b Hydroponic SF wetland

A constructed wetland system (CWS) pre-treats wastewater by filtration, settling, and bacterial decomposition in a natural-looking lined marsh (Fig 35).

A properly operating constructed wetland is claimed to produce an effluent with less than 30 mg/liter BOD (a measure of organic material), less than 25 mg/ℓ TSS (total suspended solids), and less than 10,000 cfu/100mℓfaecal coliform bacteria (an indicator of viruses and pathogens).

The two most popular CWS design types for individual or institutional sewage treatment are the ***surface flow***



(**SF**), (Figures 35a and
35b), also called ***free-water system***, and the ***subsurface flow*** (**SSF**) system (Figure 35c). Both of these are horizontal flow systems where wastewater enters at one end of a lined excavation and exits from the other end.

The two types of SF wetlands are shown in Figures 35a and 35b. The open-water wetland in Fig 35a has a small layer of sand to root the plants while the hydroponic wetland in Fig 35b does not. In the SSF system (Fig 35c), the water level is maintained below the surface of the gravel substrate by a collapsible stand-pipe structure at the discharge end of the cell which minimizes the risk of exposure to people and animals, and greatly reduces mosquito breeding. The SSF is the most common constructed wetland system used for small flows (less than 40 m^3 per day) and is often used for individual homes, small clusters of houses, or resorts.Initial trial of this system using water hyacinth proved successful (Obuh & Leton, 2006).

Ventilated Improved Pit Latrines (VIPs)

The *Ventilated Improved Pit (VIP) Latrine* is an upgrade of the *Pit Latrine System* that was popular at its inception in the early 50's in developing countries, but has been mostly

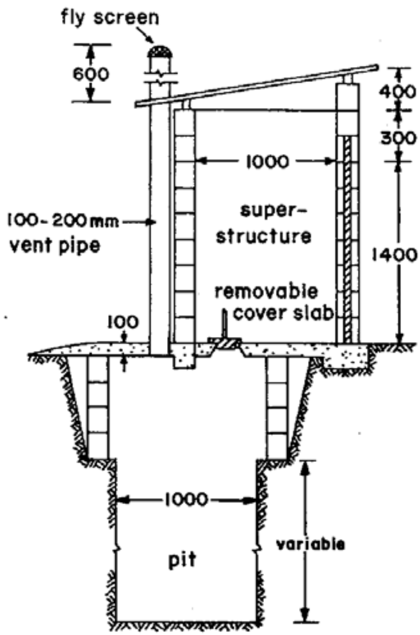


Fig 36a VIP cross section – dimensions in mm

(Kalbermatten, et al; 1980)

abandoned due to odour, insect problems and frequent structural failures. The VIP latrine consists of a pit dug in permeable soil where excreta are retained to undergo digestion and eventually be made harmless. A seat or squatting plate is built directly over the pit, generally about 1-1.5m in diameter or 1-1.5 m^2 and at least 2m in depth. A ventilated pipe (150 - 200 mm in diameter) is provided to reduce unpleasant odours and insect nuisance (see Fig.36a). A raised pit VIP that can be used in shallow water table areas such as in the Riverine is shown in Fig 36b.

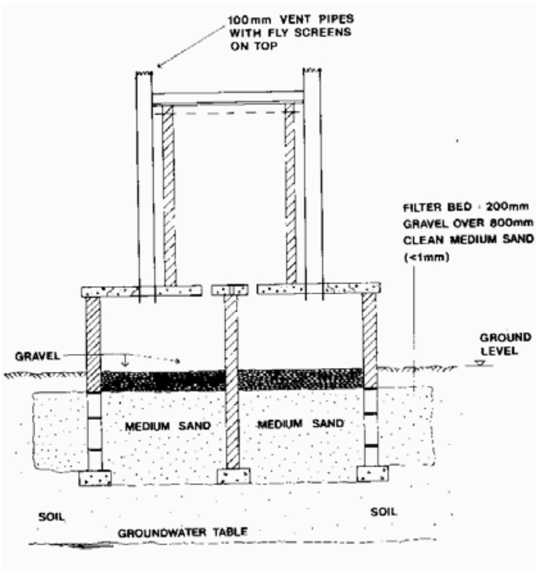


Fig 36b Raised alternating twin-pit VIP latrine

5. SOLID WASTE MANAGEMENT

Solid waste is man's non-liquid, non-gaseous waste material (including refuse) generated from homes, parks, market places, commercial centres, industrial and agricultural activities etc. These are materials that no longer have any value (in time and space) to the person who is responsible for them. Solid waste management (SWM) includes all activities that seek to minimise the health, environmental and aesthetic impacts of solid wastes. It involves the ***collection***, ***transportation***, ***treatment/disposal*** of these wastes. Improper isolation, untimely collection, lack of adequate treatment and disposal could lead to the spread of diseases. Of course, these diseases are spread by vectors such as rats, cockroaches etc. that seek for food and warmth in piles of refuse.

The management of solid waste is capital-intensive, a factor our government/politicians find difficult to grasp. They cannot understand why money that can be better spent on "useful" things should be put into what is already considered a waste, and wish that the problem would just go away. Worse still, due to low productivity (labour-intensive methods) and inefficiency, cost of solid waste handling may be as high as in developed countries (Betts, 1984). What people are not aware of however is:

- That solid waste can be a source of raw materials; and
- That if not properly managed solid waste could be a source of many diseases, even epidemic (e.g. Indian Plague – attributed to poor sanitary conditions). If these facts can be driven home to our administrators, the cost of handling solid waste may receive more sympathetic hearing.

A combination of high ambient temperature (27°C mean averages) and relative humidity (80%) implies that refuse should be collected more frequently to avoid the stench associated with bio-degradation under anaerobic conditions. In addition, more solid waste is generated because most foods are prepared from fresh crops as against processed foods.

Urban Solid Waste Management (SWM) is one of the most immediate and serious environmental and health problems confronting authorities in Nigeria. Many of our cities face serious environmental degradation and health risk due to uncollected domestic refuse on streets and in public places (e.g. markets, parks), clogged drains by indiscriminately dumped refuse, and by contamination of water resources near uncontrolled dumping sites.

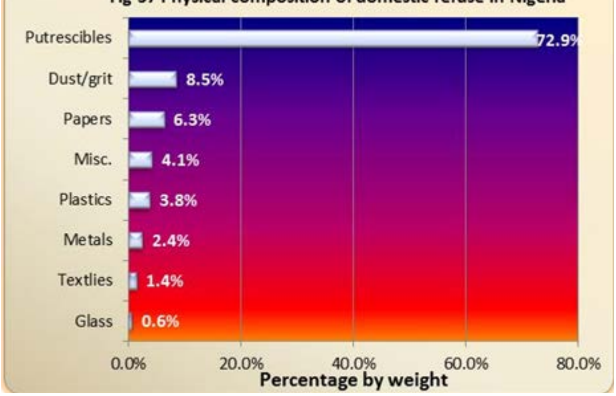
In slums within or near towns and in high density villages, piles of uncollected domestic refuse often mixed with human/animal excreta are common sights.

5.1 Potentials of Domestic Solid Waste

The major components of common solid waste can be divided into two broad categories – *refuse* and *solid bearing liquids* (sludges and slurries). Wastes such as hospital waste are treated in a separate group. Typical waste characteristics of Nigeria refuse (compiled from Schridhar M.K.C. et al. 1983; Ebere 1994) are shown in Fig 37. Sludge has the propensity to harbour pathogens and to accumulate toxic metals and organic compounds (metals: Zn, Cu, Cr, Cd, Ni; organ halogens: dieldrin, α-BHC, DDT, PCB).

From Fig 37, domestic solid waste (DSW) is a heterogeneous material containing some useful *raw materials*. On the other hand, solid waste can be a source of *toxic* and *pathogenic* substances that require safe disposal to protect public health and the environment. Thus, solid waste can be both a potential source of raw material as well as a source of toxic materials and pathogenic organisms.

Fig 37 Physical composition of domestic refuse in Nigeria



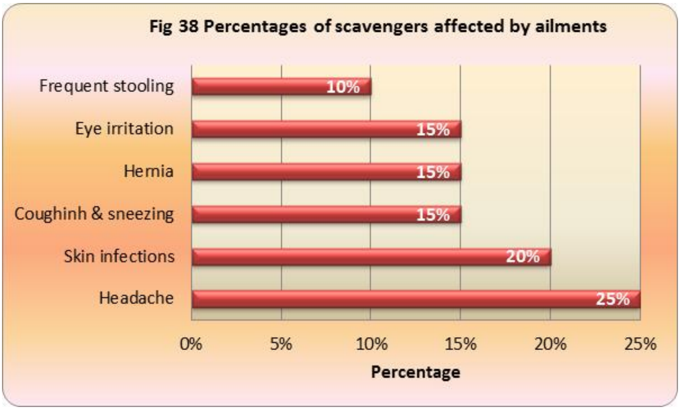
5.1.1 Source of Raw Material

Solid waste consists of many items that can be recovered and put to good use, i.e. glass, metal scraps, plastics, papers etc.(Leton & Nweke, 2005). The organic fraction can be converted by the process of modern composting into a useful humus-like end product.

5.1.2 Source of Diseases

The organic constituent of solid waste in Nigeria may include human and animal faeces e.g. from soiled disposable baby napkins, faecal matter from pets, disposable paper handkerchiefs, and deliberate inclusion of human faecal matter. In addition, the environment is normally well saturated with spores, bacteria, virus, insects, vermin (*wild animals harmful to plants and animals e.g. rats, foxes, weasels, lice*) and other vectors awaiting favourable site in which to multiply. A heap of refuse provides one of such sites. The mere presence of these cultures of potential disease-causing organisms in solids waste is not enough to cause a major health hazard. The blame for disease transmission must be placed on the flies, mosquitoes, rodents (rats, mice), cockroaches, cats, dogs etc. which are attracted to the waste heap in search of food, shelter and warmth for which a pile of refuse provides an ideal environment. Diseases are spread by parasite bites, urine, droppings, and skin contacts. The common tropical diseases transmitted by solid waste pests can be found in Vincent (1989) and Leton (2005).

A study undertaken to assess the health risks and economic value of the scavenging occupation (Leton & Nwweke, 2003) revealed that scavengers suffer mostly from ***common cold*** and ***skin infections***. Other forms of ailments are ***eye irritation***, ***stiffness of joints***, ***respiratory diseases*** and ***severe headaches*** (Fig 38). These diseases are also transferred to the scavengers' families.



5.1.3 Sources of Toxic Chemicals

Solid waste can contribute to other forms of pollution that are health hazards. Leachate generated from within the waste heap is a source of inorganic and organic hazardous substances that can migrate to contaminate surface and groundwater. In addition to domestic source (sludges) of toxic substances, the following are the main sources in waste heaps:

- Inorganic Compounds: A number of industries handle a variety of metal salts (Cu, Cd, Zn, Pb, Hg, etc.) many of which could be extremely dangerous to humans.

- Organic Compounds: Pharmaceutical, chemical and agrochemical industries produce a host of organic chemicals, many of which could be extremely dangerous to humans.

Leaching of disposed chemicals or biochemical degradation and transformation of the deposited material from within a waste tip has proved particularly hazardous to groundwater. This is particularly important in the Niger Delta with shallow groundwater levels in most places.

5.2 Waste Collection

Refuse collection and transportation absorbs up to 90% of expenditure on waste handling in developing countries according to Betts (1980). It is for these aspects of waste management that improvements in cost-effectiveness are most urgently needed. Some problems of collection and transportation operations: are

a. The widespread use of poorly designed open communal storage sites, which encourage the breeding of pests, and are difficult to clear;
b. Regular skin contact of workers in collecting and loading wastes;
c. Shortage of suitable and serviceable collection vehicles, aggravated by poor maintenance, and lack of vehicle replacement policy; and
d. Restricted access due to poor city plan and formidable traffic densities, especially in city centres like Port Harcourt.
e. Use of ignorant contractors for collection of refuse.

5.2.1 Collection System

Solid waste collection system can be divided into two broad categories:

- *Primary collection* system: involves the collection of solid waste from the point of generation to a suitable common location (transfer station).
- *Secondary collection system*: involves the collection and transportation of solid waste from the transfer station to the point of final treatment/disposal

Primary Collection System

There are four basic primary collection systems:

i. *Communal storage* – requiring delivery of waste by households to widely spaced communal storage bins.
ii. *Block collection* – where the households deliver the waste to a collection vehicle at the time of collection.

iii. *Kerbside collection* – where the households put out their bins on a footway in advance of the collection time and later retrieve them after they have been emptied.

iv. *Door to door collection* – where the collection crew enters the premises and carries the bins to their vehicle where it is emptied and returned.

Options (i) is feasible provided the surrounding of the communal storage bins can be kept tidy to control proliferation of rats and flies.

It is important that the primary collection bins are provided with tight lids as protection against heavy rainfall (up to 4500 mm in some areas) and to reduce the possibility of spread of pathogens and rats, flies/cockroach infestation.

Secondary Collection System

Secondary collection and transportation of waste to final disposal sites is often carried out using heavy motor vehicles which include the following vehicles/equipment:

a. *Flat body trucks* – here the loading and offloading of vehicles are done manually.
b. *Trucks with tipping arrangement* – In this type of vehicle, loading is carried out manually or by pay-loaders, but unloading is done automatically by tipping.
c. *Container-carrier system* – this type of vehicle serves a transfer station and carries waste to the disposal site. It is equipped with tipping mechanism.
d. *Dumper-Placer* – special steel containers 3.5 – 5.0 m^3 capacities act as storage vat. The vehicle with boom arrangement in the body, pick up the container and is driven to the disposal site. Tipping operation is handled hydraulically, and the empty container is returned and placed in its original position.
e. *Hydro*-con-*Roll off Tipper* – This is a special device mounted on a vehicle, which can take a container loaded with refuse of

10 m^3 capacity on to the chassis from the ground level, and it is driven to the disposal site. Its operation is similar to that of the dumper-placer, and is suitable for big cities having wide roads.

Close body leak-proof vehicles are preferable in order to prevent leachate dripping during collection and transportation of refuse to disposal sites. The use of open tippers as collection vehicles should be discouraged.

5.2.2 Container-Based Collection System

Methods of waste collection, which places all responsibility on the occupier to transfer waste to a stipulated collection point, will offer substantial savings over methods that delegate all responsibility to the authority to do all the work. This can be done by the provision of a container to each catchment area to which a caretaker is assigned. An employer of the local authority assigned to the container should ensure that residents in his catchments use the container properly, and the area immediately surrounding the container stance is kept clean. The container should be of a capacity that can provide storage for the catchment area for at least two days.

A single bulk container hoist vehicle with only a driver can then service around seven or eight containers with an alternate day collection schedule, with a tip situated about 15 km away. Reducing the catchment for each container, either by providing more containers of a similar capacity but with twice-weekly collection schedule, would make the system effective and more convenient for residents. The container system is a last improvement on the open communal enclosures, which can checkmate the proliferation of rats and flies.

5.2.3 Transfer Station

The transportation of collected waste poses a major problem in our cities due to poor road network and, traffic hold-ups. In addition, a small payload vehicle often means that a high proportion of vehicle operating time is spent on transporting waste to the disposal site. This places limitation on the distance over which waste can be directly hauled economically by a collection vehicle. To improve the situation, short-range transfer stations, should be sited from where waste from small collection vehicles are transferred to large, motorized vehicles, either directly or by means of simple transfer facility. Thus, ***a transfer station is a location where solid waste is transferred from***, usually, from the collection vehicles to long haul or bigger vehicles without any additional processing. Frequently, processing by compaction is included as part of a transfer station operation. In addition, transfer station may provide an opportunity for organised scavenging, thereby increasing control over an activity that often interferes considerably with normal cleansing operations.

5.4 Treatment/Disposal Options

The common options available for solid waste treatment/disposal are:

- Traditional method
- Open dumping
- Landfill
- Incineration
- Composting

5.4.1 Traditional Method

Disposal of solid waste in our traditional society is by spreading it on uncultivated lands in the upland area of the Niger Delta. This serves as a means of hastening the restoration of fertility to the soil before the next farming season. The practice has been possible because there has been enough land available per capita for the waste to be spread out without any major environmental objection. With increase in population in the rural areas and in urban and sub-urban centres, and high population density, land space per capita becomes highly restricted and the practice of land spreading of refuse cannot go on without serious environmental health problems, and a change in the ecosystem.

In the riverine areas of the Niger Delta, the traditional method is by dumping refuse in the nearby water body where the natural process of biodegradation takes place. However, with increase in population this practice has also become unacceptable as the natural capacity of the water body to purify itself is over stretched leading to offensive odour and aesthetically intolerable.

5.4.2 Open Dumping

In open dumping operations, waste is deposited in open pits (either natural or man-made) or on designated land with little or no regard for pollution control or aesthetics. Open dumping in our urban centres has led to considerable environmental problems – water pollution, air pollution, and breeding grounds for insects, birds, rodents and other carriers of diseases. The dump contents are sometimes set on fire during the dry season. This practice by no means totally eliminates the adverse environmental health impact of the dumped waste, but does contribute to reducing the volume of the accumulated waste. In the Niger Delta, replete with a lot of the areas with shallow water table, this practice leads to a smelly porridge especially during the wet season. However, street sweepings, ash, and some rubbish can be disposed of in this way.

5.4.3 Landfill

Landfill is the term used to describe a properly designed and controlled operation for the deposition of waste on land. This calls for planning and application of sound engineering principles and construction techniques. In general, the waste is spread out in thin layers, compacted down using either track type tractor or landfill compactor, and finally covering the deposited waste progressively with an inert material e.g. soil or clay. Due to high water table in the Niger Delta region, only the area method of landfill can be used. Even then, the problem of leachate has to be contended with due to high rainfall.

Of immediate concern however are the problems of *leachate* and *gas generation*. Leachate contains various organic and inorganic pollutants in suspension or solution and may contribute to groundwater pollution. Landfill gases on the other hand can give rise to explosion/ fires and has led to landfill being tagged a “time bomb”. An uncontrolled landfill can end up as a “dump”.

5.4.4 Incineration

Incineration is defined as the process of reducing combustible waste to an inert residue by high-temperature burning (Patrick, 1980). The end products of combustion include ash, noxious gases, particles and heat energy. Compared with other conventional methods of solid waste treatment/disposal, incineration offers the advantages of large reduction in the volume of the material requiring final disposal. Under certain conditions, the heat energy can be put to good use (driving turbines for power generation). It is often considered as an appropriate treatment/disposal process in areas of high population density, where land for disposal of untreated waste may be unavailable.

Incineration has several disadvantages among which are:

- High construction cost;
- High operational and maintenance costs;
- The need for skilled personnel to operate and maintain the plant;
- Difficulty in using the generated heat; and
- The need for expensive control measures to prevent air and water pollution.

In addition, for domestic refuse incineration, a large-scale, intensive operation is required to make the process economical. It is estimated that modern plants with a capacity less than 400 tonnes/day are likely to be prohibitively expensive (Buekens and Patrick, 1985).

Finally, incineration can present threats to the environment, and stringent controls are required to reduce secondary pollution from gaseous or liquid discharges from incinerators. Stack effluent invariably include acid gases, heavy metals, dust and particulates, and certain organic compounds among which are the dreaded "*dioxin*" and "*furans*".

5.4.5 Modern Composting

Composting is the biological decomposition of organic waste under controlled conditions of moisture, temperature, aeration, particle size and the fraction of nitrogen in the organic matter, usually expressed as C/N ratio. The biological decomposition is carried out by microorganisms (mainly bacteria, fungi and actinomycetes), which break down the complex organic substances into carbon dioxide, water, and a humus-like residue termed "*compost*".

A well-conducted composting operation is environmentally friendly and the compost produced has many useful applications, some of which are:

- Soil conditioner;
- Low level fertilizer;
- Potting soil;
- Mushroom growing;
- Fish feed; and
- Bioremediation of oil spilled land sites.

As a treatment method, composting is capable of reducing the waste by more than 50% and inactivation of pathogenic organisms and weed (Leton, 1984, 1994). However, a poorly conducted composting operation can be a source for the spread of infections and could lead to loss of most of the benefits listed above.

According to Brunt et al (1985), the main objectives of waste treatment are to:

- Reduce the volume and weight of material to be disposed of;
- Reduce emission, such as odours and leachates; and
- Recover resources, with possible reduced disposal cost.

Of all the waste treatment options outlined above, composting achieves these objectives better than others do.

5.4.6 Types of Modern Composting

We have three modes of modern composting:

a) Reactor or Dynamic or In-vessel composting;,
b) Aerated Static Pile Composting; and
c) Windrow Composting.

Dynamic (In-Vessel) System

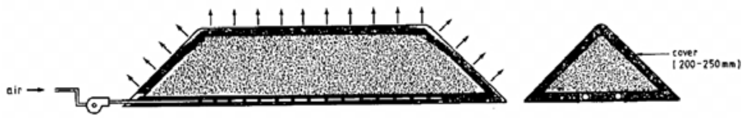
In this process, active decomposition takes place in a continuously agitated enclosed reactor. The agitation provides a high degree of aeration and attrition of the waste, thereby reducing the particle size for rapid biodegradation. The enclosed digester (reactor) permits closer process controls of the important rate controlling parameters; such as air flow, moisture and temperature can be controlled. A very rapid rate of decomposition is claimed for these systems - approximately 5 days required for active decomposition.

Aerated Static Pile System

In this system of composting, a blended admixture of composting materials is placed on a system perforated piping through which air is forced or drawn. As the name implies, static piles are not turned, rotated, or otherwise manipulated during active composting Aerated static piles don't need as much space as a windrow operation, but offer rapid biodegradation (14-21 days) and process control similar to in-vessel composting. Problems of blocked ducts and short-circuiting of air through the compost mass may occur and the forced aeration may dry the composting material and thereby upset the water balance of the process. Aerated Static Pile composting system fills the gap between the windrow and reactor type composting systems in terms of effectiveness of process control, leachates production management and vector control.

Excellent reviews on Static Pile can be found in Epstein et al 1976; Finstein et al, 1980; Leton & Stentiford, 1990).

The static pile system of composting has emerged in recent times as a simple but effective method of modern composting. Although designed for composting of dewatered sludge mixed with woodchips, the method has been successfully adapted for refuse composting (Leton, 1984)



Aerated static pile showing longitudinal and cross sectional views

A microcomputer controlled Aerated Pile Composting flow chart is shown in Fig 38 (Leton, 1984; Leton & Stentiford, 1990).

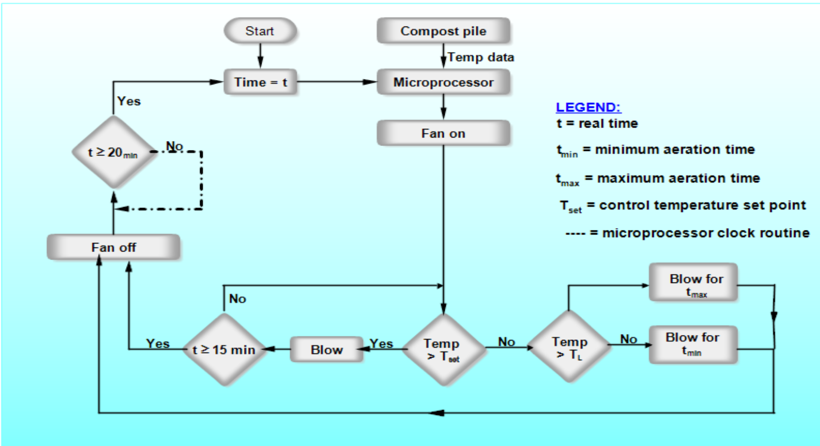


Fig 38: temperature control aerated composting pile

Windrow Composting

Windrow composting consists of piling organic matter into long rows (*windrows*). These piles are generally turned manually or mechanically as a means of aeration to redistribute cooler and hotter portions of the pile.Windrow composting is the most commonly used of farm scale composting methods. Process control parameters include the initial ratios of carbon and nitrogen rich materials, the amount of bulking agents added to assure air porosity, the pile size, moisture content, and turning frequency.While active decomposition could take about 40 days in windrow composting, it requires about 20 days in aerated static pile and about 5 days in reactor type composting system. The curing period is however identical for all types of composting systems.

In Nigeria, modern composting practice has been restricted to "Windrow System" of composting (Leton, 2001; 1995; Scridhar et al, 1983).

Figures 39a and 39b depict the Windrow Process of composting using manual turning of piles. The problem with manual turning is that it is labour-intensive and grossly inefficient. To circumvent this problem, composting plants using the Windrow method should have a type of pile turner ranging from a front-loader to a purpose-built turner (Figures39c and 39d).

Fig 39a Fresh windrow composting

Fig 39b Manual turning of composting pile

Fig 39c Front-end loader turning

Fig 39d Purpose built compost

Compost Field Trial

A field trial using compost produced above was conducted at Onne in collaboration between SPDC and IITA using plantain. Plantain production in this region is under severe threats due to fungal disease (Black Sigatoka), and serious yield declines, attributed to soil fertility depletion.

In an attempt to overcome the soil fertility depletion problem, a compost mulching regime (Fig 40) was initiated to promote perennial growth and high yield. The result showed that compost application as mulch induced a significant impact on the growth and yield of plantain. Plots treated with compost mulch had taller and more robust plants with darker-green leaves and higher yields than plants from the control plots. The optimum compost application rate appears to be about 400 - 600 tonnes/ha/y. Plants receiving the optimum application rate had 20 per cent higher yield and above 23 per cent more suckers than plants receiving no compost mulch. The full impact of compost mulch on black sigatoka could not be observed.

Treatment D 600 tones munch/ha	**Treatment A 0 tones munch/ha**
Treatment B 200 tones munch/ha	**Treatment E 800 tones munch/ha**
Treatment E 800 tones munch/ha	**Treatment D 600 tones munch/ha**
Treatment C 400 tones munch/ha	**Treatment B 200 tones munch/ha**

Treatment A **0 tones munch/ha**	**Treatment C** **400 tones munch/ha**

Fig 40 Plot layout/treatment

5.5 Hospital Wastes Management

Hospitals and clinics are supposed to safeguard public health. The effective management of hospital wastes in any area depends on the attention given to waste management

Hospital waste not properly managed can pose a threat not only to the hospital employees, refuse collection crew but also to the people surrounding the area and the entire environment. The major problem is the 10 – 25% hazardous component. These are grouped into infectious wastes sharps, pharmaceutical & chemical wastes, genotoxic waste and radioactive waste.

A study undertaken to investigate the management of hospital waste in selected hospitals in Port Harcourt (Leton & Nwandiko, 2004), identified the following outlined factors as major hindrances to achieving positive results in hospital waste management: (i) no records on waste generation (ii) poor waste segregation (iii) lack of qualified personnel as waste management crew (iv) lack of experience, and training, (v) absence of waste treatment, (vi) poor waste disposal method, (vii) unsafe handling and storage of waste and (viii) general lack of waste management guidelines.

Figs 41 & 42 reveal that 68% of the management personnel had ‘O’Level’ or lower qualification, and 82% had less than 2 years’ experience.

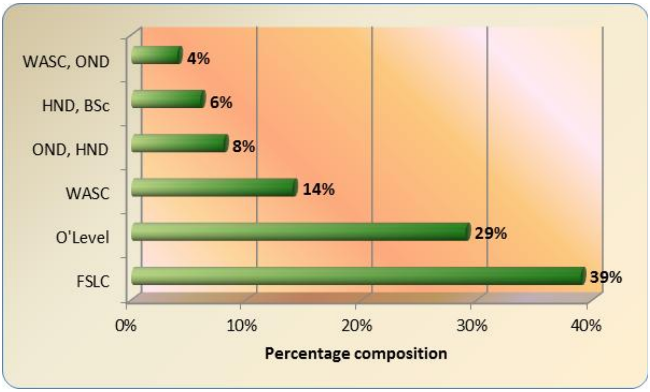


Fig 41: Qualification of Waste Management Personnel

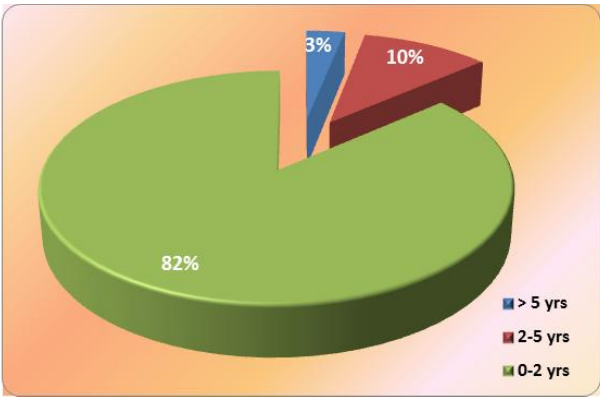


Fig 42: Waste Management Personnel Years of Experience

6. Drainage

Drainage involves the economical removal of unwanted water from the living and working environment and to protect road bases from failure to a point where it can be discharged off safely. Quite often, we see our roads acting as water channels, and the road pavement/bases permanently inundated. Drainage is also essential in the fight against malaria, as stagnant water constitutes breeding ground for mosquitoes. We have roads constructed with drains attached – where the water drains to no one knows. The drains are therefore water storage channels without linkages to water discharge points. Although Port Harcourt is flat, she is blessed with a series of natural drainage channels into which the storm drains can be discharged. Unfortunately these natural drainage channels are now development sites; people encroach on them with buildings, and some are even blocked altogether. Consequently, flooding within the city is becoming more frequent and severe. To make matters worse, the drains are often blocked. A frantic effort on our part to educate the public as to the functions of drains and the authorities as to their importance is vital if a healthy environment is envisaged and appreciated in our cities.

The issue of open drains has always been very difficult to come to terms with. Apart from the fact that it is less efficient, half of its capacity is unutilized in some instances. It is a nuisance and in most developed societies such drains are relegated to farm use mainly. We admit that the problem of maintenance of closed drains is our handicap.

7. Field Experience

The aim here is to share some of our field experience hic-ups.

BOD Determination

Principle: The method consists of filling an airtight bottle BOD of the specified size with sample, to overflowing, and ***incubating it at 20°C ± 1°C for 5 days***. Dissolved oxygen is measured initially and

BOD sensor system

after incubation, and the BOD is computed from the difference between initial and final DO. The fact is that how many labs can maintain an incubator at that temperature for 5 days without power interruption. The same could be said of faecal coliforms determination. Yes we use these sub-standard test results for our publications. I am aware that an approximate test for BOD using biosensors lasting for 30 minutes can be used to indirectly measure BOD. But that is only an approximation. ***Well, it is just a number. It does not matter.***

Determination of Groundwater Flow Direction

Ground water usually flows toward, and eventually drains into streams, rivers, and lakes. The flow of ground water in aquifers does not always mirror the flow of water on the surface. To determine the ground water flow direction, the ***water table elevations*** at three locations (wells or boreholes) are determined. The water level elevation is determined by subtracting the ***depth to water*** in each borehole from the ***surface elevation*** at the borehole location. Thus:

Water table elevation = Surface elevation – depth to water

From the water table elevations at three locations, the ground water flow direction can be determined.

What we have observed from the field is that the depth to water is used to determine ground water flow direction. This is gross error. ***It does not matter, it's just a statement. Nobody takes it seriously.***

Use of Basic Air Pollution Dispersion Modelling Equation

The Gaussian-point source dispersion equation relates average steady-state pollutant concentrations to the source strength, wind speed, effective stack height and atmospheric conditions.

Since we are concerned with receptors (people and ecosystems) at ground level, our prime interest is to be able to predict the level of dispersal of air pollutants at ground level. The concentration (C) of a gas or aerosol (< 20μ) calculated at ground level (z=0) for a distance downwind (x) is given by:

$$C(x,y) = \frac{Q}{\pi u_e \sigma_z \sigma_y} exp\left[-\frac{1}{2}\left(\frac{H}{\sigma_z}\right)^2\right] exp\left[-\frac{1}{2}\left(\frac{y}{\sigma_y}\right)^2\right]$$

Where:

C(x,y) = concentration on ground-level at point (x, y), µg/m^3 or kg/m^3

x = distance directly downwind, m

y = horizontal distance from the plume centreline, m

Q = emission rate of pollutants, kg/s or µg/s

H = effective stack height, m (H = h+Δh, where h = actual stack height, and Δh is the plume rise)

u_e = average wind speed at the effective height of the stack, m/s, usually taken as speed at stack height, u_s, m/s

σ_y = horizontal dispersion coefficient, m

σ_z = vertical dispersion coefficient, m

As noted above, u_e is the average wind speed at the effective height, usually taken as wind speed at the stack height.

From our experience, it is the ground level wind speed that is used. Wind speed should be measured at 10 m height and then interpolated to that at the stack height using the equation:

$$u_z = u_{10}\left(\frac{z}{10}\right)^p$$

where: u_z = wind velocity at height z, m/s

u_{10} = wind velocity at height 10 m

z = height above ground level, m

p = power coefficient

Again, the measurement of wind speed at ground level departs from the standards; and using the ground level wind speed in the Gaussian-point source dispersion equation is totally wrong.

Environmental Noise Study

A sound level meter is an instrument that is designed to measure sound levels in a standardised way. The older standards(Table 4) of sound level meters are given in ***IEC 60651*** for four types 0, 1, 2, 3 differing by the measurement precision. The measurement precision is reduced as the type number increases, affecting manufacturing costs significantly.

Table 4 IEC 60651 sound level meter specifications

Sound Level Meters	Use
Type 0	Intended as a laboratory reference standard
Type 1	Intended especially for laboratory use and for field use where the acoustical environment has to be closely specified and controlled.
Type 2	Suitable for general field applications
Type 3	Intended primarily for field noise survey applications

The new international standards IEC 61672 referred to the grade of sound meters as the "***Class***" whereas the old standard IEC 60651 refers to it as "***Type***". Under the new specifications we have just two standards as 'Class 1' and 'Class 2'. Class 1 is more accurate than Class 2 (see Table5).

Table 5 IEC 61672 sound level meter specifications

Grade	Definition	Tolerance	Typical Applications
Class or Type1	Precision Grade for laboratory and field use	± 0.7 dB	Environmental, building acoustics, road vehicles
Class or Type 2	General purpose Grade for field use	± 1.0 dB	Noise at work, basic environmental, motor sport

The class of meter that one needs will depend on the application and on any regulations that one needs to meet. For example, most occupational noise measurement regulations state that the lower cost Class 2 meter is adequate. Class I meter is particularly relevant for environmental noise surveys where low noise levels are being measured. For many measurements, there is little practical point in using a Class 1 unit; these are best employed for research and law enforcement. However, one may choose Class 1 for important legal applications as the evidence from the more accurate meter may be more convincing, even when the regulations do not demand it. It is not worth being tempted by a meter that does not meet the standards, especially if the noise measurements are to be used for legal purposes

B&K sound meter

Although older meters meeting the IEC 60651 (and IEC 60804) can continue to be used for most applications, when purchasing a new meter you should get one that meets the new standard IEC 61672.

The problem is that the noise meters we have encountered in the field can best be described as toys. Some people even use dosimeters for noise studies especially for EIAs. There is little or no compliance with the IEC 60651 or ICE 61672 and this is a serious trend leading towards ***Professionals without Standards***.

Exposure to excessive noise levels can lead to impaired hearing. An investigation conducted at thirty industrial sites(at workers locations) in Port Harcourt (Leton & Enamuotor, 2005), revealed that 70% of the sites visited had their workers exposed to noise dose of between 90 and 115 dBA. This is considered high to very high noise dose. Also 20% of the sites visited provided worn-out hearing protective devices or none at all. With some of our industrial setups using outdated or worn-out equipment/machines, the need to standardise noise monitoring to protect workers cannot be over emphasised.

EIA Scoping

EIA or PIA scoping is one of the major areas we have failed badly. A lot can be inferred about the competence of a person from his scoping of an EIA or PIA. We conducted a PIA on a site where the pollution episode occurred about twelve years earlier and no nearby houses. It was demanded we carryout noise and air pollution, and one may ask,- for what purpose, except to make the volume of work impressive. An interesting case was the reviewer who questioned us as to why microbiology was not included in an EIA for a road project that had no bridges, culverts, and therefore, no streams. We have to prove to ourselves that we are capable of managing such projects.

Fig 43 PIA site & waste recovered

Power Plant Pollution

We were asked to conduct an investigation into the extent, level and possible direct impacts of hydrocarbon pollutant emanating from a power plant on a local swamps and in an adjoining river.

Results of the investigation confirmed that the pollution was mainly of hydrocarbon origin (Fig 44&45). High oil levels were recorded in: surface water (effluent channel): 46-325 mg/ℓ; effluent channel sediments (287-1116 mg/ℓ) and in the receiving water body (22-124 mg/ℓ). This is far in excess of the guideline values. This was further supported by the proportion of petroleum bacteria, which showed high exposure of the organisms to high hydrocarbon presence.

High levels of some heavy metals were also recorded in the surface water in the effluent channel (Cu > 2.8mg/ℓ; Pb = 1 mg/ℓ). Accumulation of heavy metals in the bottom sediments was expected to be much higher.

Fig 44. Evidence of oil in sedimemts and macrophytes

Fig 45 Swamp covered with oil.

Note that this swarm is connected to a river body where people obtain their drinking water and rely on it for their livelihood.The manager of this company called me aside and said "Look, there are no people of substance in this community, why bother." No wonder, this said community provided power for the country and was never deemed fit to have electricity until recently. These are some of the environmental hazards our people are subjected to. It is for us not to bend to the dictates of the perpetrators of these acts, but rather, stand for the integrity of our profession.

8. Open Experience/Conclusion

I was an addicted coffee drinker with two cubes of sugar and plenty milk per standard cup. I was told sugar is bad, so I reduced sugar to one cube, and, finally, to zero. Later I was told milk is bad for health, I moved on to skimmed milk, and then to black coffee. Not too long ago, I was told coffee contains caffeine, and is bad; so I degraded my taste to decaffeinated coffee; still I am told that too is not good enough. I am now relegated to tasteless green tea and *morringa oleifera* tea. At least an effort has been made to produce skimmed milk and decaffeinated coffee.

Well, you may say the above is foreign. But, back home, I have been preached to that egusi, palm oil and native pear (ube or pee) all contain cholesterols, and are therefore, bad. That deprives me of my favourite egusi soup. A good friend told me that the cholesterol in egusi was the good type; that was encouraging, but no evidence to back-up his claim.

My contention here, just as in the case of Engineering, is why our scientists can't give us low or free cholesterol egusi or palm oil, knowing how very important palm oil is in our diet. Our local experts add *potash* to palm oil when preparing certain native delicacies such as – well I am sure you know them. Does the intent and result imply a reduction in cholesterol? As academics, we all have a role to play, whether we are engineers, scientists, or administrators, to enable us to widen our vision beyond ourselves, apply our acquired knowledge to the solution of societal problems. This is the root of the matter, and this is education.

I would like to play a video by **Sara Groves** titled "***I saw what I saw***."

I believe what went through this lady's mind when she saw what she saw was to thank her compatriot engineers, doctors, scientists, and administrators for contributing to make a difference in her country, in the attainment of the level of life they now enjoy in developed societies.

The questions for us to answer are:

1. Why are we not like these people?; and
2. Why do we have them around us?

The crux of the matter is that our training should be meaningful to us and, at the same time, guide, and enable us to apply our acquired expertise in solving societal problems.

Vice-Chancellor, thank you and God bless you all

Tambari Leton

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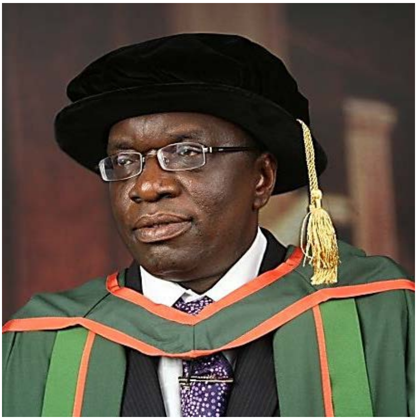
CITATION
on
Prof. Tambari Gladson Leton

B.Sc. *(Nigeria)*, M.Sc. *(Strathclyde)*, Ph.D *(Leeds)*,
MNSE, MIPHE, MIWEM, MNES, R.Eng (COREN)



BIRTH AND EDUCATION

Birth

Professor Tambari Gladson Leton was born on 5th March, 1951 at Nyobe Beeri in Khana LGA, Rivers State to Mr Benjamin Leton Akpayor and Mrs Neewa Leton (of blessed memory) of Beeri, Rivers State. He was the 6th child in a family of seven children (3 boys and 4 girls). Being the last male child, bestowed on him special privileges. He grew to be the centre of the family and the beloved of the mother, father and siblings.

Education

Professor Leton started his primary school at the Methodist School, Beeri. He later left with Mr. R.U. Deekor to Methodist School, Kaani-Bori, where he completed his primary school education in standard five.

That was the year that elementary school was introduced into the country. His secondary school started at the Birabi Memorial Grammar School (BMGS), Bori. After class two he was moved by his eldest brother (the late Dr G.B. Leton) to St. Theresa's College, Nsukka; but his education there was disrupted by the civil war. He continued his secondary school education during the war and finally completed it in Baptist High School, Port Harcourt. He subsequently gained admission into the University of Nigeria, Nsukka to read Civil Engineering in 1971 and graduated with honours in 1976. He obtained his Masters (M.Sc.) in Public Health Engineering from the University of Strathclyde, Glasgow, in 1980 and PhD from the University of Leeds, England in 1984.

PROFESSIONAL CAREER

Professor Tambari Leton is a member of the Chartered Institute of Public Health Engineers (MIPHE) and Chartered Institute of Water and Environmental Management (MIWEM) UK. He is also a member of the Nigerian Society of Engineers (MNSE) and professionally registered as an engineer with the Council for the Regulation of Engineering in Nigeria (COREN). He has served in many technical capacities on behalf on the Nigerian Society of Engineers in Port Harcourt. He was among the founding fathers of the Nigerian Environmental Society to which he is a member (MNES).

POSITIONS OF RESPONSIBILITY

Positions Held

Professor Leton is currently, the Head of Department of Civil and Environmental Engineering, University of Port Harcourt, a position he is holding for the third time (1st& 2nd in 1997 – 2001). Director, School of Basic Studies, University of Port Harcourt (2006 – 2010). External Examiner, Department of Civil Engineering, RSUST, Port Harcourt (2001 – 2004). Member, Governing Council, Rivers State Polytechnic, Bori (1998 – 2000); Co-ordinator, M.Eng Environmental Engineering, University of Port Harcourt (1996 – 1997); Caretaker-Chairman, NRC, Bori, KHALGA, (1992 – 1993); Principal Consultant, Balt Engineering

Co. Ltd. Port Harcourt (1990 to date); Engineer, Balasha & Jalon Consultant Engineers, Nigeria (1978); Engineer, Ministry of Works & Housing, Port Harcourt, Rivers State (1977 – 1978); Team Leader, Pollution Control Engineering Unit, CORDEC, University of Port Harcourt (1987 – 1992).

Service to UNIPORT Community

Member of Senate, 1997 – 2001, 2006 – date; Member, Senate Committee on Federal Capital Grant, (1991/92); Member, Senate committee on Prize (1986-1991); Member, SPATS (2006 – 2010); Member, Committee on University Scholarship and Dean's List (2011 – to date); Member, Committee on University Publishing (2011 – to date); Member, Committee on University Strategic Research Plan for 2011 - 2016 (2011 – to date).

Service to Communities outside UNIPORT

Member, Specialist Group on Appropriate Waste Management Technologies for Developing Countries, International Association on Water Quality (IAWQ) New Zealand; Member, Technology Advisory Group, UNDP INT/81/047, World Bank; Chairman, Rivers State Government Interim Guidelines and Standards for Control of Environmental Pollution; Chairman, Industrial Pollution Sub-committee, Rivers State Environmental Protection Committee; Member, Solid Waste Management Sub-committee of Rivers State Environmental Pollution Committee; Member, Rivers State Coastal Management Co-ordinating Committee (1994); Member, Review Committee on EIA for SPDC Integrated Waste Management Facilities, Etche, Rivers State.

PROJECT INVOLVEMENT

A selection of some of the projects in which Prof Leton has been directly involved are listed below:

Survey, design and reconstruction of Diobu Roads, Port Harcourt (1977/78), Ministry of Works & Housing, Rivers State; Survey, design and construction of Eteo-Ogu Road, Rivers State (1977/78). Ministry of

Works & Housing, Rivers State, Nigeria; Survey, design and construction of a link road between Okija street and Olu Obasanjo road, Port Harcourt (1977/78). Ministry of Works & Housing, Rivers State; Post-Impact Studies (PIA) of Afam's NEPA Power Plant Liquid Effluent Discharges, 1991, Rivers State Government Ministry of Environment and Pollution, Port Harcourt; Composting of Domestic Solid Waste; Pilot-Project (1994/95), Shell Petroleum Development Company Nigeria Limited, Port Harcourt, Nigeria; EIA (Soil and Water Quality Investigation for S.P.D.C.) 1996/97, Integrated Waste Management (IWM) Site, Etche, Rivers State" Shell Petroleum Development Company Nigeria Limited, Port Harcourt, Nigeria; Sampling, Testing and Analysis of Concrete Cores from the burnt OSO Warehouse, QIT (1998/99), Mobil Producing Nigeria Unlimited, Eket; Carbonation Test on Concrete Structural Elements at QIT Jetty (1999), Mobil Producing Nigeria Unlimited, Eket, (2000/2001); EIA for Shore Protection Work at Atimagbene, Burutu LGA, Delta State (2007). NDDC, Port Harcourt, Nigeria; EIA for East-West, Nyokuru-Lueku-Luebe Road Project with spur to Obette (Ogoni Unity Road), NDDC, Port Harcourt, Niger; Post Impact Assessment (PIA) of Alleged Dumping Site at Eket, 2000. Mobil Producing Nigeria Unlimited; Clean-up and biological Remediation of petroleum contaminated site at Shell well 34/35 Bomu, Ogoni, Shell Petroleum Development Company (Nig.) Limited.

RESEARCH INTEREST AND PUBLICATIONS

His research interest include, Intermittent Mixing of Waste Stabilisation Ponds; Loose boundary hydraulics; Process Control of Aerated Static Pile Composting; Onsite/low cost wastewater and water treatment systems; Health of our river systems. He has published several articles in local and international Journals, in Conference Proceedings, technical reports, chapters in books and five technical books in Civil Engineering – *Civil Engineering Fluid Mechanics Primer, Elements of Civil Engineering Hydraulics, Water and Wastewater Engineering, Pollution Control Engineering and Design of Drainage Systems.*

CHRISTIAN LIFE
The hunger for truth drove Professor Tambari Leton to the Christian faith, and then he started to attend Scripture Union (SU) morning prayers in Baptist High School Port Harcourt, but was not welcomed. It was when he was an undergraduate at the University of Nigeria, Nsukka, that he found the opportunity and encouragement to deepen his Christian faith in the Christian Union (CU) fellowship there. He held several positions of responsibility. Then they were encouraged to go back to their local churches and build up the faith. To him that was the Methodist Church of Nigeria. However there came a time when his practice of the Christian faith was not compatible with that of the Methodist faith. It was then his close friend Pastor Bosun Ajayi introduced him to the Redeemed Christian Church of God (RCCG). It took some struggling before he finally joined the RCCG, Daystar Parish, Port Harcourt. He found the release of his faith again to serve God and rose to the position of a Deacon. He rejected being made a Pastor several times based on his conviction that Pastoral duty should be a full-time job. He later moved with his family to The Kings Assembly being pastored by Pastor Chris Ugoh. His zeal for excellence for God has finally found a home. He still misses the CU fellowship at Nsukka and the NIFES fellowship.

FAMILY
Professor Leton is happily married to Godae and is blessed with three unique girls (Neme, Mbara (late) and Sisian) and a granddaughter, Sisian junior (Sisij). He has been heard saying that there are two important places in his life – his home and the office where he works. Professor Leton has invested in his home and family.

HOBBIES
Professor Leton is a lover of computing and technical innovations. Some people call him the Gadget Man. He is also passionate about quality music and creative arts.

CONCLUSION

Mr Vice-Chancellor, Sir, distinguished ladies and gentlemen, it is my honour, privilege and pleasure to present to you, our ---- inaugural Lecturer, a creative thinker, an accomplished civil engineer, an academic and a servant of Jesus Christ, a man who has rendered distinguished service to this university and mankind – Professor Tambari Gladson Leton.

Thank You

Professor N. E. S. Lale