JOURNAL OF AGRICULTURAL ENGINEERING AND TECHNOLOGY (JAET)

Aims and Scope

The main aim of the Journal of Agricultural Engineering and Technology (JAET) is to provide a medium for dissemination of high quality Technical and Scientific information emanating from research on Engineering for Agriculture. This, it is hoped will encourage researchers in the area to continue to develop cutting edge technologies for solving the numerous engineering problems facing agriculture in the third world in particular and the world in general.

The Journal publishes original research papers, review articles, technical notes and book reviews in Agricultural Engineering and related subjects. Key areas covered by the journal are: Agricultural Power and Machinery; Agricultural Process Engineering; Food Engineering; Post-Harvest Engineering; Soil and Water Engineering; Environmental Engineering; Agricultural Structures and Environmental Control; Waste Management; Aquacultural Engineering; Animal Production Engineering and the Emerging Technology Areas of Information and Communications Technology (ICT) Applications, Computer Based Simulation, Instrumentation and Process Control, CAD/CAM Systems, Biotechnology, Biological Engineering, Biosystems Engineering, Bioresources Engineering, Nanotechnology and Renewable Energy. The journal also considers relevant manuscripts from related disciplines such as other fields of Engineering, Food Science and Technology, Physical Sciences, Agriculture and Environmental Sciences.

The journal is published by the Nigerian Institution of Agricultural Engineers (NIAE), A Division of Nigerian Society of Engineers (NSE). The Editorial Board and NIAE wish to make it clear that statements or views expressed in papers published in this journal are those of the authors and no responsibility is assumed for the accuracy of such statements or views. In the interest of factual recording, occasional reference to manufacturers, trade names and proprietary products may be inevitable. No endorsement of a named product is intended nor is any criticism implied of similar products that are not mentioned.

Submission of an article for publication implies that it has not been previously published and is not being considered for publication elsewhere. The journal's peer review policy demands that at least two reviewers give positive recommendations before the paper is accepted for publication. Prospective authors are advised to consult the Guide for Authors which is available in each volume of the journal. Four copies of the manuscript should be sent to:

The Editor-In-Chief
Journal of Agricultural Engineering and Technology (JAET)
% The Editorial Office
National Centre for Agricultural Mechanization (NCAM)
P.M.B. 1525
Ilorin, Kwara State,
Nigeria.

Papers can also be submitted directly to the Editor-In-Chief or any of the Sectional Editors. Those who have access to the internet can submit electronically as an attached file in MS Word to ponwualu@yahoo.com. All correspondence with respect to status of manuscript should be sent to the E-mail address.

Table of Contents

TRACTOR FUNCTIONABILITY ASSESSMENT USING RELIABILITY AND AVAILABILITY TECHNIQUE

S. O. Nkakini[1], M. E. Eti[2] and N. Barinyima[2]
[1]Department of Agricultural and Environmental Engineering
[2]Department of Mechanical Engineering,
Rivers State University of Science and Technology, Port Harcourt, Nigeria
E-mail: nkakini@yahoo.com

ABSTRACT

The availability and reliability of a tractor in Agip Farm, in the Green River Project, Omuku in Rivers State, Nigeria were examined. Tractor FIAT 115/08BT model from Agip Farm was used. A period of 7 years (1999-2005) was considered. Parameters such as time to repair (MTTR), mean time between failure (MTBF), failure rate (λ), repair rate (τ), availability (A) and reliability (R) were calculated and data obtained used in establishing availability and reliability relationships. The computed results were below the recommended benchmark and workshop maintenance best engineering practice. Problems of low availability and reliability of the tractor were traced to lack of adequate maintenance policy, inadequate funding and involvement of in-experienced operators. However, a better form of proactive maintenance policy and strategy were recommended including reliability centered maintenance and total productive maintenance.

KEYWORDS: Maintenance, functionability, availability, reliability, Agip farm, Rivers state.

1. INTRODUCTION

Functionability of any asset depends on the reliability of maintenance services on the equipment. Disregarding the present condition of equipment-new machine, its ability to perform the intended function without frequent failure lies on effective maintenance (Eti et al., 2006). Maintenance is any activity carried out on an asset in order to ensure that the asset continues to perform its intended functions or to its original state (Dunn, 2000). Apart from preservation of the functions of assets it also concerns issues such as product quality, customer service, economy and efficiency of operation, control, containment, comfort, protection, compliance with environmental regulations, structural integrity and even physical appearance of asset (Moubray, 1995; Eti et al., 2006).

Over the last several years, managers up to the chief executive officer had come to recognize equipment upkeep as a key part of any successful operating strategy. This realization generated the use of equipment availability and reliability as the key performance indicator of maintenance and organization.

The need to improve on agricultural productivity has been one of the major problems faced by the developing countries. Nigeria is one of such countries that are heavily hit by this peculiar problem. There are so many factors that impede the growth of agriculture in Nigeria, among these is the aspect of machinery maintenance and availability. The farm tractor is one of such machines in the farm that forms the pivot of agricultural mechanization and the basis for the utilization of other machines/equipment for various agricultural activities as ploughing, harrowing, ridging, planting, weeding, fertilizer application, harvesting and transportation of farm produce. It was a realization of the relevance of the tractor that the tractors are being acquired and maintenance units made available in order to achieve a high level of reliability and availability. Maintenance has changed with asset availability and reliability becoming critical issues in capital-intensive operations.

Availability is the proportion of total time that an item or equipment is capable of performing its specified functions, normally expressed as a percentage (Dunn, 2002). It is a good measure of effectiveness. However, it is not the only measure and is not a good indication when taken in isolation

(Eti et al., 2006). Although there are various forms of measuring effectiveness, a combination of both availability and MTBF will provide a more accurate form of measurement- equipment operations. A further and even more accurate measure is that of mean time between faults (as opposed to failure). Availability is significant "value-adder" and reliability is the practical indicator of availability performance (Eti et al., 2006).

Reliability is the probability of a physical asset to perform its intended functions under a prescribed set of conditions (Dunn, 2002). In recent times, the growth of automation has meant that reliability and availability have also become key issues in sectors as driving force as health care, water supply and telecommunication. The effects of downtime have been aggravated by the World-wide move towards just-in-time (JIT) inventory management (Eti et al., 2006). The goal is to maximize the availability of the Tractors maintenance for their intended functions and minimize downtime by strategically assigning maintenance staff.

The Agip Green River Project farm is one of the farms that is being owned by private companies as a means to improving agricultural productivity in Rivers State.

Thus, the objectives of this paper are to identify circumstances causing failure of equipment in Agip Farm, the methods to eliminate / reduce the failure hence reducing maintenance costs, way in which each failure affects the system, measures to be taken to predict and prevent each failure and finally find suitable proactive maintenance for the system, and possibly the appropriate application policy for maintenance.

2. MATERIALS AND METHODS

2.1 Data Collection and Analysis

The study focused on investigation into how to improve tractor/ equipment maintenance and availability in Agip Farm, using availability and reliability techniques. The relevant data for this research were obtained using both primary and secondary source of information.

The main sources of evidence for the investigation were obtained from the Green River Project, Agip Farm, Obikom Omuku in Rivers State, through personal contacts with the top management, senior management and shop floor staff and discussions with record holders.

Further data were obtained using structured questionnaire to record information concerning the type of tractor/equipment make and model, the nature of work, condition, maintenance/repair data of tractor Fiat 115/08BT, availability of repair facilities, knowledge of farm machine as well as the existing availability and reliability records.

Information collected using both primary and secondary sources were analysed. The primary data were obtained from the structured questionnaire, personal contact and oral interviews – management team of Agip farm. By a secondary method, relevant information was obtained from maintenance and operation, from log sheet to get historic records e.g. MTBF, MTTR etc. for achieving availability, reliability and maintainability results of equipment/machines.

2.2 Applied Models

The assessment of functionability of tractor (FIAT 115/08BT) was accomplished by computation of various parameters, availability and reliability. The operating availability of an existing tractor can be obtained from historical data as:

$$\text{Availability} = {}^{\text{uptime}}/_{\text{uptime + downtime}} \quad \ldots\ldots\ldots\ldots (1)$$

The expected availability of a tractor should be based on the operating experience of similar equipment, specific performance requirement and cost constraints of the tractor have to be considered.

The initial task in setting up an availability goal is the construction of a simple model of the tractor to give an insight into the significance of the goal. This is shown in figure 1.

The tractor/unit availability is given by:

$$A = A_1 A_2 \ldots\ldots\ldots\ldots\ldots A_n = \prod_{j=i}^{n} A_1 \text{ or, } A = 1 - \sum_{j=i}^{n} U_1 \ldots\ldots\ldots\ldots (2)$$

Where: A_1 = Availability of major equipment; U_1 = Unavailability; and A_2 = Availability of equipment

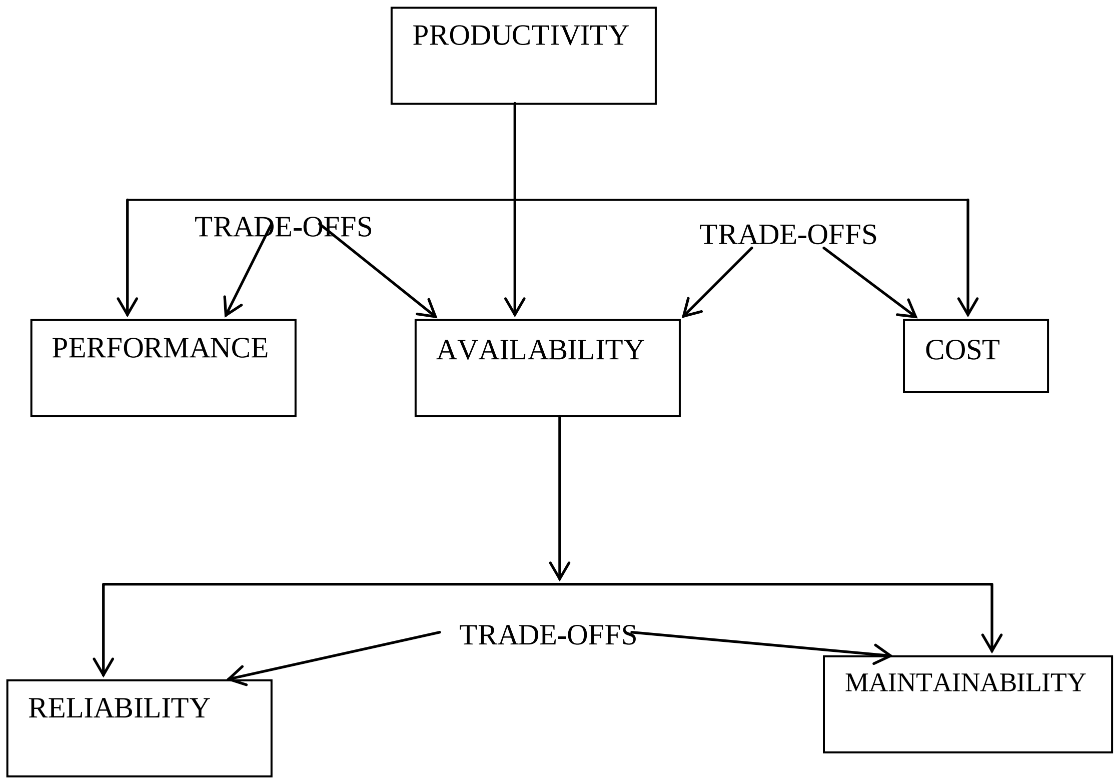

Figure 1 – Factors influencing the productivity of pumping station

Source: Eti et al. (2006).

The relationship depicted in figure 1 can be expressed mathematically in this general form:

Pr = f (A,P,C) ………………. (3)

A = g (R,M/PC) ………………(4)

Where: Pr = productivity; A,P,C = availability, performance, and cost; R,M = reliability and maintainability; and g = functional relation

From equation 4, availability is expressed as a function of reliability and maintainability subject to constraints of performance requirements and costs.

Availability is also related to both frequency and duration of analysis as follows:

$A = [1/(1 + \lambda \tau)]$ ………………. (5)

Where: λ = failure rate of number of failure/unit time; τ = restoration time to duration of failures

Thus, the availability goal can be converted into reliability and availability requirements in terms of acceptable failure rates and failure hours for each component as explicit design objectives. Application of reliability and maintainability principles to equipment requires that, the system/component availability be defined in terms of mean time between failure (MTBF) and mean time to repair (MTTR). MTBF is the reciprocal of frequency of failures and MTTR is related to the duration of failures (outages)and both can be computed from the historical data by Abernathy (1996)

$MTBF = {}^{1}/_{\lambda}$ = total operating time/number of frequency ……….. (6)

$MTTR = {}^{1}/_{\tau}$ = total failure time/number of failures …………… (7)

As soon as these two factors are known for any given system or component, then the availability of the system or component can be expressed as:

Availability = MTBF/ (MTBF + MTTR) ………………………. (8)

Reliability analysis techniques can be qualitative or quantitative and is given by Reliasoft (2000) as:

$R(t) = \exp(-t\lambda) = \exp(-t/MTBF)$ …………………… (9)

Maintainability analysis is used to evaluate the design and layout with respect to maintenance procedures and resources requirement and is given as:

$M(t) = 1 - \exp(-t/MTTR)$ ………………. (10) (Abeanethy, 1996)

From the reliability and maintainability analysis, systems or components, which have availability below the desired goal are identified.

2.3 Calculation and Data Analysis

Below are examples showing mathematical computations for obtaining tractor equipment reliability and availability parameters: MTBF, MTTR, λ, and τ.

For tractor FIAT 115/08BT equipment, year 1999
Number of failures (NF) = 8
Failure hours (FH) = 48
Operational Hours (OH) = 2032 (expected working hours of the year – FH)

The mean time between failure (MTBF) is computed using equation (6) as

$$MTBF_{(Tractor\ 1999)} = \frac{OH_{(Tractor\ 1999)}}{NF_{(Tractor\ 1999)}} = \frac{2032}{8} = 254\ Hours$$

$MTBF = 254\ Hours$

The meantime to repair (MTTR) is computed using equation (7) as

$$MTTR_{(Tractor\ 1999)} = \frac{FH_{(Tractor\ 1999)}}{NF_{(Tractor\ 1999)}} = \frac{48}{8} = 6\ Hours$$

MTTR = 6 Hours

The failure rate $\lambda_{(Tractor\ 1999)}$ is computed using equation (6) as

$$\lambda_{(Tractor\ 1999)} = \frac{1}{MTBF_{(Tractor\ 1999)}} = \frac{1}{254} = 3.937 \times 10^{-3}$$

$$\lambda_{(Tractor\ 1999)} = 0.00394$$

Repair rate (τ) is computed using equation (7) as

$$\tau_{(Tractor\ 1999)} = \frac{1}{MTTR_{(Tractor\ 1999)}} = \frac{1}{6} = 0.1667$$

$$\tau_{(Tractor\ 1999)} = 0.1667$$

The availability (A) of tractor 1999 equipment is computed using equation (8) as

$$A_{(Tractor\ 1999)} = \frac{MTBF_{(Tractor\ 1999)}}{MTBF_{(Tractor\ 1999)} + MTTR_{(Tractor\ 1999)}}$$

$$= \frac{254}{254 + 6} = \frac{254}{260} = 0.9769$$

$$A_{(Tractor\ 1999)} = 97.6\%$$

The reliability (R) of tractor 1999 equipment is computed using equation (9) where the mission time (t = 2080 hours) as

$$R(t)_{(Tractor\ 1999)} = \exp_{(Tractor\ 1999)}(-t\,\lambda_{(Tractor\ 1999)}) = \exp({}^{-t}/_{MTBF(Tractor\ 1999)})$$

$$R(2080)_{(Tractor\ 1999)} = \exp\left(-\frac{2080}{254}\right) = 0.00002$$

$$R(t) = 2.787\%$$

The same procedure was followed for years 2000 to 2005.

3. RESULTS AND DISCUSSIONS

An appraisal of tractor – Fiat 115/08 BT for availability and reliability of equipment from 1999-2005 revealed the main equipment failures for each year in Agip Farm in Rivers State. These major equipment failures were links, tire, key starter, engine/air filter, clutch and steering. Included in the tables were the date / time when equipment was repaired, duration of failures and factors responsible for the failures as shown in Tables 1 – 7.

Table 1: Main equipment failures and downtime log (1999)

Tractor	Failed Compts	Equip't Failed Date	Time	No. of Failure	Failed Hours	Equip't Repaired Date	Time	Causes of Failure
Fiat 115/08 BT	Link (Gear System	10/10/99	4pm	2	7	12/1/99	12pm	Worn out
		14/2/99	9pm			14/2/99	5pm	Rubber Pitch
		3/2/99	11pm	2	12	3/2/99	5pm	Punctured
	Time	8/9/99	8am			8/9/99	4pm	Tire
		10/4/99	8am	2	5	13/4/99	9am	Worn out
	K/Starter 7/8/99	12.00pm				10/8/99	8am	Brush
		2/2/99	8pm	2	24	4/2/99	8am	Dirty air
	Engine/air Filter	11/5/99	8am			13/8/99	8am	Filter

Table 2: Main equipment failure and downtime log (2000)

Tractor	Failed Compts	Equip't Failed Date	Time	No. of Failure	Failed Hours	Equip't Repaired Date	Time	Causes of Failure
Fiat 115/08 BT	Clutch	18/4/00	10pm	1	16	15/4/00	11pm	Worn part
	Tire	12/1/00	9am			12/2/00	8pm	Punctured
	Links (Gear)	10/2/00	9am	1	8	13/02/00	9am	Worn out Rubbers and Pitch
	Steering	10/10/00	8am	1	5	12/10/00	4am	Oil Leakage
	Engine	2/02/00	8pm	1	12	4/2/00	8am	Dirty air
		22/8/00	8am	2	24	24/8/00	8am	filter

Table 3: Main equipment failure and downtime log (2001)

Tractor	Failed Compts	Equip't Failed Date	Time	No. of Failure	Failed Hours	Equip't Repaired Date	Time	Causes of Failure
Fiat 115/08 BT	Engine/air filter	6/2/01	8am	2	24	8/02/01	8am	Dirty air filter
		13/8/01	9am					
	Tire	4/4/01	11am	2	10	5/4/01	1am	Punctured
		18/6/01	9am			18/6/01	4pm	Tire

Table 4: Main equipment failure and downtime log (2002)

Tractor	Failed Compts	Equip't Failed Date	Time	No. of Failure	Failed Hours	Equip't Repaired Date	Time	Causes of Failure
Fiat 115/08 BT	Engine/air filter	11/2/02 26/8/02	8am 8am	2	24	13/2/02 28/8/02	8am 8am	Dirty air filter
	Clutch	27/5/02 6/9/02	9am 10am	2	16	29/5/02 8/6/02	5pm 4pm	Soaked by oil
	Steering	5/5/02	11am	1	12	6/8/02	4pm	Shortage of oil in gear box

Table 5: Main equipment failure and downtime log (2003)

Tractor	Failed Compts	Equip't Failed Date	Time	No. of Failure	Failed Hours	Equip't Repaired Date	Time	Causes of Failure
Fiat 115/08 BT	Engine/air filter	4/2/03 20/6/03	8am 10am	2	24	6/2/03 22/6/03	8am 10am	Dirty air filter
	Tire	7/4/03 4/8/03	2pm 8am	2	10	8/5/03 6/8/03	10am 8am	Punctured Tire

Table 6: Main equipment failure and downtime log (2004)

Tractor	Failed Compts	Equip't Failed Date	Time	No. of Failure	Failed Hours	Equip't Repaired Date	Time	Causes of Failure
Fiat 115/08 BT	Clutch	2/3/04	11am	1	16	3/6/2004	5pm	Weaving
	Links	23/11/04	2pm	1	8	24/11/04	10pm	Worn out
	Tire	20/11/04	8am	1	6	21/11/04	2pm	Punctured
	Engine/air filter	2/2/04 9/8/04	8am 8am	2	24	6/6/04 11/8/04	8am 8pm	Dirty air filter

Table 7: Main equipment failure and downtime log (2005)

Tractor	Failed Compts	Equip't Failed Date	Time	No. of Failure	Failed Hours	Equip't Repaired Date	Time	Causes of Failure
Fiat 115/08 BT	Engine/air filter	3/3/05 16/11/05	8am 8am	2	24	7/2/05	8pm 8am	Dirty filter
	Tire	13/4/05	10am	1	6	13/4/05	4pm	Punctured

Links	3/11/05	11am	1	5	13/5/05	4pm	Worn out rubber gear

Table 8 depicts the average yearly parameters – number of failures, failure hours, operational hours, mean time before failures, failure rates, repairs rates, mean time to repairs, availability and reliability from 1999 – 2005.

Table 8: The average yearly equipment reliability and availability (1999-2005)

Parameters	Failed Compts 1999	Failed Compts 2000	Failed Compts 2001	Failed Compts 2002	Failed Compts 2003	Failed Compts 2004	Failed compts 2005
NF	8	6	4	5	5	7	4
FH	48	65	34	52	39	66	30
CH	2032	2015	2076	2028	2041	2022	2044
MTBF	254	335.83	519	405.6	408.2	288.86	511
MTTR	6	8.13	8.5	10.4	7.8	9.43	9
λ	0.00394	0.00298	0.00193	0.00493	0.00245	0.00346	0.00195
τ	0.1667	0.123	0.111	0.00361	0.129	0.106	0.111
A(%)	97.6	97.6	98.3	97.5	98.1	96.8	98.3
R(%)	2.77	2.04	0.02	5.42	6.12	7.46	0.02

NF = Number of failures; FH = Failure hours; OH =Operational hours; MTBF = Mean time before failures; λ = Failure rate; τ = Repairs rates; A (%) = Availability; R(%) = Reliability; MTTR = Mean time to repair.

For each year (1999 – 2005), results recorded in Table 8 were obtained using mathematical computation of the parameters. The recorded parameters that were relevant for the work in each of the years included the equipment/component responsible for the failures, the date/time when equipment was repaired, and the duration of failure. The data was then used to compute the equipment reliability and availability of the major (main) equipment. The mean time between failures (MTBF), means time to repair (MTTR), failure rates (λ), repair rates (τ), availability (A) and the reliability (R) were the computed parameters presented in table 8.

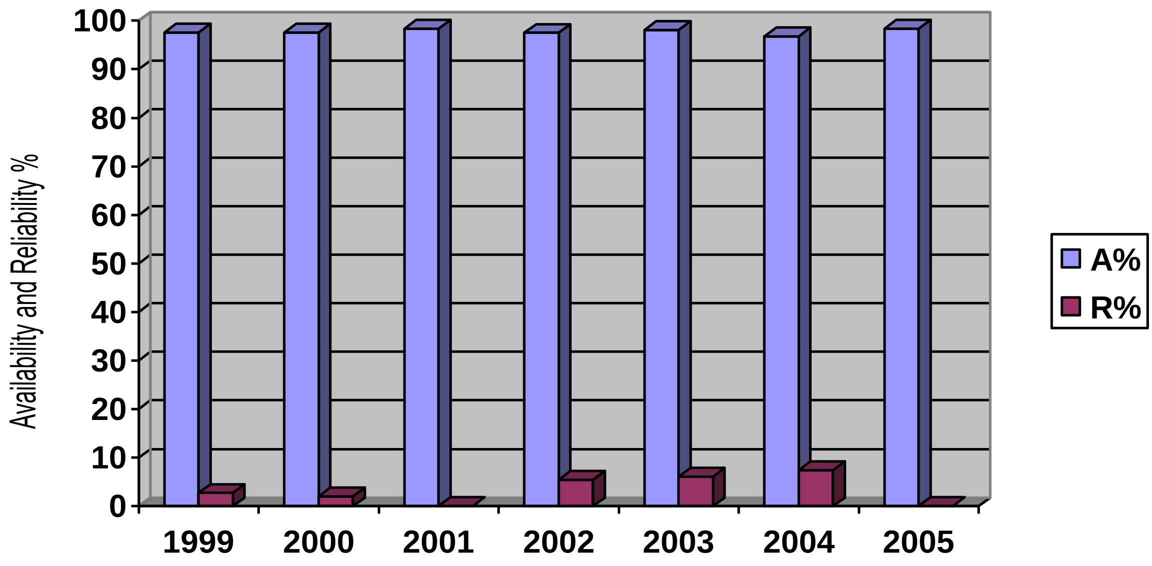

Fig 2: Equipment availability and reliability for Tractor time (1999 – 2005).

Figure 2 shows the average yearly equipment availability and reliability values for the seven-year study period. The availability values vary slightly during this period, probably because of good maintenance procedures in Agip farm. The highest value of 98.3% was recorded in 2001 and 2005 respectively. The corresponding reliability values for these two years (2001 and 2005) depicted lowest values of 0.02% respectively. The reason for this is that, these two years (2001 and 2005) recorded the lowest number of failures leading to low failure hours and higher operating hours as compared to other cases.

The obtained results in figure 2 indicated that reliability values of the tractor Fiat 115/08BT reached its peak of 7.46% in 2004.

Table 9: Benchmark data for Tractor (Fiat 115/08BT)

Equipment	Parameters	Agip Farm Tractor Fiat 115/08BT	Agip Farm Tractor Tractor Fiat 115/08BT	Best Tractor
Tractor Availability		0.97	0.98	0.98
Fiat 115/08BT Reliability		0.34	0.342	0.75

From the main result of the analysis as indicated in Table 9, the total average availability values obtained from the analysis is almost the same, when benchmarked with the industry best practice value. It is clear from the data obtained in reliability analysis that the value is quite lower, when also benchmarked with the industry best practice values of 0.98.

Adequate maintenance practices are well-known factors enhancing good operation especially in equipment services (Tractor). Inadequate maintenance, even if it does not lead to frequent equipment failure, can increase the total operating cost (Eti et al., 2006).

The trend of equipment maintenance as depicted in the equipment reliability and availability, Table 9, revealed strongly that equipment could be available, still lack reliability.

4. CONCLUSION

Statistical evaluation of resulting data sample was carried out to obtain the equipment availability and reliability of tractor Fiat 115/08BT in Agip Farm during the seven-year study period. Availability values reached its peak of 98.3% in 2001 and 2005 and reliability indicated the lowest values of 0.02% in the same years and in year 2004 reached its peak value of 7.46%. The values obtained in reliability are below expectation when compared with the benchmark values. Therefore, standard maintenance practice is to be adopted which would include the provision of a good maintenance programme total productive maintenance (TPM) and reliability centred maintenance (RCM) concept as a maintenance policy. A more comprehensive method of data recording and storage should be adopted.

Strategic development can be achieved when resource requirements are clearly understood and what systems are needed to manage the resources in such a way that tasks are done correctly, and hence preserving the function of the assets.

The development and execution of a maintenance strategy consists of three steps: formulate a maintenance strategy for each asset (work identification); acquire the resources needed to execute the strategy effectively (people, spares and tools); and executed the strategy (acquire, deploy and operate the systems needed to manage the resources efficiently).

Proper maintenance of tractor and equipment can significantly reduce the overall operating exit, while boosting the productivity of the plants. Attention should not only be concentrated on availability but also on reliability.

There should be a push towards zero downtime or zero in - service breakdowns. Also, improved maintenance tools such as RCM, TPM, roots cause failure analysis (RCFA), failure modes and effect analysis (FMEA) and others should be applied to objectively achieve maintenance objective, hence reliability and availability.

REFERENCES

Abernethy, R. B. 1996. The New Weibull Handbook, 3rd Ed. Gulf Publishing Company. Honston TV.

Dunn, S. 2002. Maintenance Terminology. Some Key Terms, A/Maintenance Glossary Key Terms. Rfm. 1.

Eti M. C., Nkakini S. O., Nkoi B, 2006. Application of availability and reliability analysis techniques to improve Bayelsa Water Board Productivity. Nigeria Journal of Engineering Research and Development.

Moubray, J. 1995. Reliability Centred Maintenance 2nd Ed Butterworth-Heinemann, Oxford. Reliasoft 2002. Failure modes; Effects and Criticality Analysis, on www.reliasoft. Com/fmca.htm.

DEVELOPMENT OF AN AXIAL FLOW MOTORIZED SORGHUM THRESHER

K. J. Simonyan[1], and P. A. Imokheme[2]
[1]Agricultural Engineering Department, Michael Okpara University of Agriculture,
P M B 7267. Umudike, Umuahia, Nigeria.
E- mail: simonyan.kayode@mouau.edu.ng
[2]Formerly, Agricultural Engineering Technology Programme
College of Agriculture, Ahmadu Bello University PMB1058, Samaru – Zaria, Nigeria.

ABSTRACT

The effect of feed rate, feeding pattern, cylinder speed, sieve oscillation and straw walker oscillation on the performance of a locally fabricated axial flow motorized sorghum thresher were evaluated in terms of threshing efficiency, cleaning efficiency, separation efficiency and grain loss. The moisture content of the sorghum grain and straw was 8 % wb and 5 % wb respectively. Results showed that decreasing the feed rate increased the threshing efficiency irrespective of the feeding pattern. Cleaning efficiency decreased with increasing sieve reciprocation and threshing cylinder speed. Feeding patterns affect the separation efficiency. Grain loss decreased with increasing feed rate while increasing sieve and straw walker oscillations increased grain loss.

KEYWORDS: Sorghum, threshing, cleaning, separation, grain loss, efficiency

1. INTRODUCTION

Sorghum (*Sorghum bicolor L*) is a very important cereal which is grown widely in arid and semi- arid zones. In Nigeria, sorghum is grown in the Sudan, Northern and Southern guinea savanna zones. It is a major source of food to most peasant families and raw material to many agro- based industries. There has been an increasing demand for its usage in the production of food, feed products, alcoholic and non-alcoholic beverages (Rooney, 2003; Rohrbach, 2004). However, traditional consumption still utilizes 98 % of the annual production (Rohrbach, 2004) of sorghum estimated at 7.704 MT in 2002 in Nigeria (FAO, 2003).

Threshing is the process of separating grains from heads. This may be accomplished by impact between the heads and a fast moving element, rubbing, squeezing or a combination of these methods (Campbell, 1976, Picket and West, 1988). Traditionally, threshing of sorghum is manual, involving beating the head with sticks. Threshing ground sometimes may be bare ground, on tarpaulin in the field, stony or rocky surface and abandoned road surfaces near the farm. For small-scale production, harvested sorghum heads are transported to homestead for storage in rhumbus, platforms, rooftops and empty rooms and are threshed when needed for consumption or disposal in the market. In this case, threshing is also done with sticks, mortar and pestle or putting the sorghum head inside a bag and beating with sticks.

Losses occur during threshing due to spillage, incomplete removal of grains from heads, damage to grain and contamination with sand and stones. The traditional method of threshing and the subsequent grain separation is physically demanding on the person performing the operation (Ali, 1986). Also, Desta and Mishra (1990) reported that indigenous threshing of sorghum is one of the most time consuming, laborious and uneconomical activities. Ali (1986) and Hassena, *et al.*, (2000) classified manual threshing of sorghum as heavy workload in terms of energy expenditure of 41.87 KJ/min and heartbeat rates/min of 150.

RUSEP (2001) reported that small-scale producers, who account for 90 % of the total agricultural production, are not using improved technology. This they opined, inhibits efficiency in terms of productivity, reduces quantity and quality of products and puts enormous strains on labour force. The relative importance of sorghum in rural food systems and to industries, suggests that opportunities exist for its commercialization.

There are different types of threshing cylinders- spike and loop cylinders thresh based on striking action mainly while rasp bar cylinders threshes mainly on friction and rubbing. Singh and Kumar (1976) published that swinging hammers cylinder type consumed more power than the rasp bar and spike tooth cylinder. Also Singhal and Thierstein(1987) reported that the spike tooth and rasp bar cylinders are safe for use among the village farmers on stationary threshers fed manually. Factors influencing threshing of crops can be broadly grouped into crop characteristics and machine parameters (Simonyan, *et al.*, 2006). Application of axial flow method in the threshing unit will increase the resident time of sorghum head in the threshing unit before discharge.

Many threshers have been imported to the country however threshing of sorghum has continued to be manual. There is need to provide farmers with appropriate sorghum thresher. The objective of this paper is to report on the development of a locally constructed axial flow motorized sorghum thresher.

2. MATERIALS AND METHODS

2.1 Design Considerations

In view of the morphology- related machine performance constraints of sorghum, the following were considered in developing the sorghum thresher-testing rig:

(i) Develop a machine to thresh sorghum efficiently using axial flow principle.
(ii) Develop a machine that will be able to clean sorghum, utilizing the differences in the aerodynamic characteristics of the sorghum grain and the constituents.
(iii) Minimize the loss as a result of threshing, separation and cleaning.
(iv) Minimize the drudgery involved in the processes.

2.2 Development of an Axial Flow Motorized Sorghum Thresher

The axial flow motorized sorghum thresher was developed to thresh, separate and winnow, exploiting differences in some characteristics of threshed sorghum materials such as size, shape, volume and weight. The reason for considering axial flow is because it will allow the sorghum heads more resident time in the threshing cylinder than cross flow. This will allow for more thorough threshing. The thresher consists of the following component parts: frame, feeding unit, threshing unit, outlet and cleaning unit. Fig 1 shows the schematic of the developed axial flow sorghum thresher.

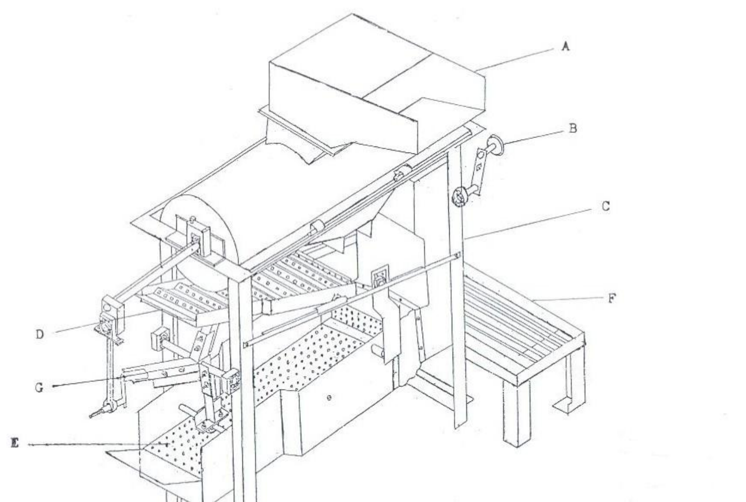

Fig. 1. Schematic of the sorghum thresher. (1) Hopper (2) Idler (3) Frame (4) Straw (5) Sieve (6) Motor (7) Crank Arrangement

2.2.1 Frame

The frame was constructed using 6.5 by 6.5 mm and 40 by 40 mm angle iron to give rigid support. The frame overall length is 910 mm, width 410 mm and height 1000 mm.

2.2.2 Feeding Unit

The hopper was inclined 20^o and 30^o to the horizontal based on the angle of repose of sorghum heads to ensure self feeding and to avoid shattering losses through the feeding unit. The hopper and chute are constructed from gauge 16 (2 mm) plate metal. The chute is 610 mm long, 350 mm wide and 130 mm high. The hopper is trapezoidal in shape which is considered fitting for sorghum in order to increase easy flow of sorghum head and reduce shattering losses during threshing. The chute and the hopper are detachable from each other.

2.2.3 Threshing Unit

The threshing mechanism employed was by impact. Arranging spikes spirally on threshing cylinder achieved this. This arrangement enables the sorghum heads to be conveyed from the threshing unit through to the straw outlet. The threshing unit consists of threshing cylinder, concave and top cylinder cover. Ejection of threshed material was enhanced by beater rods 50 mm long and 10 mm thick (4 in numbers) arranged on the threshing cylinder.

Threshing Cylinder – This is made up of a hollow pipe 3.0 mm thick, 510 mm long and 110 mm in diameter. 40 spikes, 15 mm diameter and 50 mm long, welded to the cylinder at 90^o, impart the sorghum head against the concave. The continuous impact action of the beaters, forces the grain to be detached from the sorghum head. The spiral arrangement, in form of auger, of the spikes conveys the straws out of the threshing unit axially. Figure 2 shows the schematic of the threshing cylinder.

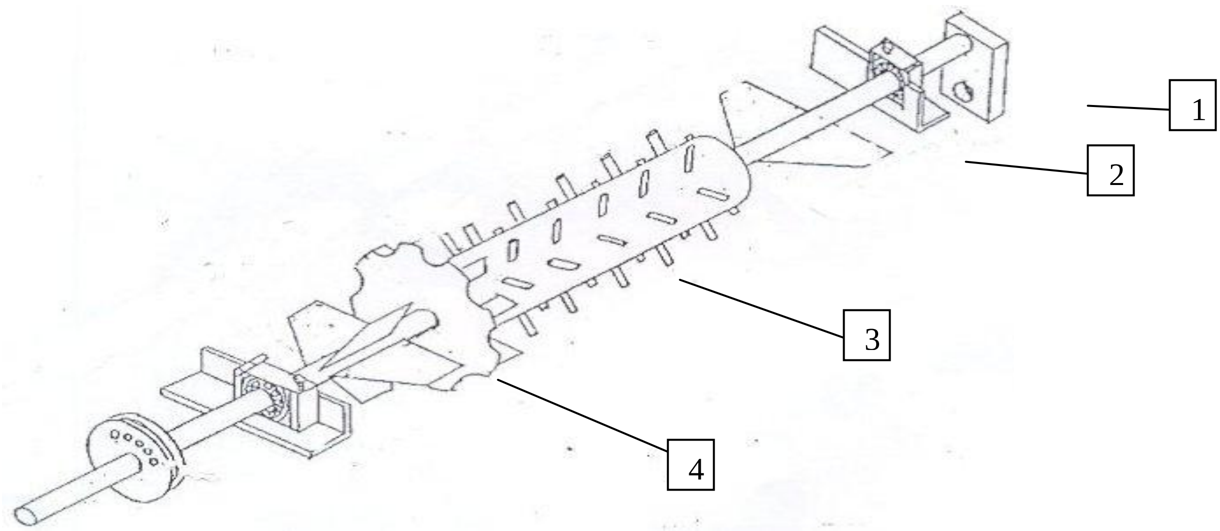

Fig. 2. Schematic of the threshing cylinder. 1. Crank Device; 2. Straw Beater; 3. Threshing Cylinder; 4. Air Blower

Concave- This is a stationary sieve located below the threshing cylinder. The concave was constructed from a plate metal 4 mm thick to be able to withstand the impacts of sorghum materials and is 610 mm long. The concave was braced with 4 metal rods of 10 mm diameter to hold the sorghum heads thereby increasing the residency within the threshing unit; the concave holes of 10 mm diameter for easy passage of the grains.

Top Cylinder Cover- This was constructed from a gauge 16 sheet metal used to encase the threshing assembly and straw outlet. The cover is a semi- circular sheet of diameter 310 mm. An opening, 350 mm by 150 mm was made at the right end for the feeding unit.

2.2.4 The Straw Outlet

This was located at the left hand side (when facing the machine side view as shown in Fig. 1) of the sorghum thresher with opening, dimensioned 20 mm by 10 mm based on the physical characteristics of threshed sorghum materials. It has 2 blades for beating out the straws and threshing the incompletely threshed sorghum head before extruding it on the straw walker.

2.2.5 Separation and Cleaning Unit

The separation and cleaning unit is composed of straw walker, shaker and sieve and air blower.

Straw Walker- This helps to remove the remaining grain from straw thereby reducing losses and cleaning by properly dispersing the threshed sorghum constituents. Straws are thrown through the front part while grains gravitate downwards across the blower. The straw walker consists of two parts: the container and the walker. It was constructed from gauge 18-sheet metal.

Shaker and Sieve- It is driven by a crank situated at the front of the shaker. It is constructed from gauge 18-sheet metal. The sieve is made from gauge 16 metal sheet with holes 6 mm in diameter bored on it based on the sorghum grain diameter(Simonyan, *et al.*, 2007) at 10 mm intervals. The sieve is 330 mm long, 240 mm wide at the front and 450 mm long, 280 mm wide at the back.

Air Blower -An axial flow fan was used for the cleaning based on aerodynamic properties of sorghum (Simonyan, *et al.,* 2008). The 4 blade impeller was made from a metal plate 4 mm thick. The fan housing was constructed from gauge 16 sheet metal 680 mm long and 30 mm wide to direct the air stream to the cleaning chamber.

2.2.6 Crank Mechanism

The crank mechanism used tom produce the reciprocating motion of sieve and straw walker assembly was constructed from flat bar 5 mm thick, 40 by 40 mm angle iron, 20 mm and 15 mm iron rods. Bolts and nuts were used to fasten them together to make it detachable. It is 30 mm long with amplitude of 7. The rotating motion of threshing cylinder is converted by the crank mechanism to the reciprocating motion of the straw walker and sieve respectively. The forward motion of straw walker produces backward motion of sieve at the same time and vice versa. The crank mechanism is termed front liner ASOPET crank.

2.3 Principle of Operation

The machine threshes the sorghum head by impact of the rotating beaters. The threshed grains fall through the concave on the sieve while the straws are conveyed out axially through the straw outlet to the agitating straw walker. The combination of air from the blower and the sieve helps to separate the grain from materials other than grain (MOG). The clean grain is obtained at the collector while the straw is ejected at the straw walker.

2.4 Experimental Procedure

Sorghum variety, SAMSORG 17(SK 5912) was selected as test crop due to its economic importance and growing market demand in malting and baby food industries as well as other agro-based industries (RUSEP, 2001). It is a late maturing variety suitable for the guinea savannah vegetation zone of Nigeria. Performance evaluation of the developed sorghum thresher was carried out to determine the effect of cylinder speed, feed rate and feed orientation on threshing efficiency, cleaning efficiency, separation efficiency, and wastage.

A kilogram of sorghum head was manually introduced through the hopper into the thresher. The approximate feed rate was determined as the material fed into the machine per unit time. Crop feeding times in seconds were measured with stopwatch. Different operational feeding patterns such as head first, side and peduncle (tail) first was carried out. The speed of the threshing cylinder was determined with a tachometer (Smith industrial Division, London H W 2 max 50 000 rpm, d = 1 rpm). The air speed from the blower was determined using an anemometer (Pruufscein fur anemometer, L- Nr, 3 010/ 112 546). Moisture content of samples was determined using the procedure detailed by Henderson, *et al*., (1997). The samples were oven dried at 130^0C for 18 hours (ASAE, 1983).The performance was evaluated based on the following:

a. ***Threshing Efficiency***:

$$TE = \left(1 - \frac{SH}{TSH}\right) x100 \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \; 1$$

Where TE is threshing efficiency, %; SH is weight of unthreshed grain, kg and TSH is total weight of grain in the sample, kg.

b. ***Cleaning Efficiency***:

$$CE = \frac{G_0}{G_0 + C_{cg}} x100 \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \; 2$$

Where CE = cleaning efficiency, %; G_0 is weight of pure grain at the outlet, kg and C_{cg} is weight of contaminant (Material Other than Grain), kg.

c. ***Separation Efficiency***:

$$SE = \frac{W_{ot}}{W_o + W_{op}} x100 \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots.. \; 3$$

Where SE = separation efficiency, %; W_o is weight of effluent ejected out, kg; W_{op} is weight of threshed heads which passed through the concave, kg and W_{ot} is weight of threshed grain ejected along with straw, kg

d. ***Grain Losses***:

$$GL = \frac{W_g}{W_T} X100 \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \; 4$$

Where GL is Grain loss from chaff outlet, %; W_g is weight of grain collected at the chaff outlet, kg and W_T is total weight of grain from outlets, kg.

3. RESULTS AND DISCUSSION

3.1 Threshing Efficiency

Table 1 gives the effect of threshing cylinder speed, feed rate and feeding pattern on the threshing efficiency. When the sorghum was fed head first, the average threshing efficiency was 71.7 %, while the highest threshing efficiency of 74.7 % was obtained when the sorghum is introduced sideways to the threshing cylinder. The least threshing efficiency of 68.2 % was obtained when the sorghum was introduced from the peduncle (tail) first. The feed rate influenced the threshing efficiency. Decreasing the feed rate increased the threshing efficiency irrespective of the feeding orientation. Increasing the cylinder speed increased the threshing efficiency. This may be due to more aggressive impact of the spikes on the sorghum head. This is similar with the result obtained by Mishra and Desta(1990) showing that threshing efficiency increased with cylinder speed. However, the threshing efficiency (68.2 -74.7%) obtained for this study is lower than the values (93.3-99-9%) by Mishra and Desta (1990). The value is also lower than 99-9% threshing efficiency obtained by Simonyan (2009) for cross flow sorghum thresher. The reason for the observed lower values may be due to high level of vibration during the operation of the machine.

3.2 Cleaning Efficiency

Table 1 gives the effect of machine parameters on the cleaning efficiency. The cleaning efficiency decreased with increasing sieve oscillations. When the reciprocation speed was 4 1/s, the cleaning efficiency was 66.7 % while at 8 1/s; the cleaning efficiency was 63.2 %. Increasing feed rate increased the cleaning efficiency. When the feed rate was 6.9 kg/min the cleaning efficiency was 66.7 % while at feed rate of 5.29 kg/min the cleaning efficiency was 62.9 %.Increasing the threshing cylinder speed decreased the cleaning efficiency. At the threshing cylinder speed of 2.72 m/s, cleaning efficiency of 65.8 % was obtained while the threshing speed of 4.08 m/s the cleaning efficiency was 63.2 %. Increasing the threshing cylinder speed resulted at more imparts on the sorghum head introduced to the concave. The materials other than grain were chopped into fine particles, which resulted in an increased range of particle sizes and formation of minute particles, which aerodynamically resembles sorghum grain thereby creating challenges in the cleaning operation. The decreases in the cleaning efficiency with increasing sieve oscillations may be due to less resident time of the materials to be separated on the sieves and increase agitations allows more materials to pass through the sieve holes. The increased load intensity of materials resulting there from may be the reason for decrease in the cleaning efficiency. The cleaning efficiency obtained for the axial flow thresher (63-66 %) is lower than 96.1% obtained for cross flow sorghum thresher by Simonyan (2009). This may be due to higher load intensity resulting from longer resident time of the materials in the cylinder and thorough threshing.

3.3 Separation Efficiency

Effects of the machine parameters on the separation efficiency are given in Table 1. When the sieve and straw walker oscillation was 4 1/s, the average separation efficiency was 94.2 %. Also when the oscillation was 8 1/s, the separation efficiency was 91.4 %. The feeding orientation affected the separation efficiency; with the highest average separation efficiency of 99.9 % obtained when the sorghum was fed tail first, while the lowest was obtained with the head first orientation pattern.

3.4 Grain Loss

Feeding pattern affected grain loss. Table 1 gives the effect of machine parameters on grain loss. Highest loss of 14.1 % was obtained when the head was first introduced while the lowest 1.8 % was obtained with the peduncle introduced first. Cylinder speed influenced grain loss from the thresher. At low threshing cylinder speed of 2.40 m/s, the grain loss was 5.57 % while at 2.72 m/s, the loss was 8.6 %. Increasing feed rate led to decreasing grain loss. When the average feed rate was 5.92 kg/min, the loss was 14.1% while the lowest loss was obtained at feed rate of 7.22 kg/min. Increasing the sieve and straw walker oscillations increased the grain loss. At oscillations 4 1/s the grain loss was lowest and highest when the oscillations was 81/s. The values obtained were within the range observed for cross flow sorghum thresher by Simonyan (2009).

Table 1: Performance evaluation of the developed thresher.

Feeding pattern	Replication	C S m/s	S O 1/s	Feed rate kg/min	T E %	C E %	S E %	G L %
	1	2.40	4	6.9	69.3	66.7	88.6	11.4
Head first	2	2.72	6	5.6	71.4	66.7	84.8	15.1
	3	4.08	8	5.3	74.4	62.9	84.3	15.8
	Average			5.9	71.7	65.4	85.9	14.1
	1	2.40	4	8.3	64.3	63.5	98.8	1.1
Tail first	2	2.72	6	7.2	69.1	65.0	98.4	1.5
	3	4.08	8	5.6	71.2	62.3	97.2	2.8
	Average			7.0	68.2	63.6	98.2	1.8
	1	2.40	4	6.9	71.4	67.2	95.0	4.2
Sideways	2	2.72	6	6.1	74.7	64.1	92.3	7.7
	3	4.08	8	4.7	77.9	64.5	92.7	7.4
	Average			5.7	74.7	65.2	93.3	6.4

CS – Cylinder Speed, SO – Sieve Oscillation, TE – Threshing Efficiency, CE – Cleaning Efficiency, SE – Separation Efficiency, GL – Grain Loss

4. CONCLUSIONS

An axial flow spike toothed sorghum thresher was developed and performance evaluation of the thresher showed that the feed rate, threshing cylinder speed and feeding pattern affected the threshing efficiency. Decreasing feed rate increased the threshing efficiency irrespective of the feeding orientation. Also increasing the threshing cylinder speed increased the threshing efficiency. The cleaning efficiency decreased with increasing sieve oscillations. Increasing the threshing cylinder speed decreased the cleaning efficiency. The cleaning efficiency decreased with increasing sieve oscillations.

Separation efficiency decreased with increasing sieve oscillations. Feeding pattern affected the separation efficiency. Increasing the feed rate led to decreasing grain losses, also increasing the sieve and walker oscillations increased the grain losses.

REFERENCES

Ali, M. A. 1986. Comparative ergonomic studies of male and female operators on selected farm tasks. Unpublished MSc Thesis. Ahmadu Bello University, Zaria, Nigeria.

ASAE. 1983. Yearbook, American Society of Agricultural Engineers. 2950 Niles Road, St Joseph, Michigan 49085.

Campbell, J. K. 1976. Development and manufacture of a thresher for developing countries of South East Asia. Agricultural Mechanization in Asia, Africa and Latin America 7(3): 31-34.

Desta, K. and Mishra T. N. 1990. Development and performance evaluation of a sorghum thresher. Agricultural Mechanization in Asia, Africa and Latin America 21(3):33-37.

FAO. 2003. FAOSTAT United Nations. http//www.apps.fao.org.

Hassena, M.; Ensermu, R.; Mwangi, W. and Verkuiji, H. 2000. A comparative assessment of combine harvesting vis-à-vis conventional harvesting and threshing in Arsi Region, Ethiopia. Mexico D F International maize and wheat improvement center (CIMMTT) and Ethiopia Agricultural Research Organization (EARO).

Henderson, S. M., Perry, R. L. and Young, J. H. 1997. *Principles of Process Engineering.* 4th Edition. ASAE Michigan USA pp 280-283.

Picket, L. K. and West, N. L. 1988. Agricultural machinery – functional elements – Threshing, Separating and Cleaning. In Brown, R.H.(Ed). *CRC* handbook of Engineering in Agriculture Vol 1. CRC press .Florida USA. Pp 65- 84.

Rohrbach, D. D. 2004. Improving the commercialization of sorghum and pearl millet in Africa. Http://www.afripo.org.uk/papers/paper22.rohrbach.pdf.30/12/14.

Rooney, L. W. 2003. *Overview: sorghum and millet food research failures and successes.* Food Science Faculty, Cereal Quality Laboratory, Soil and Crop Science Department. Texas A&M university USA. Http://www.afripo.org.uk/papers/paper09.rooney.pdf15/10/03.

RUSEP .2001. Needs assessment study for market –driven agricultural technology transfer and commercialization in Katsina State. USAID/IITA. 51pp.

Simonyan, K. J., Yiljep, Y.D. and Mudiare, O.J. 2006. Modeling the Cleaning Process of a Stationary Sorghum Thresher. Agricultural Engineering International: the CIGR Ejournal*:* PM 06 012 Vol VIII: 1-17.

Simonyan, K .J; El-Okene, A.M and Yiljep, Y.D. 2007. Some Physical Properties of Samaru Sorghum Grain. Agricultural Engineering International: the CIGR Ejournal. FP 07 008 Vol IX: 1-15.

Simonyan, K. J; El-Okene, A.M and Yiljep, Y.D. 2008. Effect of Moisture Contents on the Aerodynamic Properties of Samaru Sorghum 17. In Proceedings of the 8th International Conference of the Nigerian Institution of Agricultural Engineers. Federal University of Technology, Yola. 28th January-1st February, 2008. Pp181- 187.

Simonyan, K. J. 2009. Development of Motorized Sorghum Thresher. Agricultural Mechanization in Asia, Africa and Latin America. Summer.

Singh, B. and Kumar, A. 1976. Effect of cylinder type on threshing effectiveness and damage of heat. Journal of Agricultural Engineering Research 13 (3): 124-129.

Singhal, O. P. and Thierstein G. E. 1987. Development of an axial flow thresher with multicrop potential Agricultural Mechanization in Asia, Africa and Latin America 18(3): 57-65.

DEVELOPMENT OF A MANUALLY OPERATED FRUITS JUICE EXTRACTOR

R. S. Samaila, F. B. Olotu and S. I. Obiakor
National Centre for Agricultural Mechanization (NCAM)
PMB 1525 Ilorin, Kwara State, Nigeria

ABSTRACT

A manually operated fruit juice extractor was developed and tested. The extractor is a high precision machine which can extract juice from a wide range of fruits such as orange, tangelo, lemon lime, pineapple, tangerine and cashew. The machine has an input capacity of 29.73, 47.16 and 57.27kg/hr for orange, tomatoes and water melon, with extraction rate of 16.14, 34.08, 40.80lt/hr and extraction efficiency of 34.25, 56.69 and 99.93% respectively. The machine is recommended for the small scale fruit processors.

KEYWORDS: Fruit juice, extractor, orange, water melon, tomatoes

1. INTRODUCTION

Fruit are usually edible parts of plants. They are usually pulpy in nature and often juicy. The juice generally contains high percentage of water, fat and protein occurring in varying amounts (Ozemoyah, 1991). Both indigenous and adapted exotic fruits abound in Nigeria, these are spread over 31 million hectares of diverse cropping system spread over the five agroecological zones of Nigeria (Aiyelagbe, 1991). It is worthy of note that adequate fruit storage and processing technology can play an important role in contributing to self-sufficiency in food production. This is because adequate processing technology produces more fruit products that make fruits that have been harvested available to people over a longer period after the harvest season and also make it in the most acceptable nutrition, safe and wholesome condition. They are one of the important components of human diet because of the large contents of vitamins A., B and C as well as minerals like calcium and iron, which help meet daily nutrients requirements and good health. Availability of most fruits is seasonal and they are highly perishable in their fresh forms because of their high water content of 70-90% (Taylor, 1998). At the time of harvest fruits are still physiologically active with high rate of respiration and oxidation; thus they are prone to rapid post-harvest deterioration and losses of up to 30-69% (Taylor, 1998), under tropical condition of high temperature and relative humidity.

Fruits juice is used increasingly and extensively in the food and pharmaceutical industries. The residue left after mechanical or chemical extraction of the juice from fruits is a vitamin-rich cake which is used for the manufacture of animal feeds and in some cases texture as vitamin products for human consumption. The separation of the juice from the fruit mass is achieved by mechanical expression or solvent extraction or a combination of the two. Although considerable advance have been made in processing of exotic fruits, the indigenous ones remain under exploited due to non availability of extractors needed by local formers.

Traditionally, juice is extracted from fruits by squeezing with the hand. The process is tedious, time consuming, of limited capacity and unhygienic. Thus, there is a need to improve on the traditional method of fruit juice extraction to suit local condition.

The objectives of this work were to develop a small scale manually operated fruit juice extractor suitable for the local fruit processors, and evaluate the performance of the extractor on orange, tomatoes, water melon fruits.

2. MATERIALS AND METHODS

2.1 Design Consideration

In order to choose suitable materials for the construction of the extractor, the following factors were taken into consideration: hardness and rigidity, (that is, the ability of the machine component to resist deformation when subjected to applied force). The nature of the extractor was considered and 4mm thick stainless steel materials was selected with relevant joining to make the machine rigid. For durability and prevention of oxidation and corrosion, stainless steel sheet was used for the inner and outer cylinder because it does not react with juice from the fruit which contain ascorbic acid and sucrose while wood material was used as pressing plate and angle iron as supporting frame for rigidity.

2.2 Design Features

The fruit juice extractor was developed to be manually operated. It consists essentially of an outer stainless steel cylindrical vessel, perforated inner cylindrical vessel, a wooden plate wrapped with stainless steel sheet, screw rod and a supporting frame. Figs 1 and 2 show the isometric and exploded view of the juice extractor. The main specifications of the component of the extractor are as follows:

i. Outer Cylinder Vessel: It is 258mm deep, 270mm diameter cylindrical vessel of 4mm thick stainless steel sheet. It rests on a flat base with an exit tap welded to the bottom of the vessel through which the expressed juice flows out.

ii. Inner Cylinder: The inner cylinder is also made of stainless steel sheet perforated all over its surface. The perforations are 2mm diameter each and spaced 10mm apart. The depth of the cylinder is 224mm and the diameter is 230mm. It receives the fruits to be pressured and is enclosed in the outer cylindrical vessel.

iii. The Pressing Plate: This is a flat circular wooden disc 30mm thick and of 22mm diameter. It is wrapped with a stainless steel and bolted to a threaded rod, the rod is 900mm long, and has thread pitch of 7mm with a diameter of 27mm. The clearance between the inner cylinder and the press plate is 10mm to ensure a smooth movement of the pressing plate. On top of the threaded rod is an arm which is made from 13mm diameter steel pipe.

iv. The Supporting Frame: The supporting frame is made of 50mm angle iron bar of 690mm length. It serves as support to the cylinders as well as the entire structure.

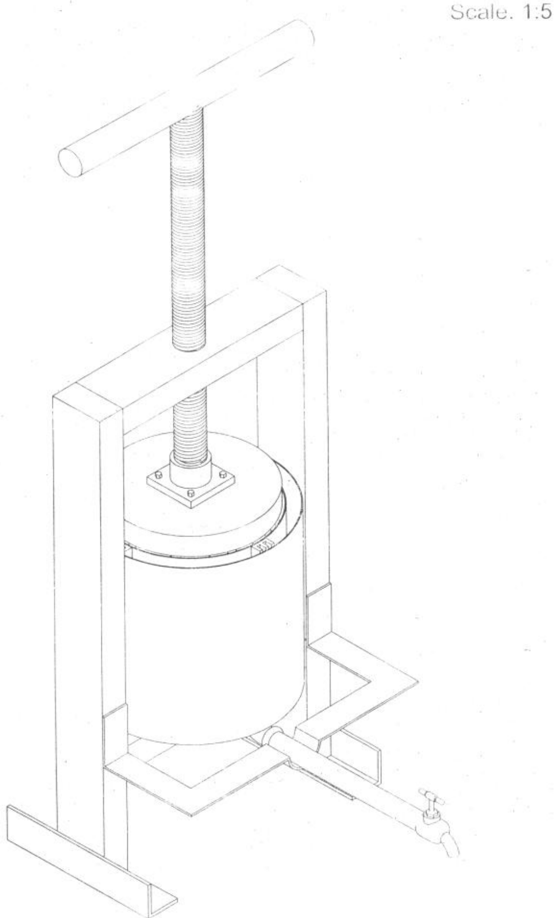

Fig. 1: Isometric view of the Fruit Juice Extractor

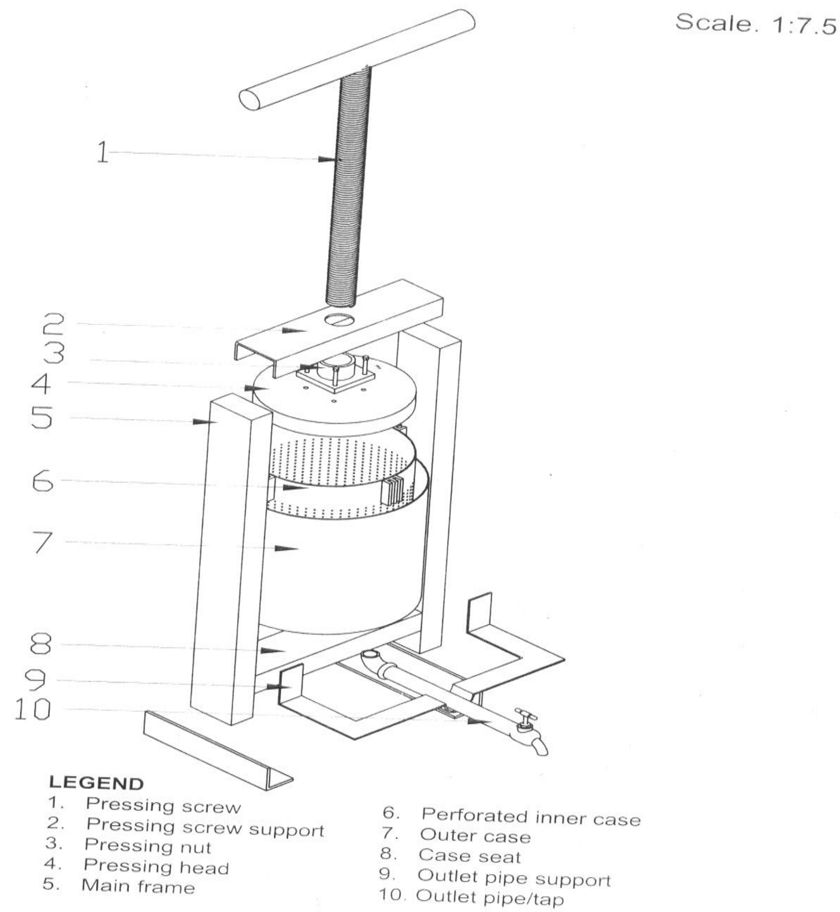

Fig. 2: Exploded View of the Juice Extractor

2.3 Operation of the Machine

The inner perforated cylinder is fed with a measured quantity of the peeled, sliced or mashed fruit (orange, pineapple, cashew, tangelo, grape, lemon or lime). The fruit can also be poured inside a clean muslin cloth before putting it inside the perforated cylinder. By turning the screw arm the juice is pressed out through perforations of the inner cylinder into the outer cylinder and then flows out through the tap on the outer cylinder into a collecting bucket or container. Enough Pressure should be applied to squeeze out as much as possible of the juice from the fruit. When the juice has been squeezed, the juice will stop flowing out with continued pressing and the residue becomes spongy. The residue could be utilized for other purpose, including animal feed.

2.4 Performance Test

The performance test of the extractor was carried out on three types of fruits namely Orange, Tomatoes and Water melon. Measured weight of each of the sample were tested, the time used for extraction and the volume of juice extracted were measured in order to determine the capacity, extraction rate, yield and extraction efficiency of the extractor. The initial moisture contents of the fruit were determined using oven dry method of moisture content determination. A known weight of the fruit samples was taken and weighed using electronic weighting balance. The samples were dried at an oven temperature of 105^0C for each of these fruits.

The following performance parameters were determined for the extractor.

a. Input Capacity (or work rate): This is the amount of fruit the extractor can handle per unit time and mathematically expressed as

$$\text{Input capacity (kg/h)} = \frac{\text{Weight of fruit fed into extractor}}{\text{Total time taken to extract juice from the fruit}} \quad \ldots\text{(i)}$$

b. Extraction Rate: It is the amount of juice extracted from the fruit per unit time and is express as

$$\text{Extraction Rate Re (Lt/h) or kg/h} = \frac{\text{Weight/ Volume of juice extracted}}{\text{Time of extraction juice}} \quad \ldots\text{(ii)}$$

c. Yield: This is the quantity of juice obtained per unit weight of the fruit and is expressed

$$\text{Yield Ye (\%)} = \frac{\text{Weight of juice obtained}}{\text{Original weight of fruit}} \times 100 \quad \ldots\text{(iii)}$$

d. Extraction efficiency Ee (%): Is the amount of juice extracted from the fruit as compared to the total juice content of the fruit.

$$\text{Extraction efficiency Ee (\%)} = \frac{\text{Weight/Volume of juice obtained}}{\text{Total Volume of juice in the fruit}} \times 100 \quad \ldots\text{(iv)}$$

3. RESULTS AND DISCUSSION

Tables 2 and 3 show the result of the performance test of the extractor on Orange Tomatoes and Water melon. It was observed that the machine performed satisfactorily on the three fruits. The value of input capacity (work rate) of the machine on water melon was highest followed by values on tomatoes and the orange. This could be due to the constituent fibre content of the fruits; input the capacities are 29.73, 47.16 and 57.27kg/h for orange, tomatoes and water melon respectively. The extraction rate of the machine on oranges is lowest compared with values for tomatoes and water melon. The values are 15.73, 34.08 and 40.80 lt/h respectively. The high fibre content in orange could be responsible for the low extraction rate of orange juice.

The juice yield of the extractor for tomatoes (32.77%) is lowest when compared with values for orange (48.49%) and water melon (54.33%), This could be due to the large quantities of juice in orange and water melon. The value of extraction efficiency of the extractor for the three fruits, are orange (35.25%), Tomatoes (56. 69%) and water melon (99.93%). This indicates that the fruit juice extractor has the highest extraction efficiency on water melon than on the other fruits.

Table 1. Juice content of the fruits used for the test

S/No.	Fruits	Percentage Juice Content
1	Orange	48:66
2	Tomatoes	32.93
3	Watermelon	55.37

Source: FAO Agricultural Sciences bullet 13 Fruit Juice Processing

Table 2: Performance indices of the manual fruit juice extractor

Fruit	Moisture content (%)	Replication	weight of peeled fruits W_1 (Kg)	No of arm turn	Quality of Juice extracted W_2(Kg)	Time of Extraction T (min)	Extraction Rate Re (kg/hr) (L/hr)		Input capacity Ci(kg/hr)		Yield ye	Extraction Efficiency Ee (%)
Orange	87.75	1	0.35	7	0.13	0.15	0.67	11.64	13.43	31.34	37.14	26.72
	85.93	2	0.32	8	0.16	0.18	0.75	12.80	14.40	25.50	50.00	32.88
	97.40	3	0.36	8	0.21	0.23	0.67	18.81	20.60	32.24	58.00	43.16
Mean	90.36		0.34	7.7	0.17	0.185	0.70	14.41	16.14	29.73	48.49	34.25
Tomatoes	90.30	1	0.50	8	0.13	0.08	0.92	8.45	5.22	32.61	26.00	39.48
	93.42	2	0.64	6	0.23	0.56	0.67	20.60	50.15	57.31	35.49	69.85
Mean	94.38	3	0.55	5	0.20	0.50	0.64	18.75	46.87	51.56	36.36	60.75
	92.70		0.56	6.3	0.19	0.38	0.75	15.93	34.08	47.16	32.77	56.69
Water Melon	93.12	1	1.00	16	0.58	0.51	1.08	32.22	28.33	55.56	58.00	104.75
	93.53	2	1.00	12	0.58	0.56	1.07	32.62	31.50	56.25	58.00	104.57
	93.10	3	1.00	11	0.50	0.68	1.00	30.00	48.80	60.00	47.00	90.30
Mean	93.25		1.00	13	0.54	0.52	1.05	31.01	40.80	57.27	54.33	99.93

Table 3: Summary of performance indices of the juice extractor

Performance parameter	Orange	Tomatoes	Water Melon
Moisture content of fruit M.C. (%)	90.36	92.70	93.25
Input capacity C_1 (kg/h)	29.73	47.16	57.27
Extraction Rate, Re (L/h)	16.14	34.08	40.80
Yield Ye (%)	48.49	32.77	54.33
Extraction Efficiency Ee (%)	34.25	56.69	99.93

4. CONCLUSIONS

An appropriate technology juice extractor was developed. Performance test on the extractor indicated that the machine performed satisfactorily on the three local fruit used for the test (Orange, Tomatoes and Water Melon) which yielded 8.49, 32.77 and 54.33% juice respectively while the extraction efficiency were 34.25 56.69 and 99.93% respectively. It is recommended that after peeling the orange, the thin coating covering the lobes should be removed before the juice extraction. This would enhance the extraction process and thus increase the juice to be extracted. The fruit juice extractor is recommended for small scale fruit processors.

REFERENCES

Aiyelagbe, I. O. O 1991. Training Manual Series No 7 on Fruit Juice Processing, National Horticultural Research Institute, Ibadan.

F.A.O: Agric Science Bullet 13 Fruit Juice Processing, food and Agricultural Science Industries Services, Agric Serves Division FAO via dalle terne coracalla Rome Italy.

Ozemoyah O. P. 1991. Design, Construction and Testing Performance of A Manually Operated Cage Press Nase/91/Pas/01

Taylor A. O. 1998. Training Manual for UNDP/UNIDO Training Programme for Women Entrepreneurs in Food Processing Industries.

EXTRACTION AND CHARACTERIZATION OF OIL FROM PRE-MATURE PALM KERNEL

C. I. O. Kamalu and P. Oghome
Department of Chemical Engineering
Federal University of Technology, P.M.B. 1526, Owerri, Nigeria.
Email: cliffkamalu@yahoo.com; ify_pros@yahoo.com

ABSTRACT

Palm kernel oil was extracted from crushed premature palm kernel using n-hexane as solvent. The experimental investigations reveal that the maximum yield of oil was obtained when the weight of the solvent used is equal to the weight of crushed premature palm kernel used. The particle size of 20 British standard sieve, that is 1.0795mm approximately is used and the temperature of the solvent is close to the boiling point, but solvent loss is so much that 50°C is recommended instead for laboratory and 60°C for industries. The characteristics of the oil were free fatty acid (0.78), iodine value (20.45), saponification value (179.35), acid value (1.54), smoke point (165^{oc}) relative density (0.9011), peroxide value (0) and refractive index (1.432).

KEYWORDS: Palm kernel oil, extraction, hexane, solvent, crushing, filtration, evaporation.

1. INTRODUCTION

Palm kernel oil is extracted from the kernel of the palm. It is a lauric oil, very similar in appearance and constitution to coconut oil, containing 83% of saturated fatty acids, mainly lauric. Palm kernel oil possess inhibitory effect on staphylococcus aureus and streptococcus sp. And it is the lauric acid which has the beneficial function of being formed into monolaurin in human or animal body. Lauric acid is the anti microbial agent in PKO (Enig, 1998). The oil can be used as an ointment for the body to minimize infections by micro-organisms and this may justify its usage amongst many people in some parts of Nigeria. It is also used as confectioner's hard fat in the production of chocolate-type coatings for baked products. It is also extensively used in margarine manufacture. The oil may be fractionated to produce a hard fat strearin, which is very useful as a cocoa butter substitute (Ranken, 1998). The purpose of extracting oil from pre-mature palm kernel is to investigate its properties and uses in comparison with that of palm kernel oil and other seed oil.

The oil from the seed can be leached with any suitable solvent for extraction. For more advantageous leaching of oil seeds, the seed must usually be specially prepared (Smith, 1998). These preparations involve dehauling, precooking, adjustment of moisture content and rolling of flaking. Other Post extraction operation may include filtration, distillation and desolventation.

2. EXPERIMENTAL METHODS

2.1 Collection and Preparation of Premature Palm Kernel

A bunch of premature palm fruit was collected and kept for two days to facilitate dehauling from the bunch. They were cracked and the nuts were collected and washed with warm water to eliminate sand and dust particles. The nuts were air-dried for one day to remove the surface moisture and also to reduce inherent moisture to 3% or less. These nuts were ground with a machine.

2.2 Determination of Percentage by Weight of Oil in Pre-mature Palm Kernel

A sample of 20g of crushed premature palm kernel, particle size 0.37 – 1.651mm, was weighed into a 250ml conical flask and properly shaken. Then equilibration occurred and the mixture was filtered into another pre-weighed 250ml conical flask using filter paper saturated with palm kernel oil. Solvent was again added to the raffinate and allowed to equilibrate. The mixture was again filtered. The process was continued until a time when the colour of the palm oil solvent mixture was exactly the colour of the pure solvent mixture, which indicated that all the oil must have been removed. The filtrate was distilled to remove the solvent and the oil recovered. The percentage of oil content was calculated by the ratio of weight of oil extracted to the initial weight of premature palm kernel (20g) multiplied by 100.

2.3 Effects of Quantity of Solvent Used on Equilibrium Yield

A sample of 40g of crushed premature palm kernel particle size 0.37mm- 1.651mm was weighed into eight pre-weighed conical flask. To each of the weighed flask, 20, 30, 40, 50, 60, 70, 80 and 90 (cm^3) of n-hexane was added. The flasks were covered with rubber corks to avoid the loss of solvent by evaporation. They were allowed to stand for two hours (allowing enough time for equilibrium to be attained amidst internal shakings.

After equilibrium, the content of each flask was filtered into different pre-weighed conical flasks using filter paper saturated with palm kernel oil. The filtrate from each flask was weighed evaporated and weighed again. Evaporation was continued until constant weight was obtained. The equilibrium yield was obtained by dividing the weight of oil extracted by the weight of solvent used in each case.

2.4 Effect of Particle Size on Rate of Solvent Extraction

Crushed premature palm kernel was characterized into different particle size. Twenty gram of each particle size was weighed into a pre- weighed conical flask; 20g ($31cm^3$) of n-hexane was added to each flask. Flasks were shaken continuously for 2 minutes and contents stirred immediately. The filtrate was weighed, evaporated and re-weighed.

2.5 Effect of Temperature on Rate of Extraction

A sample of 40g of crushed premature palm kernel of particle size 0.833-0.651mm were measure into 10 pre-weighed conical flasks. Each flask was held into a bath maintained at $60^oC^.$ Sufficient time was allowed for the temperature of flask and content to equilibrate with temperature of the bath. Some quantity of solvent n-hexane was placed inside a conical flask and heated until its temperature was $60^oC^.$ A sample of 62cm3 (40g) of n-hexane was measured out immediately and emptied into one of the flasks in the bath. The flask was shaken inside the bath and, the solution decanted after 10 seconds. The solution was evaporated and the oil recovered was weighed. This was repeated with other flasks in the bath for 20, 30, 40, 50, 60, 70, 80, 100, 130 and 150 seconds respectively. At room temperature the experiment was repeated for 1, 2, 4, 6, 7, 8, 9, 11 and 14 minutes respectively. At 150^oC, the experiment was repeated for 10, 20, 30, 40, 50, 60, 70, 80,100,130 and 150 seconds respectively.

3. RESULTS AND DISCUSSION

The results obtained are shown in Tables 1-6.

3.1 Quantity of Solvent Used on Equilibrium Yield

The effect of quantity of solvent on the yield was investigated and the result obtained showed that for a given weight of crushed premature palm kernel, the rate of oil extracted increased with increasing solvent; until an optimum point where a decrease was noticed. The optimum solvent requirement occurred at a point where weight of solvent was equal to weight of palm kernel used as shown in Table 1. This means that for most efficient solvent utilization, weight of solvent used must be equal to weight of kernel used for a batch extractor and the mass flow rate of solvent must equal mass flow rate of feed kernel, a continuous multistage extractor (Nickerson and Ronsivall, 1980; A.O.C.S). The palm kernel oil was characterized for saponification value, acid value, free fatty acid, smoke point, refractive index, specific gravity using standard methods.

Table 1: Quantity of solvent used on equilibrium yield

Flask no	Wt of kernel (g)	Wt of Flask Empty (g)	Volume of Solvent (cm3)	Wt of solvent (g)	Wt of Flask Evaporation (g)	Wt of Oil Extracted (g)	Wt of oil /Wt of Solvent used (g)
A	40.00	107.77	20.00	13.00	108.77	1.00	0.077
B	40.00	86.63	30.00	19.50	89.47	1.84	0.094
C	40.00	110.47	40.00	26.00	114.03	3.56	0.137
D	40.00	112.00	50.00	32.50	117.22	5.22	0.163
E	40.00	116.24	60.00	40.00	124.74	8.50	0.213
F	40.00	112.02	70.00	45.50	121.30	9.28	0.204
G	40.00	115.04	80.00	52.00	125.25	10.20	0.196
H	40.00	113.03	90.00	58.50	124.21	11.18	0.191

3.2 Effect of Particle Size

The effect of particle size on rate of solvent extraction and weight of oil is represented in Table 2. It was observed that optimum particle size exist for which maximum extraction occurs. Reduction in particle size decreases radial distance that must be traversed by solvent molecules and lead to higher oil output. As reduction in size continued, a point was reached when the cell membrane of the crushed palm kernel, which act as semi- permeable for diffusing solvent molecules, are destroyed. As a result of this, oil extraction was dominated by washing rather than leaching.

Table 2: Particle size on rate of solvent extraction

Flask no	Particle size Range (mm)	Average of Particle size	Wt of Feed	Wt of Filtration flask (g)	Wt of Flask + Filtrate	Wt of Flask + Oil	Wt of Oil (g)
A	1.651	1.651	20	62.45	74.05	65.37	1.60
B	0.833-1.651	1.0795	20	62.08	74.65	66.07	2.75
C	0.37-0.833	0.495	20	61.34	72.44	65.24	4.61
D	0.248-0.37	0.295	20	60.89	73.42	66.01	3.61

Table 3: Properties of premature palm kernel oil

Parameter / property	Value
Saponification value	179.35
Acid value	1.54
Iodine value	20.45
Specific gravity	0.9011
Smoke point	165^{o}C
Concentrating oil	0.0939g/mol
% oil	45.85%
Peroxide value	0

3.3 Saponification Value

Saponification value is related to the average molecular weight of the premature palm kernel oil sample. Saponification value obtained is 179.35 as shown in Table 3. This compares well with those obtained for soybeans, oil bean and melon (Holdman and Panlsingh, 1980). High saponification means that the oil sample is good for soap both for industry and domestic use. But the value obtained fell below (the range reported by Ranken, 1988).

3.4 Acid Value

Acid value is a measure of free fatty acid in the oil as a result of deterioration. Deterioration results in hydrolysis of triglycerides to yield free fatty acid, and the longer an oil is stored, the higher the fatty acid. This may be used as a measure of extent of deterioration. The acid value obtained is 1.54 and the FFA obtained was 0.78. This shows that on storage, the oil will deteriorate and the acid value will increase.

3.5 Specific Gravity

The relative density or specific gravity of oil sample at 25^{o}C is 0.9011. (Table 3). Since the specific gravity of each oil fat lies within a narrow range, if determined at a given temperature, therefore; the figure is a diagnostic value in the consideration of the quality of or purity of the materials. Precise determination of specific gravity is also used in assessing the weight of oil in bulk shipment (Treybal, 1981).

3.6 Refractive Index

Refractive index is related to degree of unsaturated free fatty acid, conjugated bonds. Therefore, in oils with high free fatty acids, the refractive index will be lower; except in oxidized oils where it will be higher the refractive index obtained is 1.432. This can be compared with those of coconut (1.454), cotton seed (1.475), soybean (1.475) and palm oil (1.4564) according to Vanoss, 1975. The difference in refractive indices of various oils is due to the fact that fatty acids have lower refractive indices than their corresponding triglycerides so that the presence of free fatty acids appreciably lowers the refractive indices of the oil samples during analysis. Lower refractive index is probably due to the biodegradation of triglyceride components into free fatty acids (Gooding, 1985). Its measure is significant in that it can be determined with ease and rapidity and also affords in many cases a simple and reliable method for rapid sorting of fats suspected of adulterations (Mweropedia, 1989).

3.7 Iodine Value

Since the iodine value of oil denotes practically the percentage of halogen by weight calculated as iodine absorbed under condition of test. It is a measure of unsaturation of oil. The value obtained for premature palm kernel oil is 20.45 as shown in Table 3. but from Perry et al, 1973, palm oil (53.20); soybeans (125-135); cotton seed (99-115), coconut (7-11) and palm kernel oil (19.12). As the iodine value of the extracted oil is 20.45, it is not liquid at room temperature and cannot be good for margarine.

3.8 Smoke Point

Various seed oils from different sources exhibit different smoke points. For example, the smoke point of oil from premature palm kernel under analysis is found to be 165^{o}C, which is quite different from that redish oil (240^{o}C) and of fluted pumpkin oil (159.30^{o}C) (Nickerson and Ronsivalli, 1980). Therefore, this is a physical characteristic for the identification of oils.

4. CONCLUSIONS

The extraction and characterization of premature palm kernel oil have been investigated. The effect of particle size on the yield of oil was considered. The properties of oil studied were comparable with other seed oils mentioned in the work. Oil from premature palm kernel can be used for soap making and other related purposes.

REFERENCES

A.O.C.S. 1977. Journal of American oil Chemists Society. Volume 54, number 6.pp 215 – 270. June.

Enig, M.G. 1998. Lauric oils as antimicrobial agents. In nutrients and foods in AIDS (Waston R.od) CRC Press London pp 81-87

Gooding, C.H. 1985. American Institute of Chemical Engineering, Journal. MC Graw-Hill Publication, January 7.

Heldman, D.R and Paulsingh R. 1981. Food Processing Engineering. 2nd Edition DVI Publishers p 341

Mweropaedia, 1989. Knowledge in Dept. Encyclopaedia Britannica. Volume 13, 15th Edition, p 256.

Nickerson, J. T. R and Ronsivalli l. J. 1980. Elementary Food Science. AVI Pub. Company, 2nd Edition.

Ranken, M.D. 1988. Food Industries manual, 2nd Edition Blankie and sons Ltd. Van Nostrand Reinhold Company, New York. Pp 199, 204.

Smith, L.W. 1998. “Edible oils and Fats”. Materials and Technology, volume 8. p 6

Traybal, R.E. 1981. Mass –Transfer Operation. 3Rd Edition. MC Graw-Hill, boston. Pp 243, 726, 736.

Vanoss, J. F. 1975. Materials and Technology. Longman. J.H. De Bussy, vol 18, p 36.

INVESTIGATION OF SOIL PHYSICAL PROPERTY AND OKRA EMERGENCE RATE POTENTIAL IN SANDY LOAM SOIL FOR THREE TILLAGE PRACTICES

S. O. Nkakini[1], A. J. Akor[1], I. J. Fila[1] and J. Chukwumati[2]
[1.] Department of Agricultural and Environmental Engineering,
Rivers State University of Science and Technology, Port Harcourt, Nigeria
nkakini@yahoo.com
[2.] Department of Crop Science, Rivers State University of Science and Technology,
Port Harcourt, Nigeria

ABSTRACT

Three common tillage practices: conventional (ploughed + harrowed), conservative (ploughed), and no-tillage for Okra crop production *(Abelmosehus Esculentus)* were conducted for a period of one growing season in 2006, on a sandy loam soil. Three depths of cultivation, 0-5, 5-10 and 10-15cm were used in the experiment. All soil physical measurements were taken immediately after the tillage operations to determine the effect of these tillage practices on the soil properties and okra emergence rate. The three tillage operations at the three different depths, indicate bulk density values of 1.43g/cm^3,1.24g/cm^3 and 1.18g/cm^3 respectively, moisture contents of 12.22%$_w/_w$, 13.32%$_w/_w$ and 11.68%$_w/_{w,}$ porosity level of 57.33%$_v/_v$, 62.83%$_v/_v$ and 65.66%$_v/_v$ in no-tillage being the lowest were obtained. The data obtained were analyzed statistically using Analysis of variance (ANOVA) and percentage analysis. There was no significant difference between soil bulk density and porosity, but significant difference between soil moisture content was found. Emergence rate of okra was favoured by conventional tillage by showing highest mean emergence rate of 69.2%, percentage seed and seedling mortality of 100% and mean period of ultimate emergence of 0.88 when compared with other tillage treatment considered. The result showed that no-tillage treatment recorded the lowest emergence parameters.

KEYWORDS: Okra, emergence, tillage systems, soil properties, climate

1. INTRODUCTION

Tillage practices play very vital roles in adjustment of soil moisture content to meet the needs of crops production as they create optimum soil environmental condition for the seed germination, emergence of seedling plant, growth and high crop yields (Yusuf and Asota 1997, Adamu and Ezeaku, 2002, Nkakini, 2004, Attanda et al., 2006).

Soil tillage is (Kepner et al., 1978; Aluko and Lasisi, 2009) the mechanical manipulation of soil to develop a desirable soil structure for a seedbed and a specific surface configuration for planting, irrigation, drainage, harvesting operation etc. According to Lal, (1979) tillage is the physical, chemical or biological soil manipulation to optimize conditions for seed germination, emergence and seeding establishment. The Soil Science Society of America (SSSA) (1987) defined tillage as the physical modification of the soil properties for the express purpose of crop production. Conventional tillage is the involvement of a primary tillage operation followed by a secondary tillage operation to prepare a smooth, thrash free seedbed (Onwualu et al., 2006, Nkakini, 2006). Conservative tillage (plouhging) is the initial major soil working operation employed to reduce soil strength, cover organic residue and pulverize the soil (Onwualu et al., 2006, Nkakini 2006). Zero or No – tillage is the ultimate in minimum tillage, which involves planting into an essentially unprepared seedbed (Onwualu et al., 2006, Nkakini, 2006)

Tillage practices influence nutrient uptake, soil aerations, infiltration, erosion, root system proliferation, leaf growth and yield by changing soil structure and moisture removal patterns over the growing season. These factors, in turn, contribute to the quality and quantity of the crop emergence and germination.Emergence is an outgrowth as a pickle or hair growing from the tissue under the epidermis of a plant. (Weabsters Dictionary 2004). Emergence rate index is an indicator of the type of seedling environment created by the tillage treatment (Yusuf, 2001, Hakimi and Kachru 1976). Germination is the growth of an embryonic plant contained within a seed, which results in the formation of the seeding (Wikipedia, 2004).

The physical properties of soil are influenced by tillage operation (Hakimi and Kachru 1976). The effect of different tillage practices on soil properties and crop emergence is still problem under consideration, investigation so far made showed that results vary with soil type and their properties, crop types, climate, management practices, etc. (Anozodo, 1983). Therefore, more information on the mechanisms, processes and practical management technique that could enable farmers avoid severe deterioration of the physical status of soil and enhances seedling emergence need to be provided. Tillage, though could pose some problems to organic matter and soil compaction. Tillage is an unavoidable practice.

Okra differs from other crops in terms of crop maturity and ability to attain full vegetative cover within a short period of time. It also has different rooting systems and root concentrations, 50mm below the surface. It's response to nutrient recycling and decomposition dynamics could possibly point to okra emergence as having potential for effective maintenance of a sustainable soil profile when properly incorporated into the soil during tillage operations.

This research examines the optimum tillage operation system, that may lead to high profit margin for Okra. The specific soil type, and seedbed preparation for okra cultivation becomes clear through this research work. The specific objectives of this research are to investigate the effects of tillage depth on some soil physical properties, okra emergence rate potential for three common tillage systems and to determine the most suitable tillage type of seedbed preparation for its production.

2. MATERIALS AND METHODS

2.1 Experimental Site

The experiment was conducted at the School Farm of the Rivers State University of Science and Technology, Nkpolu, Port Harcourt, Rivers State of Nigeria, latitude 0.5^0 0.1.N, longitude 0.6^0 57E, altitude of 274mm with an average annual rainfall of about 557.3mm in September (Port Harcourt Met. 111/2) 2006 and the field experiment was a period of one growing season. The location has well drained soil classified as sandy loam using the textual triangle (Santosh, 1987) with composition of 76% sand, 7.28% silt and 15.95% clay. The experimental field has been left fallow for about two years under rain fed condition in a sandy loam soil before the research was conducted. The total annual rainfall of the study area is about 2543.2 from (Jan. – Oct. 2006). Table 2 shows the total monthly rainfall amount from meteorological center (2003 – 2006 Oct.)

2.2 Experimental Design and Treatments

The land area mapped out is 32m x 52m. The land was cleared manually, followed by stumping. Test plots of 4 x 4 m^2 with a head-land of 10 m apart from the plots serving as the turning and hitching point for implements were selected. The depth of cultivation 15 cm was used as initial preparation of the plots. Three tillage treatments were used and laid out in a randomized complete block design (RCBD) with three replications.

The tillage treatments were: ploughing (P_1), ploughing plus harrowing (P_2) and no-tillage (P_3). The specifications of the implements used in tillage operations are shown in Table 1.

Table 1. Specification of implements used for various tillage treatments

Power and implement	Type and comments
Disc Plough	3, furrow mounted plough
Disc Harrow	Offset trailing type disc harrow with 28 discs and a depth wheel. Width of work: 3109mm. Diameter of discs 600mm.
Tractor	Source of power used for all implements was a STEYR SSF RSUS – 5312, 6 cylinder, 86hp diesel tractor.

2.3 Field Operations

The disc plough was used for ploughing operation while subsequent pulverization of the soil was accomplished with the aid of the normal traditional hoe and matchet common among local farmers. Disc harrow and disc plough were used for ploughing, combined with harrowing. The device was adopted to enhance and provide a more effective improvement of soil tilth resulting in adequate and sufficient seed-soil contact.

Matchet and hoe were used for no-tillage operation, to smoothen the soil, creating minimum soil tilths, by opening a narrow hole to obtain seed coverage.

Tractor was used as power source for pulling farm implements. The tractor type is of model STEYR SSF RUSU – 5312, (weight 2350 kg), cylinder, 86 hp diesel.

2.4 Measurement of Soil Physical Properties

Three (3) core samples were taken at three randomly selected locations from each plot at depths of 0-5, 5-10 and 10-15 cm for bulk density, soil moisture content and porosity. The soil parameters measured were bulk density, soil moisture content and porosity.

All the measurements on the soil physical properties were done immediately after tillage operation to determine the effect of these three common tillage practices on the soil properties and okra emergence rate.

2.5 Cultural Practices

The cropping season, and total rainfall during the year 2006 are listed in Table 2.

Table 2. Total rainfall (mm), during the year 2006

Cropping season	Months of rainfall (mm)									
2006	Jan	Feb	Mar	April	May	June	July	Aug	Sept	Oct
	39.6	103.7	95.6	59.8	397.4	344.7	392.6	267.8	557.3	284.7

Two weeks after the soil preparations and treatment, okra seeds (V-35 variety) were planted. The crops were manually planted. They were planted 60 cm between rows and 20 cm at seed rate of four (4) seeds per stand in for four (4) rows at each treatment plots (Clemson, 2006). The planting was done on the 6th of October, 2006 when rainfall had reduced, in comparison with the previous months. Weeding was not performed because there were no weeds till the end of seedling emergence.

2.6 Germination and Seedling Emergence

Germination and seedling emergences were monitored after planting and records were maintained on seedling emergence starting from the day of initial emergence and continued until the emergence was fully completed in all the treatments plots. From the emergence counts, the following emergence parameters were determined using the formula (Joshi 1897).

i. Mean period of ultimate emergence (MPUE)

$$\bar{X} = \sum_{i=1}^{n} \frac{NiDi}{U.E} \quad (1)$$

ii Rate of emergence (RE)

$$RE = \sum_{i=1}^{n} \frac{N}{Di} \quad (2)$$

iii Percentage Seed and Seedling Mortality;

$$SSM = \frac{U.E}{T.G}(100\%) \quad (3)$$

Where: N = Daily increase in seedling number
D = Number of days from sowing
U.E = Ultimate emergence (the maximum number of seedling that emerged during the experiment).
T.G = Total Germination

2.7 Data Analysis

The average of all measured parameters for this one planting season were analyzed using analysis of variance (ANOVA) and simple mean statistical methods.

3. RESULTS AND DISCUSSION

3.1 Soil Physical Properties

3.1.1 *Bulk Density*

The effect of tillage on bulk density from various tillage treatments over all depths are presented in Table 3. It can be observed that the "No-tillage" operation produced the highest value of bulk density of 1.43g/cm^3, closely followed by 1.24g/cm^3 in ploughed operation and 1.18g/cm^3 being the lowest in ploughed plus harrowed operations at the depths of 0-5, 5-10 and 10-15cm respectively. The influence of the depths of cultivation on the physical soil properties is summarized in block total treatments being 3.505g/cm^3, 3.780g/cm^3 and 4.29g/cm^3 value of bulk densities respectively.

In general, soil bulk density increased with tillage depths under all tillage treatments. This agreed with earlier findings of Agboola, (1981) that the more intensity the tillage, the higher the bulk density of the surface and sub-surface soil. The higher bulk density value observed in no-tillage operation could be attributed to the fact that the soil in no-tillage plot was not disturbed in any case. This corresponded to the findings of Nwagu and Oluka (2006), Aluko and Lasisi (2009). Bulk density decreased with increasing degree of tillage.

Table 3. Effects of tillage treatments on soil physical properties of different tillage levels October 2006

Soil Physical Properties	Depth of soil Samplings (cm)	Treatments T1 No – till	T2 Plow plot	T3 Plow & Harrow	Block Total
Bulk Density	0-5cm	1.29	1.11	1.11	3.51
(g / cm3)	5.10cm	1.31	1.30	1.18	3.78
	10-15cm	1.71	1.32	1.26	4.29
Mean		1.43	1.24	1.18	3.85
Moisture Content	0-5cm	10.95	12.45	10.15	33.55
(% $^{w}/_{w}$)	5-10cm	11.56	13.45	11.51	36.52
	10-15cm	14.15	14.05	13.38	41.58
Mean		12.22	13.32	11.68	37.21
Soil Porosity (% $^{v}/_{v}$)					
	0-5cm	59.0	65.5	68.0	192.5
	5-10cm	44.5	61.5	65.5	171.5
	10-15cm	68.5	61.5	63.5	193.5
Mean		57.3	62.8	65.7	185.8

Analysis of variance were used to determine the significant difference among independent variables. The results of the analysis of variance using completely randomized block design indicates that there was no significant difference effect of treatments and depth at ($P \leq 0.05$) of bulk densities at different tillage levels.

Table 4. ANOVA effect of tillage treatment on soil bulk density at different tillage levels.

Sources of Variance (S. V)	**d_f n – 1**	**SS**	**Ms (ss/d_f)**	**F_{cal}**	**Table $_F$** Ftab (0.05)
Total variation (n-1) 9	8	0.254	0.032	2.67	
Total treatment 3	2	0.102	0.051	4.25	6.94 NS
Depth 3	2	0.106	0.052	4.42	6.94 NS
Error (total variance) - (treatment + depth)	4	0.064	0.012	1.00	

NS: Not significant ($P < 0.05$)

The variation of the bulk densities among the tillage treatments operations is shown in Figure 1 for three different tillage operations; no-tillage, ploughed and ploughed plus harrowed. This figure shows the overall mean bulk density for all the types of tillage treatments. Furthermore, the overall depths of tillage operations showed the highest for no-tillage, but little variation among bulk density for other tillage operations. The mean bulk density is lower in ploughed plus harrowed tillage operation. This indicates that the bulk density of the soil was influenced by the tillage treatments.

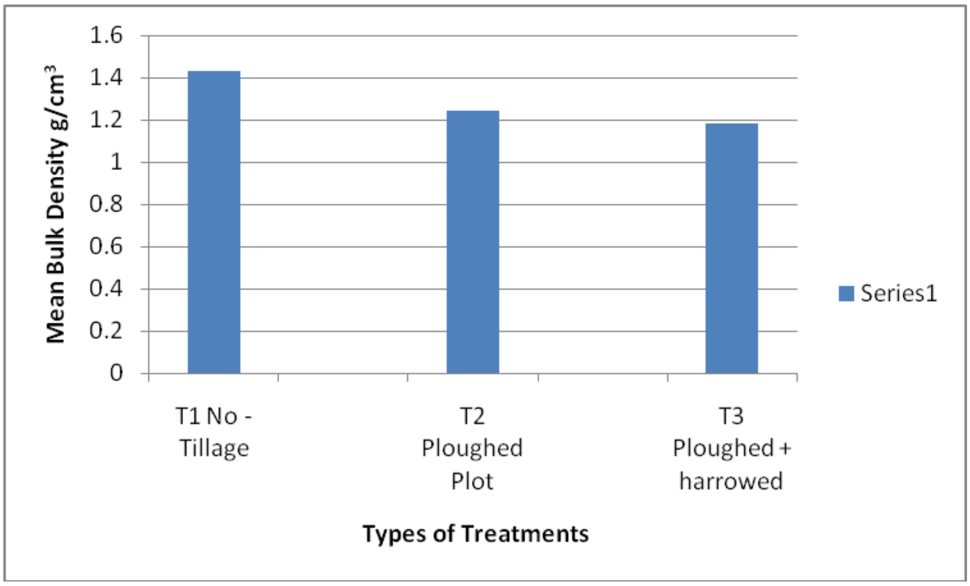

Figure 1:Effect of different tillage treatments on bulk density.

3.1.2 Soil Moisture Content

Soil moisture content (%, $_w/_w$) is presented in Table 3. In all the measurements, moisture contents for no-tillage, ploughed, and ploughed plus harrow tillage operations were higher at the tillage depth of 10-15cm than those at 0-5 and 5-10cm tillage depths. The ploughed plot recorded a relatively high level of moisture content of 13.32% ($_w/_w$) at a depth of 10-15cm. This is closely followed by the no-tillage plot which recorded a moisture content of 12.22% ($_w/_w$) and relatively low level of moisture content of 11.68% ($_w/_w$) at the same depth was recorded in ploughed plus harrowed plot. And in block total treatments, 33.55, 36.52 and 41.58% ($_w/_w$) are recorded at depths of 0-5, 5-10 and 10-15cm respectively.

The analysis of variance results showed that there was no significant difference at ($P \leq 0.05$) in moisture content among the tillage treatments. This might be due to evaporation control caused by tillage at different depths. This corresponds to the findings of Chaplin et al., (1986) who reported no significant difference effect on soil moisture content of tillage system (mould board plow, chisel plow, ridge plant and no-till) on irrigated corn yields. But there is significant difference at ($P \geq 0.05$) in moisture content among the depths in the plots.

Table 5. ANOVA effect of tillage treatments on soil moisture content (% w / w) at different tillage depths

Sources of Variance (S. V)	**d_f n – 1**	**SS**	**Ms ($^{ss}/d_f$)**	**F_{CalF}**	**Table $_F$** Ftab (0.05)
Total variation (n-1) 9	8	16.53	2.070	3.91	
Total treatment 3	2	4.423	2.223	4.19	6.94 NS
Depth 3	2	10.99	5.495	10.37	6.94 SS
Error (total variance) - (treatment + depth)	4	2.117	0.530	1.00	

NS: Not significant ($P < 0.05$)
SS: Significant ($P > 0.05$)

The mean values of the moisture content for the three tillage treatments are shown in Figure 2. Higher soil moisture content was observed in ploughed plot than in the no-tillage and ploughed plus harrowed plots. This could be attributed to better infiltration rates, increased water holding capacity resulting from the larger pore spaces etc in the ploughed plots.

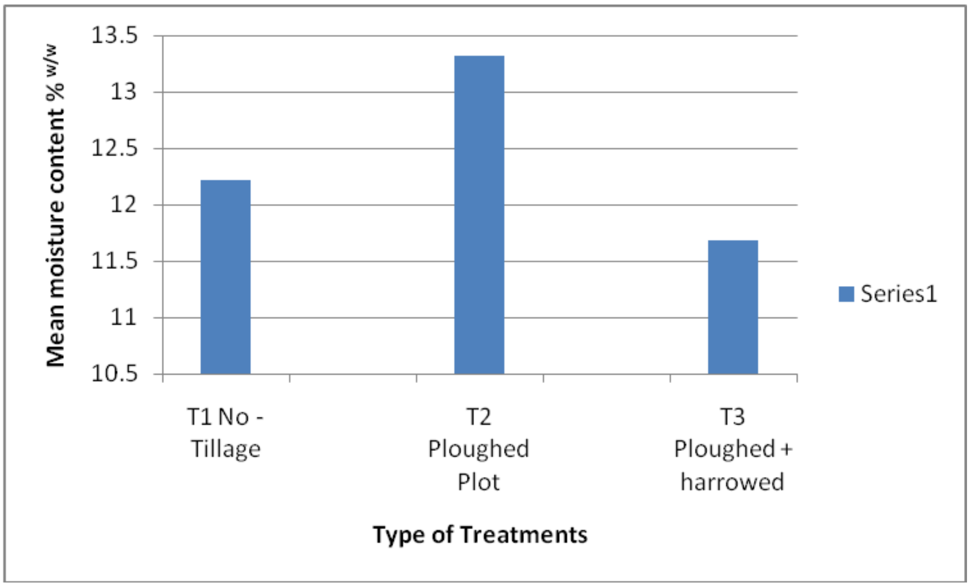

Figure 2. Effect of tillage treatment on soil moisture content

3.1.3 Porosity

The soil porosity values before planting during the one season planting are shown in Table 3. The porosity value of 57.33%($_v/_v$) was lowest with no-tillage and 65.66%($_v/_v$) highest with ploughed plus harrowed tillage before planting at the tillage depths of 0-5, 5-10 and 10-15cm. This may be due to looseness of the soil at the depth of 10-15cm. A result of highest value of 193.5%($_v/_v$) porosity was obtained at the depth of 10-15cm in block total treatment.

The result from analysis of variance, indicated that there was no significant difference at ($P \leq 0.05$) between the porosity values at tillage treatments and depths of the plots.

Table 6. ANOVA effect of tillage treatments on soil porosity % (v / v) at different tillage depths

Sources of Variance (S. V)	**d_f n – 1**	**SS**	**Ms ($^{ss}/d_f$)**	**F_{CalF}**	**Table $_F$** Ftab (0.05)
Total variation (n-1) 9	8	510.72	63.84	0.851	
Total treatment 3	2	107.72	53.86	0.718	6.94 NS
Depth 3	2	162.89	51.45	0.686	6.94 NS
Error (total variance) - (treatment + depth)	4	300.11	75.03	1.00	

NS: Not significant ($P< 0.05$)

The mean porosity values for comparison of tillage effect at various tillage depths is depicted in Figure 3. Ploughed plus harrowed tillage had the highest mean value of porosity, followed by ploughed tillage alone and the least was no tillage.

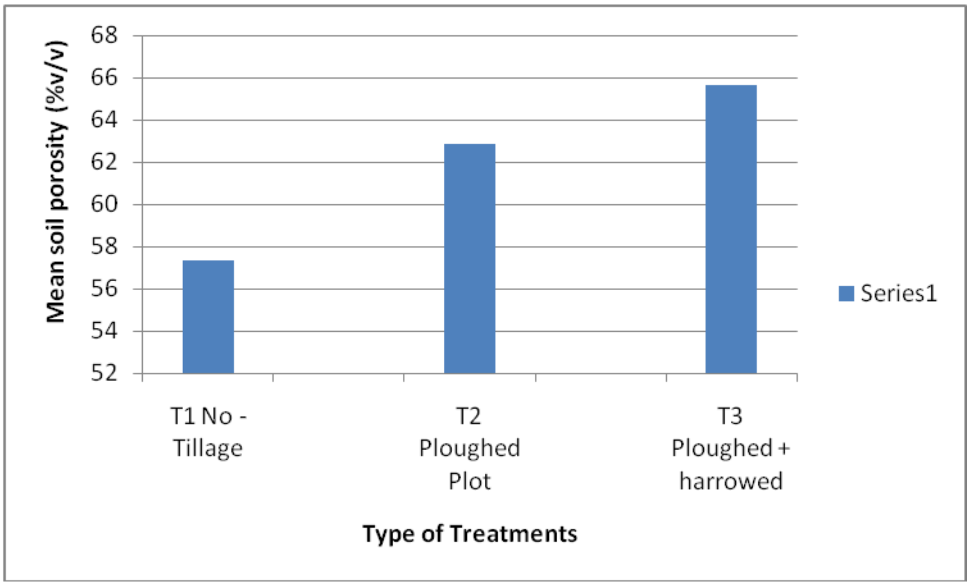

Figure 3. Effect of tillage treatment on porosity.

3.1.4 Crop Emergence

From Table 4, the average emergence rate in various tillage operations, percentage seed and seedling mortality, mean period of ultimate emergence and rate of emergence (RE) are depicted. The highest mean emergence rate of 69.2 was found in ploughing and harrowed tillage operation, like wise the percentage seed and seedling mortality of 100%. No-tillage operation was found to be lowest in seed and seedling mortality of 90.28%. No – tillage compared to other types of tillage had the potential of reducing the free flow of air and water into and within the soil profile (Nwagu and Oluka 2006). This affected the crop emergence rate. Ploughed tillage operation recorded 97.2% of seed and seedling mortality. The results obtained are all within 5 days after planting. The highest seed and seedling mortality on the ploughing plus harrowing tillage was attributed to the effect of soil pulverization, which offered little or no structural impendence to seedling emergence.

The mean period of ultimate emergence of 2.77 is highest in no-tillage, 1.23 and 0.88 in ploughed and ploughed plus harrowed respectively. Similarly, the rate of emergence of 1.1, 0.78 and 2.22 are for ploughed, ploughed plus harrowed and no-tillage plots respectively. Crop emergence samples were taken on each of the plots. Emergence samples were taken by counting the number of plants in the areas of the plots after seedling. Total number of okra seeds planted per treatments plot are 72 stands.

Table 4. Average emergence rate in various tillage treatments.

Tillage Operations	Number of seeds & days of emergence					Mean of emergence	Percentage % seed & seedling mortality	MPUE	RE Rate of emergence
	1st day	2nd day	3rd day	4th day	5th day				
Ploughing (P_1)	60	62	65	68	70	65	97.2	1.23	1.1
Ploughing + harrowing (P_2)	65	68	70	71	72	69.2	100	0.88	0.78
No-tillage (P_3)	45	55	56	60	65	56.2	90.28	2.77	2.22

Table 7, shows the results of ANOVA of the effect of three common tillage operations. ANOVA results indicated statistical significance differences among the treatments and blocks factors related to crop emergences.

The significance differences were probably because of difference levels of pulverizations in the three common tillage practices. Also due to large amount of precipitation which brought all soil moisture contents to the same values since the experimental field was rain fed. Figure 4 illustrates the average crop emergence for the plots.

Table 7. ANOVA effect of various tillage treatments on crop emergence

Sources of Variance (S. V)	**d_f n – 1**	**SS**	**Ms ($^{ss}/d_f$)**	**F_{CalF}**	**Table $_F$** Ftab (0.05)
Total variation (n-1) 15	14	757.73	54.12	8.24	
Total treatments 5	(t-1) 4	265.06	66.26	10.08	3.84 SS
Blocks 3	(m-1) 2	440.13	220.06	33.51	4.46 SS
Error (total variance) - (treatment + blocks)	8	52.54	6.567		

SS: Significant difference at ($p \geq 0.05$)

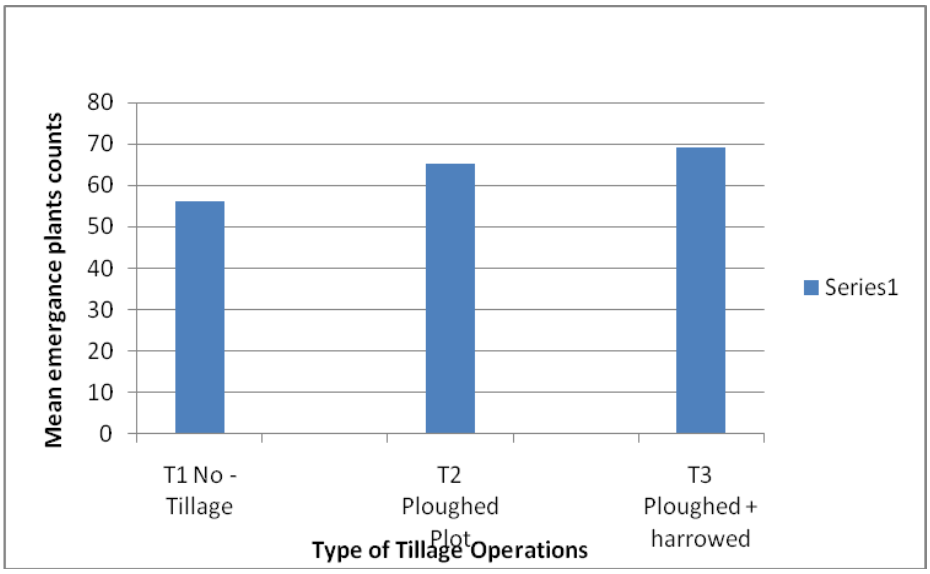

Figure 4: Effect of tillage treatments on crops emergence.

4. CONCUSIONS

The research study evaluated the effect of no-tillage, conservation tillage (ploughing) and conventional tillage (ploughing and harrowing) on soil physical properties and emergence rate of okra. On the basis of significant results obtained from this investigation, the following conclusions can be drawn:

i. The tillage treatments showed no significant effect on soil bulk density and porosity, but significant difference on soil moisture content.

ii. Increasing the depth of cultivations increased the values of soil bulk density, soil moisture content and porosity for all tillage treatments used.

iii. Conventional tillage shows superiority in provision of enabling environment for seedling emergence over other tillage types investigated.
iv. The poor seedling emergence observed with Okra plants on plots treated with zero tillage would likely result to low crop yields.
v. Combination of ploughing and harrowing produced the highest seedling emergence and would lead to subsequence highest yield.

It is concluded that emergence rate of okra was favoured by conventional tillage for profitable okra production over any other tillage treatments tested in this study (one year period).

REFERENCES

Agboola A. A. 1981. The effects of different soil tillage and management practices on the physical and chemical properties of soil and maize yield in a reinforces zone of Western Nigeria. Agron. J. 73:247-251.

Attanda M. L, Yusuf D. D. and Ndirika V.L.O. 2006. The effect of soil compaction in different tillage practices on seed emergence and Maize Yield in Samaru Nigeria. Proceedings of the 7th International Conference and 28th Annual General Meeting of The Nigerian Institution of Agricultural Engineers. Zaria 2006.

Aluko O. B. and Lassis D. 2009. Effect of tillage methods on some properties of a tropical sandly loam soil under soybean cultivation. Proceedings of 3rd International conference of WASAE and 9th International conference of NIAE, January 25 – 29, 2009, Ile – Ife Nigeria.

Adamu S. and Ezeaku C. A. 2002. Effect of tillage on the growth and yield of cowpea (Vigins unguiculate (L) Walp) at Bauchi in the northern guinea savannah zone of Nigeria. Journal of Applied Science. Vol. 5. Number 2. p 2276 – 2785.

ASAE, 1984. American society of Agricultural Engineering standard S. 361.1

Chaplin J. M. Lueders and Rugg D. (1986) A study of compaction and crop yields in loamy sand soil after seven years of reduced tillage. Transaction of ASAE (29) 2:389 – 392.

Clemeson 2006. Home & Garden Information Centre. Available online http://hgic,clemson.edu

Hakimi A. H. and Kachru R. P. 1976. Response of Barley Crop to Different Tillage Treatments on Calcareous Soil. J. agric Engng. Res (1976) 21, 299 – 403.

Joshi N. L. 1987. Seedling emergence and yield of Pear Millet on natural crushed arid soil in relation to sowing and cultural methods. Soil Tillage Research, 10(2): 103 – 112.

Michael A. M. and Ojiha T. P. 2003. Principal of Agricultural Engineering Vol. 1 New Delhi, Jain Brothers Publishing Co; 1988, P 299.

Meteorological 111/2 Services 2006. Department of meteorological services. Register of rainfall from 2003 – 2006 Oct., Port Harcourt Rivers State.

Nkakini, S. O. 2004. Unpublished lecture note on farm mechanization AEN 413, Rivers State University of Science and Technology, Port Harcourt.

Nwagu A. N. and Oluka S. I. 2006. Optimum tillage system for okro production in all ultiosl of south Eastern Nigeria. Journal of Agricultural Engineering and Technology (JAET) Volume 14, 79 –85.

Onwualu A, P., Akubuo C. O. and Ahaneku I. E. 2006. Fundamentals of Engineering for Agriculture .Immaculate Publication Limited 2 Aku Street, Ogui New Layout Enugu Nigeria.

Santosh K. G. 1987. *Soil Mechanics* 1st Ed. Khanna Publisher 2.B Nath Market, Nai, Sarak. Delhi – 11000 6 (Inida).

Webster's comprehensive dictionary 2004. The new international webster's comprehensive Dictionary of the English Language. Trident Press international 2004 Edition.

Wikipedia, 2006. The free encyclopedia Dictionary English Language. Trident Press International Edition.

Yusuf D. D. and Asota C. I. 1997. Effect of machinery traffic, tillage treatment and moisture content on maize and emergence of seedling on sandy, loamy and clay soils of Nigeria. Journal of Engineering Research Vol. 5:74.

Yusuf D. D. 2001. Mathematical modeling of machine – soil interaction effect on maize. PhD Thesis submitted to Agricultural Engineering Department. Ahmadu Bello University, Zaria.

EVALUATION OF TWO INFILTRATION MODELS' PARAMETERS ON AN IRRIGATION EXPERIMENTAL PLOT

M. A. Oyebode and A. S. Yahaya
Department of Agricultural Engineering
Faculty of Engineering, Ahmadu Bello University, Zaria, Nigeria
E-mail: muyideenoyebode2004@yahoo.com

ABSTRACT

Two time-dependent infiltration models -Kostiakov, 1932 and Philip, 1957- were studied to evaluate the model parameters and to test their applicability and accuracy on the soils of the proposed irrigation experimental plot located behind the Department of Agricultural Engineering, Ahmadu Bello University, Zaria. The top soils varied from sandy loam to loam. The infiltration rates of the soils were measured using double ring infiltrometers. Kostiakov's model accurately approximated the field infiltration rates of soils tested. Philip's model accurately characterised the field tests but tended to over-estimate the infiltration rates for longer time periods. Student t-test showed that there were no significant differences between the models and the field infiltration rates at 5% confidence interval. Kostiakov's model, however, exhibited better adaptability on the soils tested and is therefore recommended for use on the experimental plot.

KEYWORDS: Infiltration models, double ring infiltrometers, soil texture, initial moisture content, bulk density, soil intake rate.

1. INTRODUCTION

Adequate water resource management is essential for stable and efficient agriculture. Hence, efforts are being directed towards water management and conservation activities such as irrigation and control of flood and erosion. Realistic planning of these water management activities requires sufficient information on the rate at which different soils take up water under different conditions. Data on rates of infiltration of water into soils can be used to supplement other soil information which could assist soil scientists, engineers, hydrologists and others to deal more effectively with a wide spectrum of water resource management and conservation problems.

Basically, infiltration is the entry of water into the soil through its surface. Michael (1978) defined infiltration as the soil characteristics determining the maximum rate at which water can enter the soil under specific conditions, including the presence of excess water. This means that the intake rate is limited by soil factors only. The factors affecting infiltration have been reported by Lewis and Power (1938).

Infiltration characteristics of a given soil are part of the dominant variables influencing irrigation. The total irrigation time or intake opportunity time will have to be estimated from the soil intake rate. In addition, the amount of water applied in a border or furrow irrigation upon which advance and recession expression have been determined will have to be estimated from infiltration expression using the contact time. In sprinkler irrigation, the application rate must not exceed the soil intake rate and similarly stream sizes for border and furrow systems are governed by the soil infiltration rate. Therefore, the role played by infiltration in irrigation and the hydrologic cycle in general is an exceedingly important one.

Researchers have condensed soil infiltration characteristics into a number of simple mathematical models, for example the equations of Green and Ampt (1911), Kostiakov (1932), Horton (1940), Philip (1957), Holtan (1961), Talsma and Parlange (1972) and Collis-George (1977). However, as a result of lack of adequate understanding of the equation parameters for different soils and conditions make the use of the equations difficult. This paper presents the findings of an evaluation study on two simple time-dependent infiltration equations for their applicability and accuracy on the predominant soils of an irrigation experimental plot located behind the Department of Agricultural Engineering, Ahmadu Bello University, Zaria, Nigeria.

One of the earliest infiltration models is perhaps the Kostiakov's (1932) equation derived empirically through regression of field infiltration data, represented by Eq. (1), as:

$$f = at^b \quad \text{.......... (1)}$$

in which f *is* infiltration rate at time, t, (mm/hr); t is time since infiltration started, (hrs); a and b are soil parameters depending on antecedent water content and structural stability

Field infiltration data are used to fit the infiltration equation given in Eq. 1 and the least square estimates of the equation parameters evaluated using method of least squares. Equation (1) is made linear by logarithmic transformation and 'a' and 'b' are evaluated for residual sum of squares, S(a,b) as follows:

$$S(a,b) = \sum_{i=1}^{n}(Inf_i - In\,a - b\,Int_i)^2 \quad \text{.......... (1.1)}$$

The Philip's two-term equation is given by

$$F = St^{1/2} + ct \quad \text{.......... (2)}$$

in which cumulative infiltration F, is related to time, t, by two parameters, the sorptivity S, and the coefficient c. Sorptivity is the single most important quantity governing the early portion of infiltration (Philip, 1957); it varies for different soils as it depends on the structure and the pore-size distribution of the soil, and is also influenced by antecedent water content (Bouwer, 1978). A problem in using Philip's equation is the uncertainty in estimation of the parameter c (Youngs, 1968; Swartzendruber and Youngs, 1974; Parlange, 1975).

An infiltration equation similar to the Philip's equation was developed and tested in a series of studies by Talsma and Parlange (1972) who found that the coefficient c in Philip's equation could be represented by $\frac{1}{3}K_s$, where K_s is the saturated hydraulic conductivity of the soil.

The apparent steady state infiltration rate sustained for about 1 hour is used as an estimate of the saturated hydraulic conductivity, K_s. For the measurement of sorptivity, the second term of the right-hand side of Philip's equation can be neglected. Therefore, if one plots the early portion of the experimental cumulative infiltration versus the square root of the elapsed time on a normal scale paper, the sorptivity for the existing antecedent soil condition can be obtained from the slope of the curve (Chong, 1979). Since this method is simple and rapid, many measurements can be made with limited funds and labour for characterizing infiltration.

From Eq. (2), the infiltration rate becomes,

$$f = \tfrac{1}{2} St^{-1/2} + c \quad \text{.......... (2.1)}$$

in which f is infiltration rate (mm/hr), and other terms as previously defined.

The objective of this work was to evaluate Kostiakov's and Philips infiltration models in Zaria, Nigeria.

2. MATERIALS AND METHODS

2.1 Site Selection

The choice of the one hectare experimental plot was in line with the desire of Agricultural Engineering Department, Ahmadu Bello University, Samaru, Zaria, to establish an irrigation experimental plot behind the Department. Samaru lies between latitude 11° 11'N and longitude 7° 38'E on altitude of 686 m above mean sea level. The land is characterized by a gently undulating topography and very long gentle slope. The rainfall is monsoonal in origin averaging about 1100 mm per annum which starts in May and ends in October with a peak in August.

It was difficult to select the infiltration measurement points because infiltration measurement is laborious and tiresome and it could be expensive where water is limited. Selecting measurement points through formation of grids will require about sixteen grid points for an area of about 1 hectare. Considering six replications per point for acceptable result in line with the suggestion of Burgy and Luthin (1956), one would have about ninety six infiltration runs altogether.

In view of the difficulty stated above, measurement points were randomly selected and the soil textural class determined. The predominant soil types were chosen for infiltration measurement points. This approach is justified by the fact that soil texture is a dominant property of the soil as many of the soil characteristics such as water holding capacity, hydraulic conductivity, infiltration characteristics and porosity are related to it. The experiment was conducted in the months of May and June, 2007.

2.2 Soil physical properties of the experimental site

The formation of Samaru soils has been formed by the addition of fine drift material onto a sedentary soil derived from pre-Cambrian basement complex formation which has a high proportion of fine sand at or near the surface (Higgins, 1962). The surface texture varies from loamy sand to sandy loam depending upon the erosion history of the heavier soil below.

Table 1 shows some physical properties of the experimental site. Samples were taken at depths of 150 mm down the soil profile to a depth of 300 mm. The detailed explanations of how the soil textural class, bulk density and soil moisture content before infiltration runs were carried out have been reported elsewhere (Yahaya, 2008).

Table 1. Some physical properties of experimental site

Sampling point	Soil depth (mm)	Soil texture (a)	Bulk density (g/cm^3)	Initial M.C. by dry weight (%)
A	0 – 150	Sandy loam	1.56	4.0
	150 – 300	Loam sand	1.65	5.0
B	0 – 150	Sandy clay loam	1.59	7.0
	150 – 300	Loam	1.68	8.0
C	0 – 150	Loam	1.67	6.0
	150 – 300	Silt	1.72	7.0

(a) USDA Textural classification.

1.3 Experimental Methods

Infiltration rates were measured using double ring infiltrometers and the water level in the inner and outer rings were kept, as much as possible, equal at all times. Three infiltrometers were used. One set had inner and outer rings of 24.89 cm and 54.5 cm diameter, respectively, and height of 32 cm while the second set had inner and outer rings of 25 cm and 52 cm diameter, respectively, and height of 31.5 cm. The third set had inner and outer rings of 25.2 cm and 50 cm diameter respectively and height of 27.5 cm.

Their bottom rims were sharpened for easy entry into the ground to a depth of about 10 cm from the surface. The depth of penetration was to prevent any blow out effects. Before the start of measurements, dry grass in place of jute sack was spread at the bottom of the inner and outer compartments of each infiltrometer so as to minimize soil surface disturbance, when water was poured into the compartments. In the grassy areas, the grasses were cut as low as possible with a pair of scissors and care was taken not to uproot grasses. Water was then poured from a bucket into the infiltrometer compartments simultaneously and as quickly as possible. As soon as the bucket was emptied, the water level was read and the local time noted. From there on, readings were taken at 5-minute intervals for the first 20-minutes, 20-minute intervals for the next 100 minutes and 30-minute intervals for the next 60 minutes, giving a total duration of 3 hours.

The water levels in the inner and outer compartments were constantly kept equal by adding water, as needed in the outer compartment which depletes faster. Some time lag was allowed before starting another replicate so that no two infiltrometers required reading at the same time.

On each of the three soil types tested in the experimental plot, a total of six infiltration measurements were made at different points, as explained above. Ahmed (1982) in a similar experiment used six replications also to obtain his results, at a location less than 10 km from the experimental site.

2. RESULTS AND DISCUSSION

The average values of field infiltration rates and cumulative infiltration of the three measurement points A, B and C are shown in Table 2 while Fig. 1 indicates the theoretical and experimental infiltration curves corresponding to the average infiltration rates for the same measurement points. The field infiltration curves have a general shape, starting from relatively very high values, which reduce rapidly to about half the initial values within the first 20 minutes, and continue to decrease gradually until a more or less constant value is reached. The total time taken to attain this final value was about 3 hours. The final infiltration rates ranged from 32.0 mm/h to 37.0 mm/h.

The soil parameters from infiltration models are given in Table 3 for all the measurement points. Considering the coefficient of determination (R-square) values, Kostiakov's model has a better performance with R-squre values which ranged from 0.996 to 0.998 for all the soils indicating accurate approximation. The performance of the Philip's model followed closely with R-square values ranging from 0.990 to 0.996. Table 4 shows the results obtained when the field infiltration rates were compared to those predicted by the infiltration models. Philip's model satisfactorily approximated the experimental values. However, the model over-estimated the infiltration rates in the later part of the tests. In other words, for longer time periods, the model tends to over estimate the infiltration rates. Philip's model was based on some assumptions giving it fairly restrictive boundary conditions such as unlimited flow area, uni-axial flow, anisotropic, deep and homogenous soils (Ahmed, 1982). These boundary conditions made the model highly sensitive to deviations from ideal field conditions. Kostiakov's model accurately characterized the experimental tests for all soil conditions and time periods.

The infiltration rates from the two infiltration models were statistically analysed and the resulting t-values indicate that the values obtained from both the Kostiakov's and Philip's models were not statistically different at 5% confidence interval. Hence, it may be inferred that the values of infiltration rates from the two models do not statistically differ from the field infiltration rates. The relationship between the measured and predicted estimates of infiltration rates from the two infiltration models are also shown in Fig. 2. In general, the results obtained in this study conform approximately well with results obtained on similar soils by Ahmed (1982), Yohanna *et al*. (2006) and Igbadun and Idris (2007).

Table 2. Average values of infiltration rates and cumulative infiltration of points A, B and C

Time (hr)	**Point A**			**Point B**			**Point C**		
	Depth of water inf (mm)	Inf rate (mm/hr)	Cum inf (mm)	Depth of water inf (mm)	Inf rate (mm/hr)	Cum inf (mm)	Depth of water inf (mm)	Inf rate (mm/hr)	Cum inf (mm)
0.08	15	180	15	13	156	13	13.5	162	13.5
0.17	11	132	26	9	108	22	9	108	22.5
0.25	9	108	35	7	84	29	8	96	30.5
0.33	8	96	43	6	72	35	7	84	37.5
0.67	23	69	66	18	54	53	19	57	56.5
1.00	19	57	85	15	45	68	16	48	72.5
1.33	17	51	102	13	39	81	14	42	86.5
1.67	15	45	117	11	33	92	12	36	98.5
2.00	14	42	131	10	30	102	11	33	109.5
2.50	18	36	149	13.5	27	115.5	15	30	124.5
3.00	18	36	167	13.5	27	129	15	30	139.5

Inf. – infiltration, cum - cummulative

Table 3: Soil Parameters for Infiltration Models

Soils	Kostiakov's model			Philip's model			Final infiltration rate (mm/hr)
	a	b	R^2	s	c	R^2	
A	57.4	-0.458	0.998	92.3	12	0.996	36.7
B	43.76	-0.494	0.996	92.3	9	0.996	30.5
C	47.73	-0.482	0.996	88.24	10	0.990	32.0

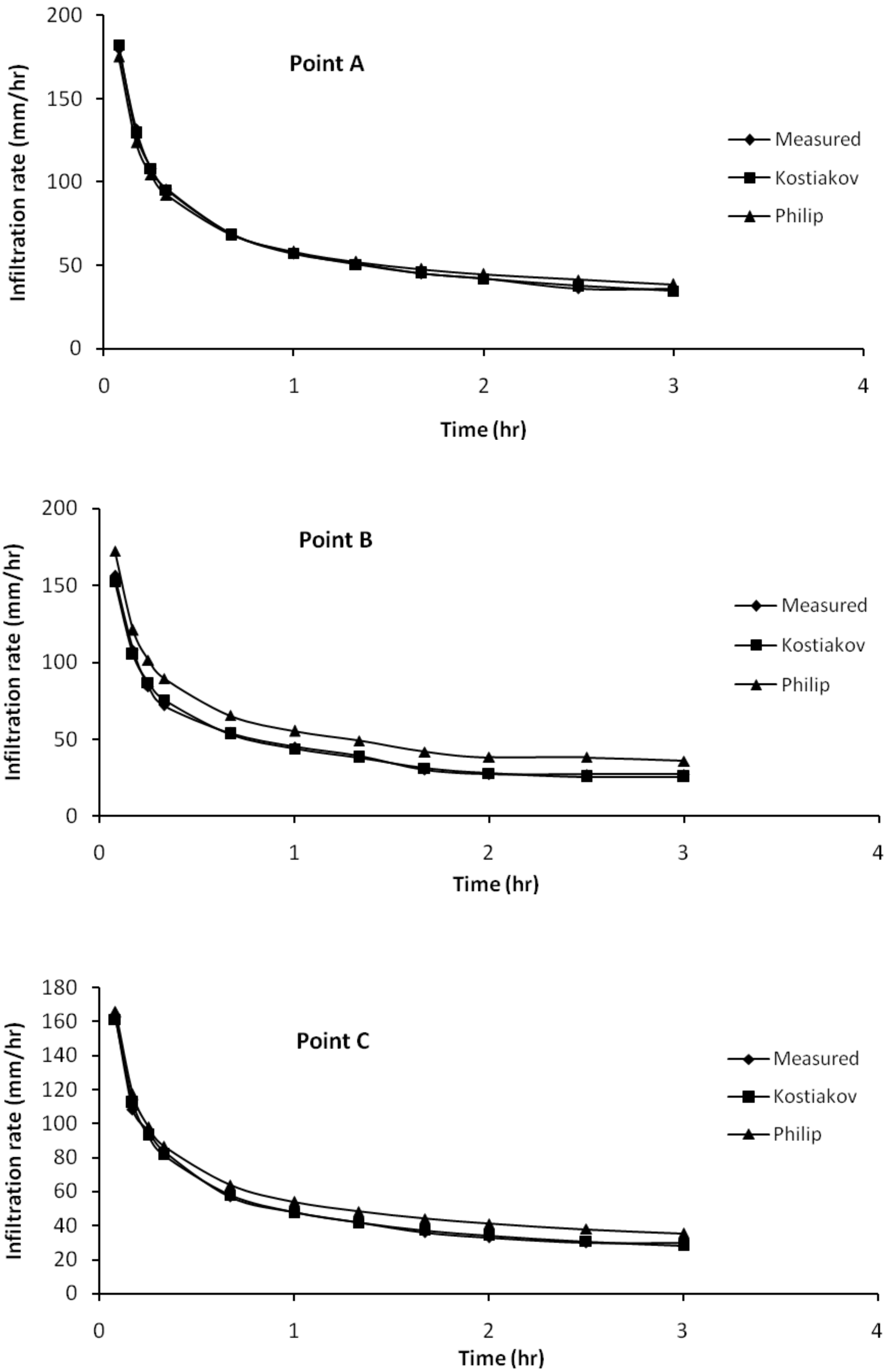

Fig. 1. Predicted infiltration curves compared with experimental curves

Table 4. Comparison between measured data and predicted data from the two infiltration models for points A, B and C

Cum time (hr)	Point A			Point B			Point C		
	Measured inf rate (mm/hr)	Kostiakov's (mm/hr) $f=57.41\ t^{-0.458}$	Philip's (mm/hr) $f=46.15\ t^{-0.5}+12$	Measured inf rate (mm/hr)	Kostiakov's (mm/hr) $f=43.76\ t^{-0.494}$	Philip's (mm/hr) $f=46.15\ t^{-0.5}+9$	Measured inf rate (mm/hr)	Kostiakov's (mm/hr) $f=47.73\ t^{-0.482}$	Philip's (mm/hr) $f=44.12\ t^{-0.5}+10$
0.08	180	182.5	175.2	156	152.4	172.2	162	161.3	165.9
0.17	132	129.3	123.9	108	105.0	120.9	108	112.1	117.0
0.25	108	108.3	104.3	84	86.8	101.4	96	93.1	98.2
0.33	96	95.4	92.3	72	75.7	89.3	84	81.5	86.8
0.67	69	68.9	68.4	54	53.3	65.4	57	57.9	63.9
1.00	57	57.4	58.2	45	43.8	55.2	48	47.7	54.1
1.33	51	50.4	52.0	39	38.0	49.0	42	41.6	48.3
1.67	45	45.4	47.7	33	33.9	44.7	36	37.3	44.1
2.00	42	41.8	44.6	30	31.0	41.6	33	34.2	41.2
2.50	36	37.7	41.2	27	27.8	38.2	30	30.7	37.9
3.00	36	34.7	38.6	27	25.4	35.6	30	28.1	35.5

Cum – cumulative, inf – infiltration, Kostiakov 1932, Philips 1957

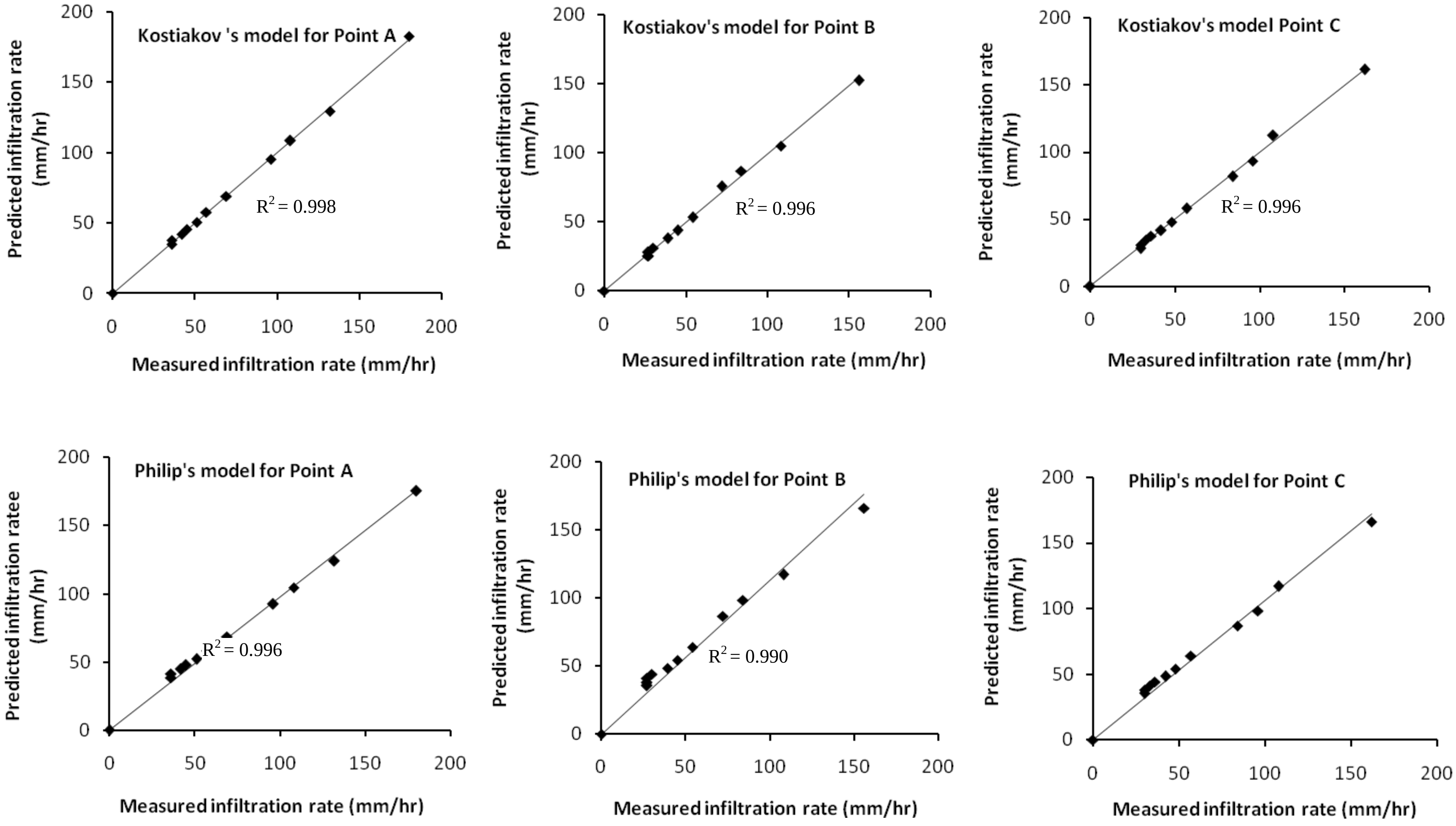

Fig. 2: Relationship between measured and predicted estimate of infiltration rate from the two infiltration models

3. CONCLUSIONS

The two time-dependent infiltration models studied herein, provided good overall agreement with the field infiltration rates, and are therefore capable of predicting the infiltration rates of the soils studied. The analysis made between the measured and estimated models indicated that Philip's model showed high sensitivity to deviations from ideal conditions. For longer time periods, the model tends to over-estimate the infiltration and since the soils attained their infiltration capacity values within three hours, the model needs note be applied for periods longer than three hours.

Kostiakov's model accurately approximated the field infiltration rates of the soils. Kostiakov's model exhibited better adaptability on the soils tested and better represents the infiltration rates of the soils at the site considered.

REFERENCES

Ahmed, A. 1982. Infiltration rates and related soil parameters of some selected Samaru Soils. M. Eng. Thesis, Agric. Eng. Dept., Ahmadu Bello University, Zaria.

Bouwer, H. 1978. Groundwater hydrology. McGraw-Hill Book Co., New York, N.Y.

Burgy, R.H. and I.N. Luthin. 1956. A test of the single and double-ring types of infiltrometers. Trans. *Amer. Geophy. Union*, 37: 189-191.

Chong, S.K. 1979. Infiltration prediction based on in-situ measurements of soil-water properties. Ph.D dissertation, University of Hawaii. 99p.

Collis-George, N. 1977. Infiltration equations for simple soil systems. Water Resource Res. 13: 395-403.

Green, W.H. and G.A. Ampt.. 1911. Studies on soil Physics. 1. The flow of air and water through soil. *J. Agr. Sci.* 4: 1-24.

Higgins, G.M. 1962. Upland soils of the Samaru and Kano areas (Mimeo) Soil Survey Dept., IAR, Zaria, 30 pp.

Holtan, H.N. 1961. A concept for infiltration estimates in watershed engineering. USDA, *Agr. Res. Service Pub*. 41-51.

Horton, R.E. 1940. An approach toward a physical interpretation of infiltration capacity. *Soil Sci. Soc. Am. Proc.* 5: 399-417.

Igbadun, H.E. and Idris, U.D. 2007. Performance evaluation of infiltration models in a hydromorphic soil. *Nig. J. Soil & Env. Res.* Vol. 7: 2007, 53-59.

Kostiakov, A.N. 1932. On the dynamic of the coefficient of water percolation in soils and on the necessity for studying it from a dynamic point of view for purposes of amelioration. Trans. 6th Congress Int. Soc. Soil Sci., Moscow, Part A, pp. 17-21.

Lewis, M.R. and W.L. Powers. 1938. Study of factors affecting infiltration. *Soil Sci. Soc. Amer. Proc.* 3: 334-338.

Michael, A.M. 1978. Irrigation theory and practice. Vikas Publ. House PVT Ltd., New Delhi.

Parlange, J.Y. 1975. A note on the Green and Ampt equation. *Soil Sci.* 119: 466-467.

Philip, J.R. 1957: The theory of infiltration: 4. Sorptivity and algebraic infiltration equations. *Soil Sci.* 84: 257-264.

Swartzendruber, D. and Youngs, E. G. 1974. A comparison of physically based infiltration equations. *Soil Sci.* 117: 165-167.

Talsma, T. and Parlange, J. Y. 1972. One dimensional vertical infiltration. Aust. *J. Soil Res.* 10: 143-150.

Yahaya, A.S. 2008. Performance of Two Infiltration models on soils of Proposed irrigation experimental plot, B. Eng. Project, Agric. Eng. Dept., Ahmadu Bello University, Zaria.

Yohanna, A.D., Laudan, K.J., Ohanwe, C.N., Tom, N. Itodo and Paulina A. Yusuf. 2006. Infiltration and hydraulic conductivity measurement on two irrigated soils in Bauchi town. Proc. 7th Inter. Conf. Nig. Inst. Agric. Engr. (NIAE) Vol. 28, pg 231-236.

Youngs, E.G. 1968. An estimation of Sorptivity for infiltration studies from moisture movement consideration. *Soil Sci.* 106: 157-163.

QUALITY EVALUATION OF VARIOUS WATER SOURCES IN ILORIN

O. O. Olla and I. E. Ahaneku
National Centre for Agricultural Mechanization (NCAM), P.M.B. 1525, Ilorin, Nigeria
Email: drahaneku@yahoo.com

ABSTRACT

Water from seven sources within Ilorin town and its surrounding communities were sampled during the wet and dry seasons of 1996 for quality analysis. The water quality evaluation consisted of collecting and analyzing water samples from the seven water sources. Water samples were analyzed for physical, chemical as well as bacteriological properties in order to ascertain their relative quality in relation to the drinking water standard (Maximum contaminant level, MCL).

The results show that some physical and chemical test parameters were above the World Health Organization (WHO) standard. In particular, the Iron and Manganese contents were too high for the samples taken from Agba dam, Oyun river, the Ile-apa spring and the wells, respectively. The borehole sample from the University of Ilorin permanent site had its manganese above the maximum permissible level too. The turbidity levels of most of the water sources were also found to have exceeded the maximum permissible level, while most other physical and chemical parameters were within the permissible limit. The bacteriological analysis indicates that some of the water sources namely, Agba dam (raw), the spring at Ile-Apa, Oyun River and the well water from Sabo-Oke area, harbour pathogenic organisms, thus making them unsafe for consumption without proper treatment. Based on the results of this evaluation, water quality improvement measures were recommended.

KEYWORDS: Water quality, water sources, water pollution, potability.

1. INTRODUCTION

Safe and adequate supply of water, combined with proper sanitation is an essential component of primary health care. Water quality refers to the characteristics of a water supply that will influence its suitability for a specific use. Potable water is that which is free from harmful bacteria, viruses and parasites. Specific germs or parasites in contaminated water may cause typhoid fever, dysentery, diarrhea (Barabas, 1986) or intestinal worms such as hookworm, roundworm and tapeworm. Excessive level of nitrate in water can cause serious illness and sometimes death in infants less than six months old. The primary hazard from consuming water high in nitrate is methaemoglobinemia (sometimes referred to as "blue baby syndrome") (IDEQ, 2001). Improving access to safe drinking water can result in tangible benefits to health; therefore, every effort must be made to achieve a drinking water quality as safe as practicable (WHO, 2006). The fact that untreated water may be dangerous is seldom realized (especially in rural areas inhabited by people with little or no education) until after a case of sickness or death. Of increasing concern is the frequency with which humans are being infected with diseases from animals through unprotected water sources. Such diseases include leptospirosis (a disease transmitted through dog urine entering the drinking water), anthrax, tuberculosis, and infectious hepatitis.

It has been reported that, no fewer than 1.2 billion people, particularly in third world countries still lack access to potable water (Daily Times, 2003). Some of the effects of the presence in toxic amounts of minerals in water can be recognized in the resulting taste, discolouration, deposition of sediments and turbidity of the water. A global survey of community water supply conducted by WHO (1993) indicated that in rural areas of the developing countries where vast majority of the population live, over 85% of the people do not have satisfactory access to reasonably uncontaminated water. It was also observed that Africa has the lowest total water supply coverage of any region of the world (WHO/UNICEF, 2000). This is responsible for the various water-related diseases that account for at least three million deaths yearly. Nigeria, being part of Africa, the situation here is not different. It is an observable fact that majority of the water sources available for use by Nigerians, especially in the rural communities, are untreated.

According to Sule (1993), between 1983 and 1988, a water supply project worth ₦120m was executed in Kwara State of Nigeria with the assistance of external donors. However, since 1988, there has been a decline in further water development projects, especially with the exit of the aid agencies, while the population of the communities has been on the increase with consequent expansion of residential areas. Due to this rapid expansion in both human population and habitation, the people seek ways of providing themselves with water for domestic use in the absence of public water supply. Consequently, shallow wells are now dotted all over the new areas of Ilorin town and surrounding communities. Where surface water exists, there is no provision for treatment. The potability of these water sources depends on the physical, chemical and bacteriological characteristics of the water. Since most of these water sources are exposed to different forms of pollution; there is therefore the need to carry out quality analysis of the available water sources to ascertain that desirable limits are not exceeded.

The objectives of this study were: to determine the potability of the different water sources available to people in Ilorin and its surrounding communities and to proffer possible solutions to the problems associated with water quality.

2. METHODOLOGY

2.1 Water Sources and Locations

Seven different water sources available to people in Ilorin were selected for analysis, namely, surface sources (Oyun river, spring water and the Agba dam raw water); underground sources (borehole and wells). Other sources sampled were the treated water and the rain. Deliberate effort was made in selecting the sources with high density of use. Selection was also made to cut across different social classes of Ilorin residents. Oyun River is located along the University of Ilorin permanent site road. The borehole is located at the University of Ilorin and serves majority of the University of Ilorin community. The spring water source is located at Ile-Apa village, a neighbouring village to the University of Ilorin permanent site, where off campus students live. Agba Dam is in the Government Reserved Area (GRA), Ilorin. The shallow wells are located at Sabo-Oke area, behind Maraba motor garage. The location of these water sources are also indicated in Fig. 1.

2.2 Quality Analysis

Two sets of samples from different water sources were taken, a set for both wet and dry seasons of 1996. The samples were collected in clean labeled bottles and tightly covered to prevent contamination. All samples were taken to the laboratory for immediate analysis. In few cases of delay in analysis, the samples were stored in a refrigerator for preservation. The samples were analysed for physical, chemical and bacteriological properties in accordance with standard methods (APHA, 1995, Environment Canada, 1979).

Fig. 1. Ilorin and environs showing sampling locations

3. RESULTS AND DISCUSSION

Table 1 shows the physical and chemical constituents analysed. The results show that few physical characteristics like colour and turbidity were above the WHO (1993) maximum permissible limit. The colour was above the permissible Hazen Unit range in samples from Agba dam during the wet season. The same situation was applicable to River Oyun sample during both the wet and dry seasons, and the spring water source located at Ile-Apa village during the dry season. The high colour unit of these surface water sources may not be unconnected with activities upstream of the water sources as well as their unprotected nature as is the case of the spring water, coming out of a rock.

Turbidity was above the maximum permissible limit in samples from Agba dam, the University of Ilorin borehole, Oyun River and Ile-Apa spring during both wet and dry seasons; while the permissible limit was exceeded for Sabo-Oke wells only during the dry season. However, presence in excess of these physical parameters in the water sources has no health implication, but may only affect acceptability of these sources for potability purpose.

The spring water source at Ile-Apa was high in iron (Fe^{2+}) during the dry season, while magnesium was in excess in the well samples from Sabo-Oke area of Ilorin during both wet and dry seasons. This could be ascribed to the dissolving action of water as it passes through underground iron deposits or when in contact with iron and steel surfaces. The consequence of excess iron is in the taste of the water as it gives it an objectionable taste. Other effects of this excess is in colouration of fabrics due to deposition of its red/brown oxides when used for laundry purposes. It also causes the growth of autotrophic bacteria in water distribution mains.

The results of the bacteriological analysis are presented in Table 2. These data show that the bacteriological status of four out of the seven water sources is poor. The colony growths, number of coliform organisms as well as e-coli per 100 ml of sample were exceeded in the four samples for both the wet and dry seasons. These sources include Agba dam, the Ile-Apa spring, the Sabo-Oke well and the Oyun River. The results indicate the presence of pathogenic organisms such as bacteria, virus or protozoa. These pathogenic organisms have been reported to be responsible for the high mortality rates in developing countries with an estimated death rate of 10 million annually, especially for young children below the age of 5 years (Barabas, 1986). This is as a result of their associated deadly diseases such as typhoid and cholera. The treatment of these diseases is relatively expensive for resource-poor rural dwellers. Thus, the prevention of these diseases through appropriate water treatment methods and water source protection is highly advocated.

Table 1. Values of physical and chemical constituents analyzed in relation to season.

	Agba Raw Water	Treated Water	Oyun River	Spring	Borehole	Well	Rain
Phenolphthalein Alkalinity (mg/l)							
Wet	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Dry	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Methyl Orange Alkalinity (mg/l)							
Wet	55.00	25.00	55.00	45.00	90.00	205.00	50.00
Dry	30.00	20.00	80.00	65.00	90.00	105.00	N.A
Total Hardness (mg/l)							
Wet	52.00	36.00	76.00	36.00	80.00	240.00	16.00
Dry	36.00	48.00	120.00	76.00	96.00	136.00	N.A
Ca^{2+} Hardness (mg/l)							
Wet	32.00	28.00	44.00	20.00	56.00	168.00	12.00
Dry	24.00	32.00	72.00	48.00	64.00	96.00	N.A
Mg^{2+} Hardness (mg/l)							
Wet	20.00	8.00	32.00	16.00	24.00	72.00	4.00
Dry	12.00	16.00	48.00	28.00	32.00	40.00	N.A
Ca^{2+} (Total) (mg/l)							
Wet	12.40	13.20	12.40	9.80	14.80	168.00	6.20
Dry	9.60	12.80	28.80	19.20	25.60	38.40	N.A
Mg^{2+} (Total) (mg/l)							
Wet	2.12	4.70	8.60	5.20	9.20	72.00	2.40
Dry	2.90	3.90	11.60	6.80	7.80	36.00	N.A
CO_2 (mg/l)							
Wet	2.50	2.00	2.00	1.00	2.00	1.00	0.20
Dry	3.00	1.50	3.00	3.00	2.00	2.00	N.A
CI^{-} (mg/l)							
Wet	3.00	6.00	4.00	3.00	6.00	25.00	0.01
Dry	4.00	7.00	6.00	4.00	5.00	3.00	N.A
Fe^{2+} (mg/l)							
Wet	0.80	0.15	2.20	0.50	0.15	0.15	0.50
Dry	0.15	0.00	0.50	1.20	0.05	0.40	N.A
CU^{2+} (MG/L)							
Wet	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Dry	0.00	0.00	0.00	0.00	0.00	0.00	N.A
Mn^{2+} (mg/l)							
Wet	0.15	0.05	2.20	0.50	0.15	0.35	0.05
Dry	0.25	0.00	0.40	0.45	0.05	0.25	N.A

Pb^{2+} (Mg/l)								
	Wet	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Dry	0.00	0.00	0.00	0.00	0.00	0.00	N.A
PH	Wet	6.90	6.50	6.30	6.40	6.70	7.30	7.10
	Dry	6.90	6.60	7.30	6.10	6.20	7.20	N.A
Colour (H.U)								
	Wet	60.00	6.00	80.00	12.00	25.00	9.00	5.00
	Dry	20.00	5.00	60.00	350.00	6.00	7.50	N.A
Na^{+} (mg/l)								
	Wet	2.50	0.50	3.50	1.50	0.50	3.50	0.00
	Dry	2.80	0.50	5.20	1.80	0.70	4.20	N.A
K^{+} (mg/l)								
	Wet	3.50	1.50	2.00	2.00	4.50	3.50	0.00
	Dry	4.70	1.50	5.60	4.20	4.70	3.50	N.A
NO^{3-} (mg/l)								
	Wet	1.20	0.20	0.70	1.40	7.20	0.00	1.40
	Dry	0.40	0.20	1.40	1.20	0.02	1.80	N.A
SO_4^{2-} (mg/l)								
	Wet	16.50	24.00	14.50	13.50	19.60	3.00	12.00
	Dry	16.00	16.00	8.60	6.06	13.40	1.50	N.A
Turbidity (NTU)								
	Wet	9.00	3.50	6.50	8.00	11.50	2.00	5.00
	Dry	10.50	3.50	26.50	19.00	6.50	10.50	N.A
NH_3 (mg/l)								
	Wet	0.036	0.002	0.020	0.014	0.048	0.000	0.032
	Dry	0.012	0.002	0.024	0.020	0.002	0.026	N.A
Total Solids (mg/l)								
	Wet	384.0	216.0	344.0	276.0	420.0	88.0	404.0
	Dry	296.0	168.0	442.0	344.0	192.0	404.0	N.A
Suspended Solids (mg/l)								
	Wet	112.0	60.0	96.0	72.0	144.0	16.0	140.0
	Dry	92.0	48.0	184.0	126.0	60.0	168.0	N.A
BOD (mg/l)								
	Wet	6.20	4.20	5.40	5.00	5.20	7.60	7.60
	Dry	4.60	3.00	4.80	4.60	3.00	5.80	N.A

**N.A. = Not applicable*

Table 2. Result of bacteriological analysis of the samples in relation to season

Nature of sample/season		Colony growth/ml on Nutrient agar	Most probable No. of Coliform agar	Most probable No. of E Coli per 100ml
Agba Dam:	Wet	300	180+	25
(Untreated)	Dry	170	120	4
Agba Dam:	Wet	20	Nil	Nil
(Treated)	Dry	5	Nil	Nil
Spring:	Wet	126	90	12
	Dry	100	60	6
Borehole:	Wet	32	14	Nil
	Dry	26	5	Nil

Rain:	Wet	2	Nil	Nil
	Dry	N.A	N.A	N.A
Well :	Wet	300	180+	6
	Dry	300	100	7
River:	Wet	145	160	32
	Dry	120	50	8

Drinking water, regardless of its source, is usually subjected to one or more of a variety of treatment processes aimed at improving its safety and/or aesthetic quality. There are three major stages in water treatment for rural community, namely chemical dosing, sedimentation and filtration. These processes are selected according to the source of the water and the contaminants that require removal. Surface waters should undergo coagulation, sedimentation, rapid sand filtration and disinfection. Common examples of disinfectants used for treatment include chlorine, chlorine dioxide, ozone, or chloramines with a dosage of 1 part per million (ppm) as recommended by WHO, (2006). Figure 2 shows the proposed treatment plant for the Oyun River (surface water). This treatment plant will adequately treat water from surface sources.

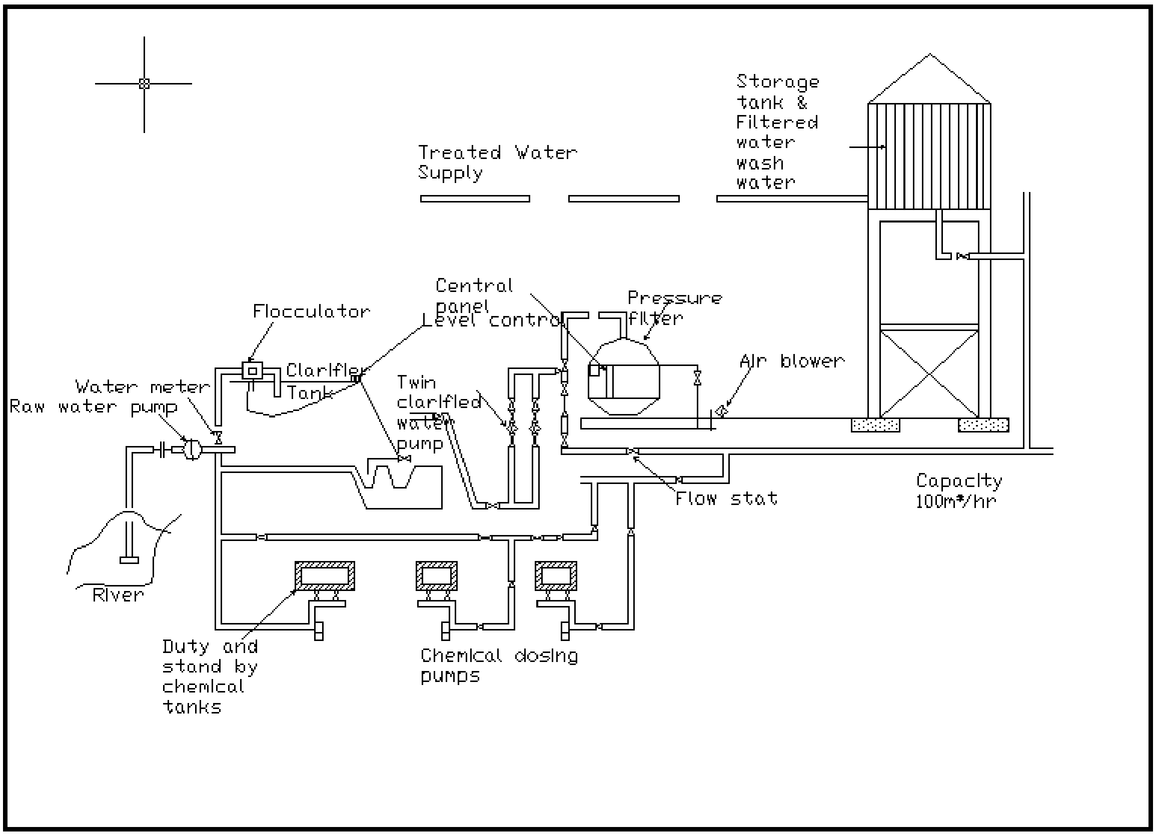

Fig. 2. Proposed water treatment plant for Oyun River

Source: Civat Engineering Co. Ilorin

On the other hand, Ground waters, which are often naturally filtered, usually undergo less treatment and should be limited to disinfection alone. Additional treatment processes could include pH adjustment, softening, addition of corrosion control chemicals, alkalinity adjustment, carbon filtration/adsorption, membrane filtration, slow sand filtration and supplemental fluoridation. Fig.3 shows a typical set-up which can adequately treat an underground water source.

It was also observed that most of the unprotected water sources have their physical, chemical and bacteriological parameters exceeding the WHO maximum permissible limit. This emphasizes the need for source protection for the improvement of water quality. Some of these water sources, especially the spring and wells could have been fit for consumption with little or no treatment if there is adequate source protection. Rain water, if harvested using a clean vessel may require no treatment.

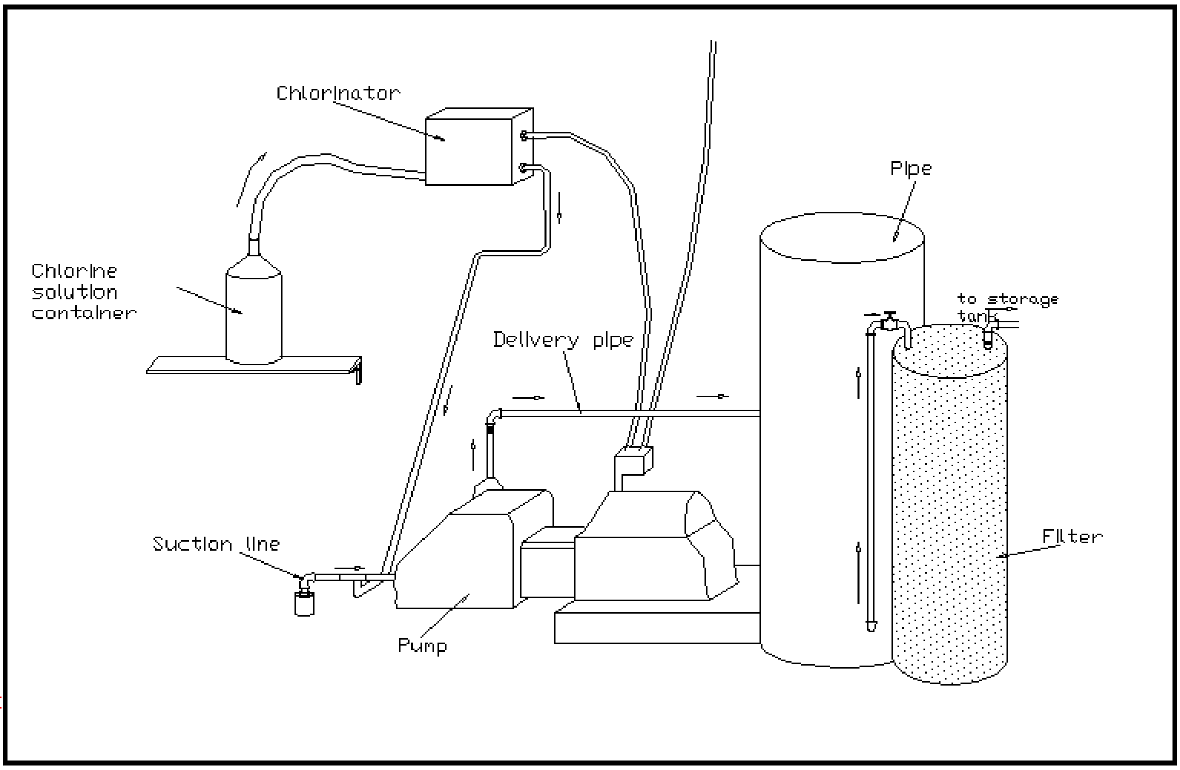

Fig. 3. Treatment of set-up for correction of excess iron, turbidity and manganese

4. CONCLUSIONS AND RECOMMENDATION

The quality characteristics of water from seven sources of water available to people in Ilorin and its surrounding rural communities were analysed. Results show that most of these water sources are not fit for consumption, because of their bacteriological status. Therefore, the water from these sources require treatment. It is also important that adequate source protection should be put in place in order to minimize pollution. The information emanating from this study could help the Kwara State Government and concerned wealthy individuals to implement both water protection and treatment programmes for the state.

REFERENCES

American Public Health Association (APHA), 1995. Standard methods for the examination of water and wastewater, 19th ed. APHA, Washington D.C.

Barabas S. 1986. Monitoring natural waters for drinking water quality, World Health Statistics Quarterly, 39(1), 32-45.

Daily Times 2003. Adequate water supply: Earth dams raise hope. Nov. 20, 2003, pp 12.

Environment Canada, 1979, Analytical methods manual, inland waterway directorate, water quality branch, Ottawa, Canada.

Idaho Department of Environmental Quality (IDEQ) 2001 Groundwater Quality Evaluation.

Sule B.F. 1993. Quality of rural water supply. Water, Sanitation, Environment and Development publication presented at the 19th WEDC conference, Accra, Ghana. Pp. 295-297.

WHO 1993. International Standards for drinking water Guidelines for drinking water quality, vol. 1, Recommendation, 2nd edition, WHO, Geneva.

WHO/UNICEF Joint Monitoring Programme for Water Supply and Sanitation 2000. *Global water supply and sanitation assessment 2000 report*. Geneva, World Health Organization, Water Supply and Sanitation Collaborative Council and United Nations Children Fund.

WHO 2006. Guidelines for Drinking Water Quality. First Addendum to third edition, Vol. 1, Recommendations.

HYDRAULIC AND HYDROLOGIC DESIGN OF A DAM ACROSS ULASI RIVER AT OKIJA, ANAMBRA STATE, USING *SITES*

G. I. Okonkwo and C. C. Mbajiorgu
Agricultural and Bioresources Engineering Department
University of Nigeria, Nsukka, Nigeria
E-mail: ifyglory77@yahoo.com

ABSTRACT

SITES is a computer program that assists the engineer in the hydraulic and hydrologic analysis of dams. It develops inflow hydrographs and uses the storage-discharge relationship at dam sites to route design flood hydrographs through existing or proposed reservoirs (Lobrecht et.al, 2007). In this study, it was applied to a hypothetically proposed reservoir site on the Ulasi River at Okija, Anambra state.

Ulasi River is located in south eastern Nigeria, sourced at Dikenafai in Imo state (latitude 05^{o} 45'N and longitude 07^{o} 10'E). The Upper Ulasi River (UUR) catchment is designated in this study from the area around Dikenafai to the river crossing of the Onitsha–Owerri express/highway at Okija, Ihiala L.G.A. of Anambra state. Based on this designation, data on the UUR watershed, proposed site of the reservoir at Okija, as well as on hydrologic and hydraulic parameters were collected. A database for *SITES'* application was developed using the software's control words in a logical sequence, and then inputted appropriately into the program.

SITES' output are outflow hydrographs of the design inflow hydrograph routed across the principal spillway for flood control, across the auxiliary spillway for stability design and over the freeboard of the auxiliary spillway for inundation protection, as well as calculated embankment quantities required for construction of the reservoir. These results are presented in this paper for the proposed reservoir. They show that the percentage reduction in peak flow across the principal spillway is 89%, and the peak flow reduction for stability design is 58%. The elevation and associated storage volume, surface area, and the principal spillway discharge (outflow) at the maximum pool stage are 184.3m, $39.5x10^5m^3$, $14.19x10^5m^2$, and $13.4x10^3m^3/hr$, respectively, given the estimated values of the relevant input parameters for the proposed reservoir site.

1. INTRODUCTION

In some areas, water resources are not sufficient both in quantity and quality, to meet every legitimate demand. Different sectors where water resources developments are needed include: agricultural sectors, domestic purposes, hydropower generation, industrial use and recreation etc. It is well known that water is essential for human survival and health. Therefore, there is need for every individual to have access to safe and sufficient quantity of water for personal consumption, sanitation and other purposes. Development of water resources involves storage and conveyance of water from the place of natural occurrence to the place of beneficial use. Society's first answer to problem of the grossly uneven distribution of water resources was to build large aqueducts and dams to even out variations in river runoff over time and to move water from regions of surplus to regions of deficit (Ven, 1988).

Water Resources Site Analysis computer program (SITES) (USDA, 1999), is a new version of the Soil Conservation Services (SCS) DAMS2 program. The program is used in the design and proportioning of dams with floodwater features as well as to route historical or synthetic flood events through existing dams and reservoirs, and to predict or evaluate flood spillway performance. The program develops the inflow hydrographs from homogeneous subareas, combines them, and routes the resulting hydrograph through the valley to the dam site. The program can also compute embankment and other construction quantities to provide information for cost comparison between alternatives.

Ulasi River has not been developed for people around there especially to have access to safe water with ease. Because of this, *SITES* computer model is used to check the feasibility of dam design across the river.

2. ULASI RIVER

Ulasi River is a widely spread river, located be found in the Eastern part of Nigeria. The river has its source from the mini falls at Eze ama in Dikenafai in Ideato south Local Government Area of Imo state which is at latitude 05^0 45'N and longitude 07^o 10'E (Ilo, 2003). At Eze Ama, after dropping, the water flows sub-surface to emerge as a mini lake about a kilometer westward. Ulasi River, however, starts from this area and flows in a northwestern direction to Okija in Anambra state, then turns south back into Imo state to be received by Oguta Lake (Fig. 1). Along the flow, the river collects water from many smaller seasonal and perennial tributaries. The river overflows its bank in August and gradually recedes by subsequent months (Ejeahalake, 1998).

The Upper Ulasi River (UUR) catchment starts from the area around Dikenafai to the river crossing of the Onitsha-Owerri road at Okija, Ihiala LGA in Anambra state, as shown in Fig. 2 after Ilo (2003).

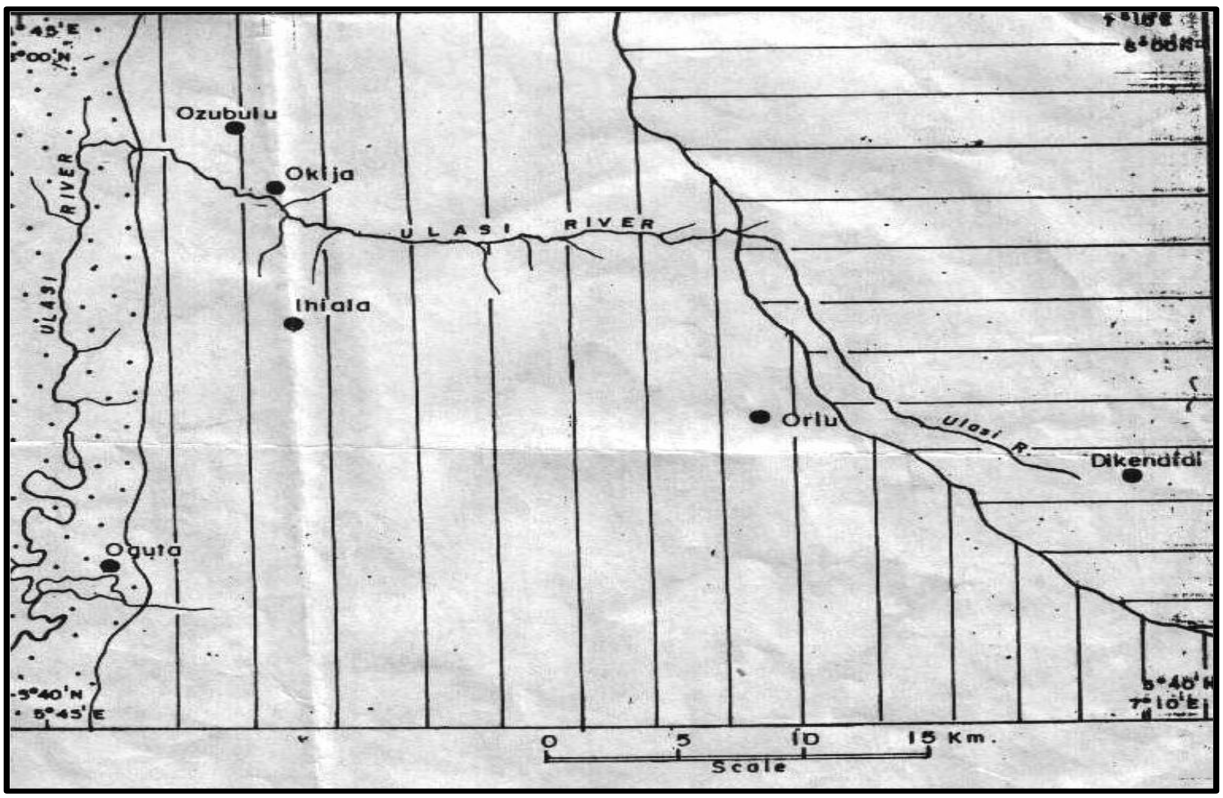

Fig. 1. Map of Ulasi River starting from the source Dikenafai to Oguta Lake

3. THEORY OF *SITES*

Figures 3a and 3b show schematic diagram and typical cross section of a dam and are used to illustrate program terminology for a dam designed according to TR–60 (NRCS (Natural Resources Conservation Service) Technical Release 60, Earth Dams and Reservoirs) with a single stage principal spillway (USDA, 2005).

The basic hydrologic techniques and assumptions used in the SITES program are as follows:

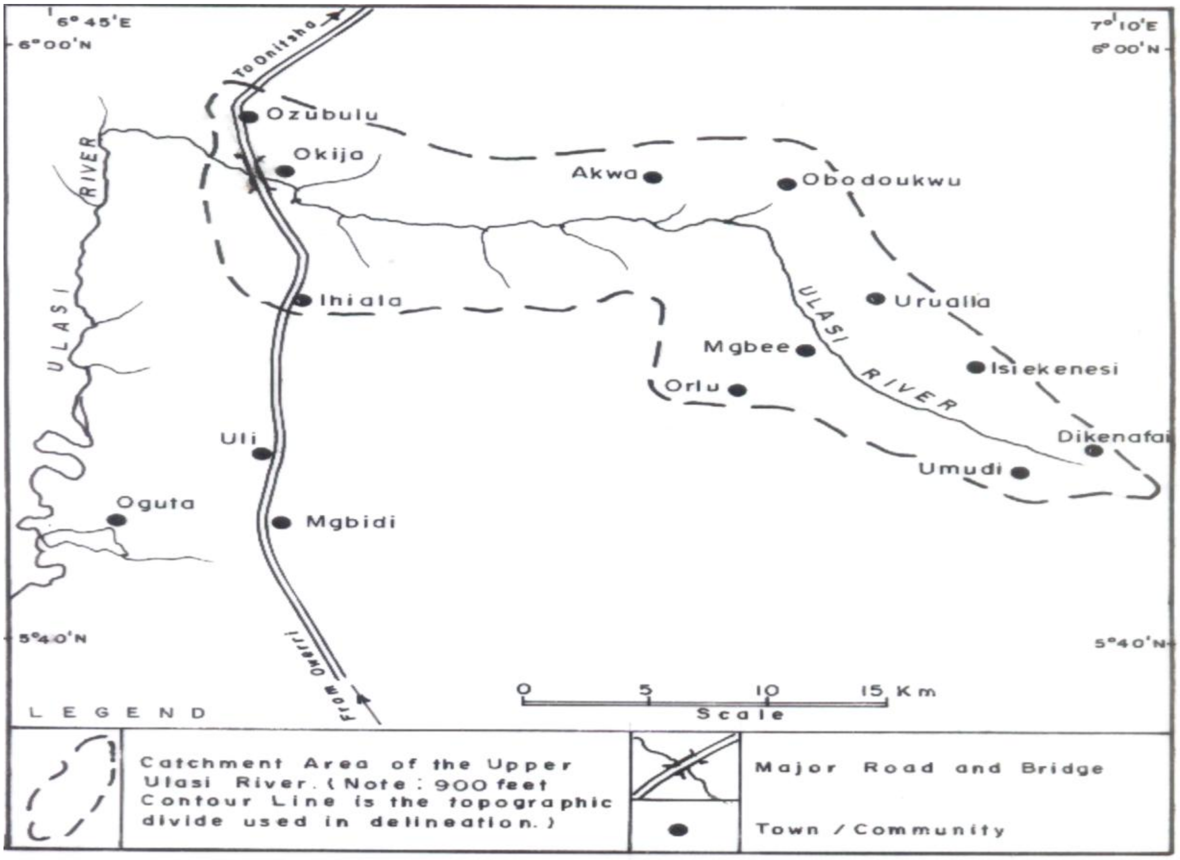

Fig 2. Catchment Area of the Upper Ulasi River (UUR), after Ilo (2003)

(i) Watersheds—Divide the watershed (drainage area above the structure) into as many subwatersheds as required to define hydrologic effects. Hydrologic effects are influenced by tributary entrances, watershed shape, valley slope changes, homogeneity of the runoff curve number, and location of water impoundment areas. The program assumes each sub watershed as hydrologically homogeneous.

(ii) Rainfall—The program applies rainfall amounts for specified durations and temporal distributions uniformly over a (sub)watershed. The program uses distributions based on a constant time increment. Small size of time increments best defines rainfall intensities and provides the more accurate hydrograph development.

(iii) Runoff—The program develops a mass curve of runoff for each (sub) watershed. The runoff curve number (CN), rainfall volume, and rainfall distribution are the input variables needed to determine this mass curve. Runoff curve numbers for each (sub) watershed are determined based on soil, land use, and hydrologic condition information. The program computes the runoff volume (Q) in inches from rainfall using the NRCS (Natural Resources Conservation Service) runoff equation. The NRCS runoff equation assumes the initial abstraction equals 0.2 of the maximum retention ($I_a = 0.2S$). The program distributes the runoff volume over time by subtracting consecutive incremental Q values from the mass curve of runoff to obtain the incremental runoff volumes.

iv Hydrograph development —The program develops an incremental unit hydrograph for each (sub) watershed. It calculates the unit hydrograph time increment (ΔD) as a function of the time of concentration (T_c) and the rainfall distribution time increment.

The program then adjusts the ΔD to provide a whole number of ΔD's to the peak of the unit hydrograph and to ensure that the number of ΔD's in the flood hydrograph base do not exceed the number of points limitation of the program. The program determines coordinates of the incremental unit hydrograph for each ΔD using its ratio to the peak, the drainage area, and the incremental runoff volume (ΔQ) determined for each ΔD. The program determines the composite flood hydrograph for each (sub) watershed by summing the incremental hydrograph coordinates. The program stores the composite flood hydrograph values at times related to the specified number of hydrograph points. The peak flow value of the hydrograph is the maximum coordinate. Time of concentration (Tc) may be computed by velocity method and the value is entered as input, or the program will compute Tc using the Kirpich equation or the Lag equation.

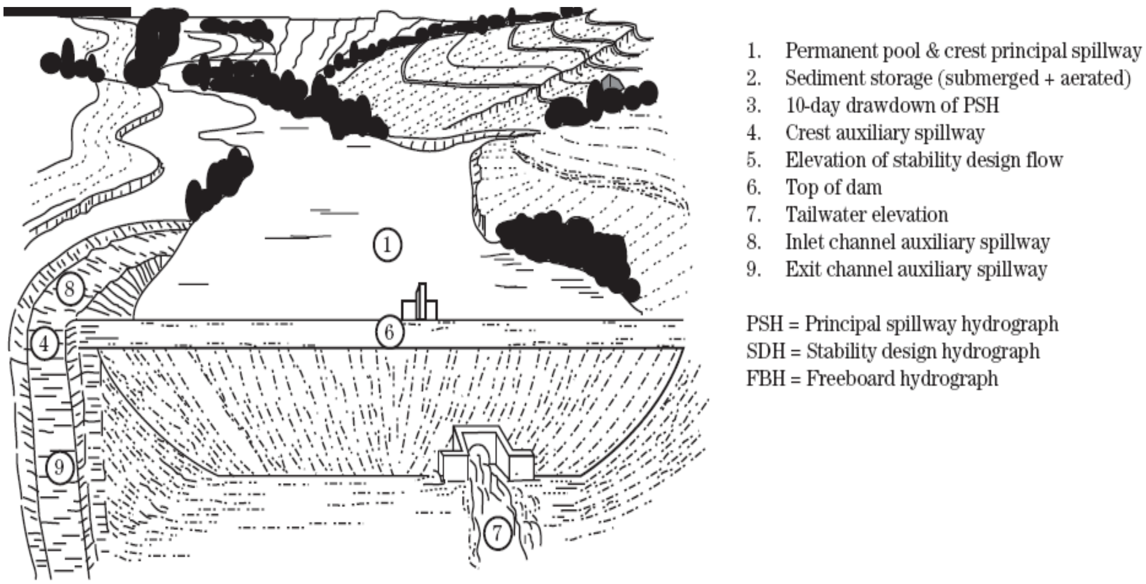

Figure 3a. Schematic diagram of a Dam (Source: USDA (2005))

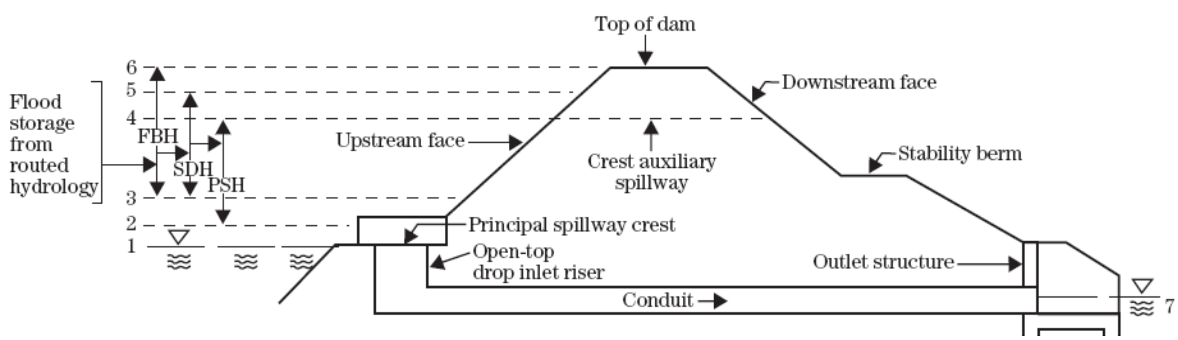

Figure 3b**:** Typical cross section of a Dam (Source: USDA (2005))

(v) Reservoir stage–storage—The program computes reservoir storage by the average surface area method assuming a linear relation between elevation-area points. Given total volume-storage data, the program uses the storage directly.

(vi) Reservoir stage–discharge— Discharge rating curves for the spillways are entered or the program is allowed to compute them. *SITES* determine principal spillway (PS) rating curves by standard hydraulic formulas for weir, orifice and pipe flow and for hood inlet configurations. It assumes constant tailwater for pipe flow. The program can develop auxiliary spillway (AS) rating curves using one of the four methods described below (USDA, 1996).

Method 1—The WSPVRT method: This develops water surface profiles based on a full trapezoidal cross section using a combination of the direct step and standard step methods. The procedure uses the direct step method within reaches and the standard step method to establish conditions at reach nodes. The procedure provides for use of user specified values of Manning's "n" in computing flow resistance. Conditions governing flow resistance are allowed to vary from reach to reach. Backwater computations begin with critical depth at the upstream end of the first supercritical reach. The program determines the location of the first supercritical reach for each discharge based on slope only; it does not consider reach length and the possible influence of downstream reaches. If no supercritical reach is present, computations begin with normal depth at the upstream end of the first reach above tailwater. Ratings are based on energy head at the reservoir end of the inlet channel.

Method 2—The frictionless side slope method: This develops water surface profiles based on discharge per foot (q) of bottom width (BW) assuming vertical frictionless side slopes, constant Manning's "n", and critical depth at the control section with an adjustment for the actual side slopes (z). Profiles start at critical depth at the downstream end of the crest section. The program adjusts the total discharge capacity of the auxiliary spillway (QAS) to the total flow area by the equation (1):

$$Q_{AS} = q\left[BW + z\left(\frac{q^{\frac{2}{3}}}{g^{\frac{1}{3}}}\right)\right] \qquad (1)$$

Where: Q_{AS} = total discharge capacity of auxiliary spillway, g = gravitational constant, z = actual side slopes, BW = bottom width, q = discharge per foot of bottom width.

Method 3—TRAPW develops water surface profiles based on an incremental forward projection procedure using the complete trapezoidal cross section with a given side slope ratio and a constant Manning's "n". Profiles start at critical depth at the downstream end of the crest section. The program divides the inlet channel length into 2000 reach increments for the water surface profile computation.

Method 4—The ASFILE method selects precomputed subcritical discharges per foot of bottom width (q) for given flat inlet channel lengths and retardances A to E with normal depths at the control section. The program determines the total discharge capacity of the auxiliary spillway (QAS) by the equation (2):

$$Q_{AS} = q(BW + zd) \qquad (2)$$

Where: d = depth of flow in the spillway, BW = bottom width, z = actual side slopes, q = discharge per foot of bottom width, Q_{AS} total discharge capacity of the auxiliary spillway.

(vii) Reservoir routing - The program routes the composite flood hydrograph through a reservoir using the storage-indication method. The storage indication routing uses multiples of the hydrograph time increment (ΔD) and the elevation-discharge-storage data. NRCS criteria and input data establish the starting elevation for design routing. For simulation runs the starting elevation is at the principal spillway crest (permanent pool), unless otherwise specified.

4. MATERIALS AND METHODS

(a) Reservoir Site Description

The elevation in feet corresponding with the reservoir surface area was arranged in increasing order (see Table 1). The initial storage volume was assumed to be 292.8 acre feet. Then the program computes the discharge and the remaining storage volume. In this study the principal spillway crest and permanent pool were set at 2600 acre-feet of storage. An allowance of 30 acre-feet is provided for sedimentation between the principal and auxiliary spillway crests.

(b) Watershed Data Development

The watershed is under the humid climate area zone. The runoff curve number is 82, the drainage area is 7.5 square miles, and the time of concentration is 2.57 hours.

(c) Rainfall Data for the Application

Accumulated rainfall amount at 24 hours time increment was used. This study was based on principal spillway hydrograph with 1-day rainfall of 3.1 inches and 10-day rainfall of 6.0 inches and also the stability design hydrograph on 7.5 inches of rainfall and the freeboard hydrograph on 2.57 inches. These are all point rainfalls.

(d) Principal Spillway data

The principal spillway is single stage with an entrance loss coefficient of 1.0 and a weir length of 18 feet. In this study the principal spillway is a 36-inch diameter conduit pipe, 250 feet long with manning’s coefficient "n" of 0.013 and a tailwater elevation (elevation in feet of the hydraulic grade line at the principal spillway outlet) of 584.0.

(e) Auxiliary spillway data

The surface of the first geologic material is an alluvium followed by weathered rock, shale and limestone. This surface for auxiliary spillway is a natural ground. The records for centerline profile of the surface materials were arranged in coordinates of “x” and “y” pairs for station (distance) and elevation respectively. Stations increases from left to right in the downstream directions. The auxiliary spillway side slope ratio is 2.5 and the exit channel slope is 3.5 percent. The physical parameters like plasticity index, representative diameter, percent clay, dry bulk density of the surface materials used are shown in Table 2. Bottom width of 100 feet for an auxiliary spillway was used in this study.

Table 1: Reservoir surface area data used in this study

Elevation (feet)	Surface Area (acres)
590	76.6
592	106.9
594	142.8
597	180.6
601	262.7
605	360.3
609	456.9
613	557.7
615	607.7

Table 2: Spillway data used in this study

Parameters	Value
Plasticity index	10
Representative Diameter of the material	0.008
Percent Clay	15

Dry Bulk Density	110

1. RESULTS AND DISCUSSION

The elevation and associated storage volume, surface area, and principal spillway discharge at the maximum pool stage attained by routing the principal spillway hydrograph are summarized in Table 3. Stability design hydrograph results and Freeboard hydrograph results are shown in Figures 4a and 4b. Abbreviations used in the output data are shown in Appendix I.

Table 3. Results of design flow routing over the principal spillway

EMAX (m)	VOL–MAX (m^3)	AMAX (m^2)	QMAX (m^3/hr)	PS STORAGE (m^3)
184.3	3950653.8	1418964.5	13427.8	1951643.7

Table 4a. Result of design flow routing over the freeboard and stability design hydrograph

	BTM WIDTH (m)	MAX ELEV (m)	VOL-MAX (m^3)	AREA-MAX (m^2)	AUX. HP (m)	VOL-AUX (m^3)
SDH	30.48	185.2	5340068.2	1704554.3	0.72	1144071.3
FBH	30.48	185.9	6662626.9	1941297.9	1.4	2466753.3

Table 4b. Result of design flow routing over the freeboard and stability design hydrograph continued

	Peak Discharge (m^3/hr)			Auxiliary Spillway				Exit Channel Flow		
	Q-PS	Q-AUX	Q-TOT	CRITICAL DEPH (m)	CRITICAL VELOCITY (m/hr)	CRITICAL SLOPE-SC (m/m)	25% OF Q SC (m/m)	MAX VELOCIY (m/hr)	EXIT SLOPE (m/m)	FLOW DEPTH (m)
SDH	4593	26805	31401	0.39	2210.05	0.006	0.02	2635	0.01	0.34
FBH	4825	94349	99174	0.88	3281	0.003	0.006	4743	0.035	0.6

The plot of time against inflow discharge (Qin) and outflow discharge (Qout) indicates the shape of the inflow and outflow hydrographs respectively. Figure 4 shows the plot of time against Qin and Qout of the Principal Spillway hydrograph. From the plot, the peak inflow is 123926.8m^3/hr at time 121hrs. Figures 5 and 6 show the plot of time against Qin and Qout for stability design hydrograph and freeboard hydrograph respectively. In the three hydrograph plots shown below, peak inflow is greater than the peak outflow. The difference between the peak inflow and the peak outflow is much in the principal spillway hydrograph than in the stability design hydrograph and freeboard hydrograph.

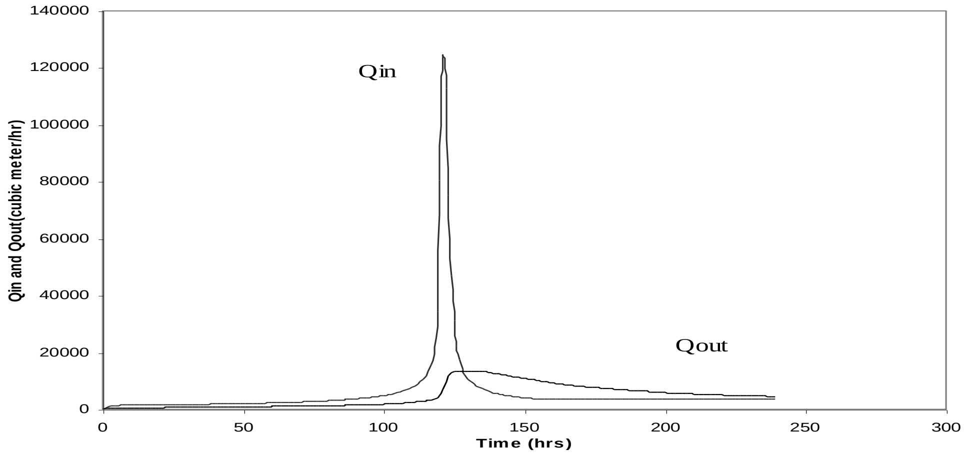

Figure 4: Principal spillway hydrograph plots

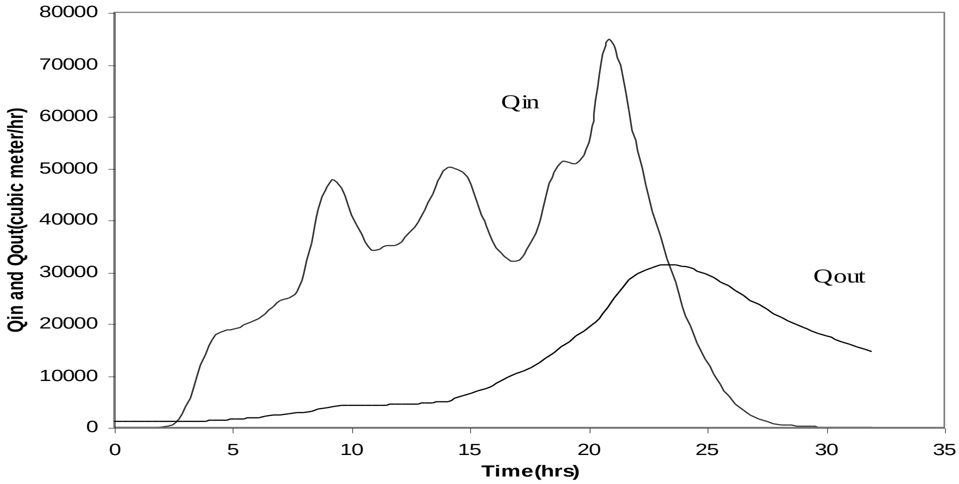

Figure 5: Stability design hydrograph plots

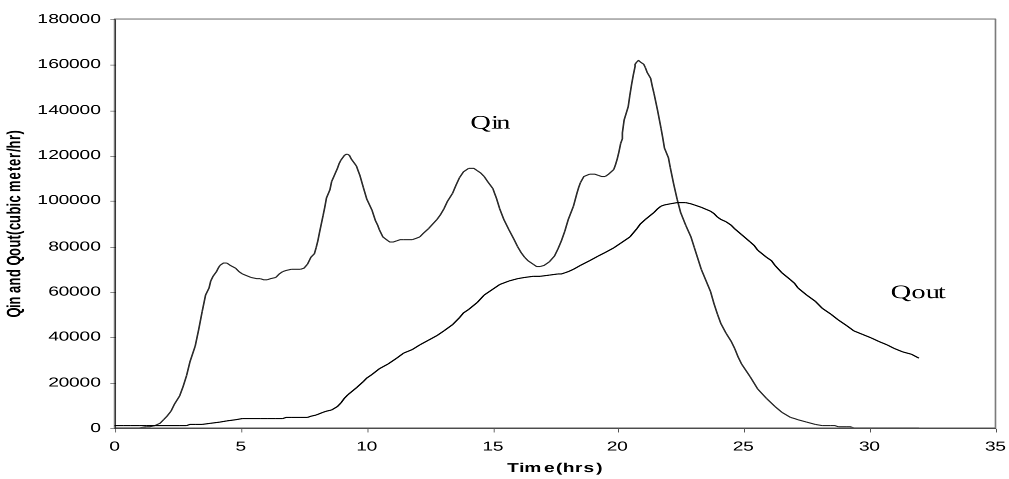

Figure 6: Freeboard hydrograph plots

2. CONCLUSION

From the above, we can conclude that the percentage reduction in peak flow for principal spillway hydrograph is 89%, for stability design hydrograph is 58%, and for freeboard hydrograph is 38%. The hydrograph data above are useful in checking the quick return flow, baseflow, starting elevations, and the effects of the routing. Hence Water Resources Site Analysis computer program (SITES) for Dams Design has being successfully applied to Ulasi River in Anambra state and the above results for single structure were obtained.

REFERENCES

Ejeahalaka, K.K. 1998. A Drinking water quality study of the Ulasi River at different locations in Ihiala L.G.A, Anambra state, Nigeria. Project report in Agric Engineering department, University of Nigeria pp.1-3

Ilo, 2003. Delineation of the Upper Ulasi River Catchment for resource management studies. A mini project report in Agric Engineering Department, University of Nigeria. P 3

USDA, 1996. United State Department of Agriculture. SITES: Water Resources Site Analysis computer program. User manual.

USDA, 2005. United State Department of Agriculture. SITES Water Resources Sites Analysis Computer Program, version 2000.5 User Guide

Ven, T.C. 1988. Hill series in Water Resources and Environmental Engineering. Mcgraw, London. P 242

Lobrecht M., 2007. SITES-Water Resources Sites Analysis Computer Program. Published by the American Society of Agricultural and Biological Engineers, St. Joseph, Michigan www.asabe.org

APPENDIX I: Abbreviations used in the Output

HYD TYPE	Hydrograph type
AMAX, AREA-MAX	Surface area at peak outflow in acres
AS	Auxiliary spillway
AUX	Auxiliary (reference to auxiliary spillway)
BTM or BW	Bottom width of auxiliary spillway
EMAX	Elevation at peak outflow
FBH	Freeboard hydrograph
HP	Flow depth at inlet to auxiliary spillway above its crest (H_p)
HYD	Discharge hydrograph
MAX	Maximum
NRCS	National Resources Conservation Service
PS	Principal Spillway
PSH	Principal Spillway hydrograph
Q	Discharge
Q-AUX	Discharge through auxiliary spillway
QMAX	Discharge at peak outflow
Q-PS	Discharge from principal spillway
Q-TOT	Same as Q-TOTAL
Q-TOTAL	Combined principal and auxiliary spillway discharge
Sc	Critical slope
SDH	Stability design hydrograph
TOT	Total
VOL	Volume

VOL-AUX	Volume to flow depth (H_p) in auxiliary spillway
VOL-MAX	Volume at peak outflow
WAVE BERM	Wave action beam width
25% of Q	Critical slope (based on ¼ of the peak discharge)

PERMEABLE REACTIVE BARRIERS AS A GROUNDWATER POLLUTION CONTROL ALTERNATIVE IN NIGERIA

J. N. Nwakaire[1] and C. C. Mbajiorgu[2]
Department of Agricultural and Bioresources Engineering
University of Nigeria, Nsukka, Nigeria.
Email: [1]joelnkem@yahoo.com
[2]const.c.mbajiorgu@talk21.com

ABSTRACT

Groundwater pollution is a worldwide phenomenon and the wide ranging consequences are gradually being realized. Research into methods of groundwater cleanup or remediation has increased and various techniques have been developed and applied. "*Ex situ*" pump-and-treat systems have been used widely, particularly in the United States of America. However, the success of such approaches has been questioned, considering the high costs involved, but the advantage lies in its long-term use which includes low cost of maintenance. As an alternative, "*in-situ*" treatment techniques that remove contaminants while the groundwater resides in the aquifer are being developed. The use of permeable reactive barriers as an alternative ground water pollution control was examined based on successful results from United States of America. Ways of applying such pollution control alternative in Nigeria were analyzed with special work done on categorizing the different pollutant regionally. Government support of such system with private partnership will aid successful implementation of the pollution control method.

KEYWORDS: Permeable reactive barriers, groundwater, pollution, control

1. INTRODUCTION

Groundwater quality comprises the physical, chemical, and biological qualities of ground water. Temperature, turbidity, color, taste, and odor make up the list of physical water quality parameters. Since most ground water is colorless, odorless, and without specific taste, we are typically most concerned with its chemical and biological qualities. Although spring water or groundwater products are often sold as "pure," their water quality is different from that of pure water. Naturally, ground water contains mineral ions. These ions slowly dissolve from soil particles, sediments, and rocks as the water travels along mineral surfaces in the pores or fractures of the unsaturated zone and the aquifer. They are referred to as *dissolved solids*. Some dissolved solids may have originated in the precipitation water or river water that recharges the aquifer. The importance of groundwater for the existence of human society cannot be overemphasized. Groundwater is the major source of drinking water in both urban and rural areas. Besides, it is an important source of water for the agricultural and the industrial sector. Water utilization projections for 2010 put the groundwater usage at about 50% (EPA 2003). Being an important and integral part of the hydrological cycle, its availability depends on the rainfall and recharge conditions. Till recently it had been considered a dependable source of uncontaminated water.

The quality of groundwater is affected by non-point source pollution from agricultural practices as well as disposal on the land of untreated wastes, as leachates carry contaminates into the groundwater body. The interest, therefore, is on the applicability of permeable reactive barriers (PRBs) as an in-situ ground water pollution control method. PRBs are a passive treatment technology used to treat contaminated groundwater consisting of a zone of reactive material(s) built below the ground to clean up polluted groundwater (EPA 2003). The reactive zone may be installed as a wall to intercept a migrating plume of contaminated groundwater or the contamination is funneled by a permeable barrier like slurry walls to a gate or vessel containing the reactive media. The reactive media is selected to absorb the pollutants from groundwater or to convert harmful chemicals to harmless by-products. PRBs are generally are used for long term treatments expected to be in service for years and can be used for remediation of areas with metallic contaminants, chlorinated hydrocarbons, chlorinated solvents, complex mixtures of different chemicals, organic and inorganic contaminants.

The objectives of the study are to establish a theoretical basis for use of the permeable reactive barriers and establish the regional groundwater pollutants in Nigeria. Also, the problems associated with existing methods of groundwater quality control were identified and different reactive or remediation materials for the identified pollutants recommended.

2. REVIEW OF LITERATURE

2.1 Principles of Groundwater Flow

Groundwater is one component of the earth's water cycle. The water cycle, called the hydrologic cycle, involves the movement of water as water vapor, rain, snow, surface water and groundwater. The earth's water is constantly circulating from the earth's surface up into the atmosphere and back down again as precipitation (see Figure 1, Hydrologic Cycle).

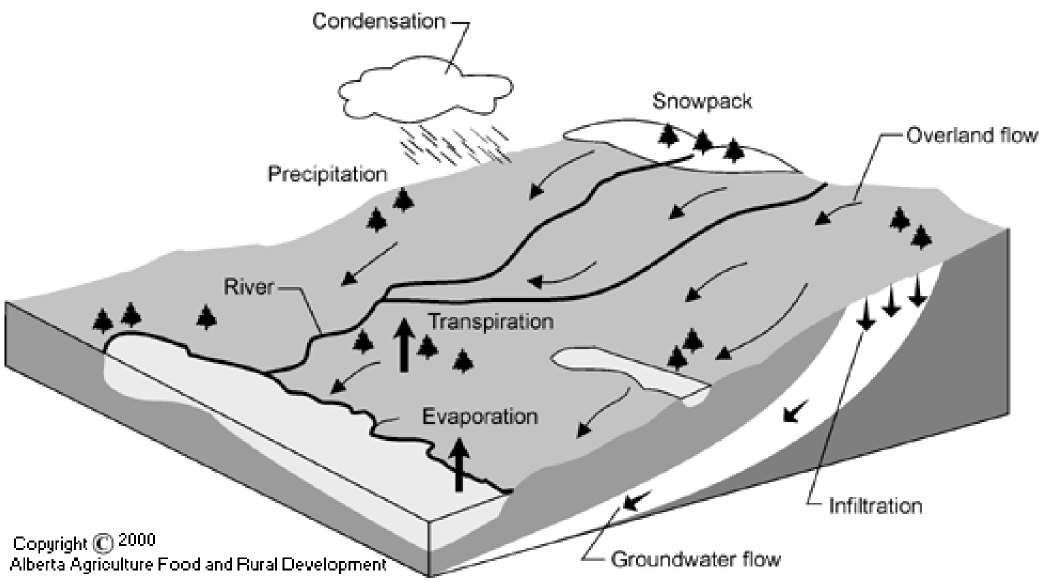

Figure 1. The Hydrologic Cycle

The layers of soil and rock below the water table are classified in two broad categories; aquifers and aquicludes.

Aquifers are water bearing layers (or formations) that yield water to wells in usable amounts. Typical aquifers are made of sand, gravel or sandstone. These materials have large enough pore spaces between grains that water moves freely. Coal and shale are also suitable aquifer materials provided they are fractured (or cracked) enough to allow water to move through them easily (David, 1959). *Aquicludes* are water bearing formations that cannot yield adequate water for wells. Examples of these are clay and unfractured shale and coal. The pore spaces between grains of these materials are so small that water moves extremely slowly. Unconfined aquifers are exposed directly to the atmosphere through openings in the soil. The volume of water in unconfined aquifers is mainly dependent on seasonal cycles of precipitation that refills the aquifer. A confined aquifer is trapped below an upper confining layer of rock, clay or shale. When a well is drilled into a confined aquifer, the water level rises above the level of the aquifer. Aquifers that are completely saturated with water and under pressure are called artesian aquifers (see figure 2). For every system there are principles governing the system. The filtration, percolation, extraction and eventual treatment of ground water, involves fundamental principles of groundwater movement. External forces that act on groundwater include gravity, pressure from the atmosphere and overlying water and molecular attraction between solid and water.

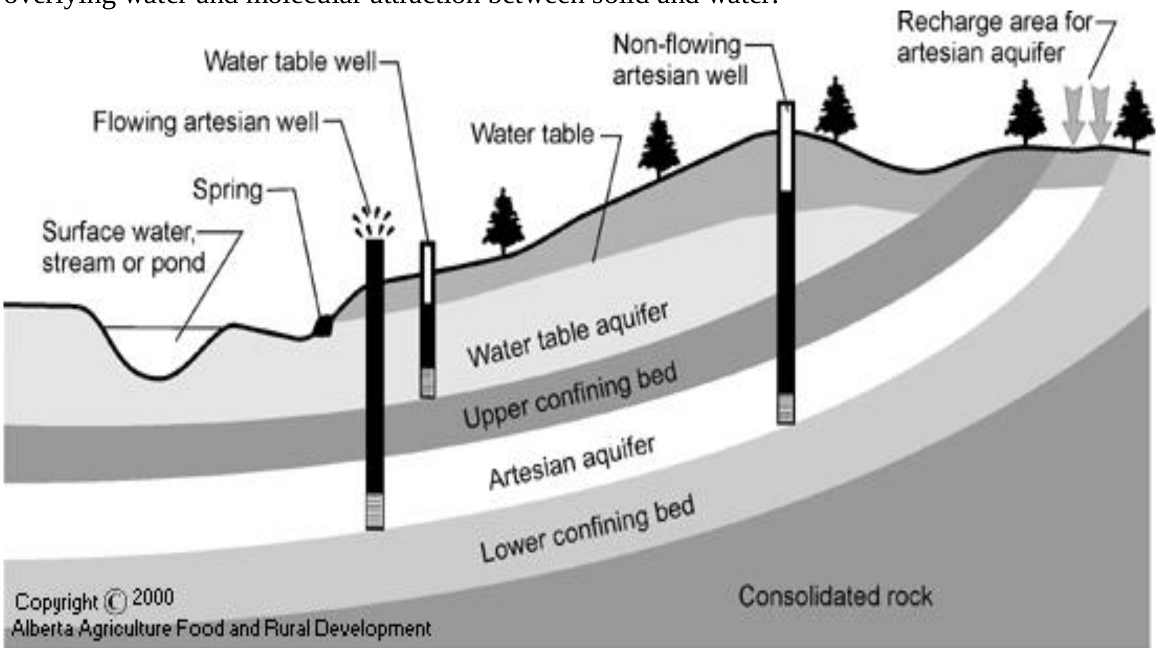

Figure 2: Types of Aquifers

In the saturated zone, groundwater flows through interconnected voids in response to difference in fluid pressure and elevation. The driving force is measured in terms of hydraulic head. Hydraulic head is defined by Bernoulli's equation (Riley and Parkin, 2000).

$$H = z + \frac{P}{\ell g} + \frac{V2}{2g}$$ --Eqn (1)

Where H is hydraulic head, z is elevation above datum, p is fluid pressure with constant density ℓ, g is acceleration due to gravity, and v is fluid velocity.

Pressure head (h*p*) is defined as $hp = {}^{P}/_{\ell g}$ --Eqn (2)

By convection, pressure head is expressed in units above atmospheric pressure. In 1856 Henry Darcy, a French hydraulic engineer studied the movement of water through porous material. He determined an equation that described groundwater flow, which states that the rate of flow is directly proportional to the hydraulic gradient (∂h/∂l or I) between the two points (Bouwer, 1978).

$$Q = KA\,{}^{\partial h}/_{\partial L} = KAI$$ ---Eqn (3)

Where Q is volumetric flow rate, A is cross-sectional area of flow, I is hydraulic gradient, and K is hydraulic conductivity.

The velocity of groundwater is based on hydraulic conductivity as well as the hydraulic head.

$$V = Q/A = KI \text{ -- Eqn (4)}$$

Where V is Volumetric flow velocity.

The hydraulic conductivity is a function of the properties of the porous medium and properties of the fluid

$$K = {k\ell g}/{\mu} \text{ -- Eqn (5)}$$

Where K is hydraulic conductivity, k is intrinsic permeability of porous medium, ℓ is fluid density, g is acceleration due to gravity, and μ is dynamic viscosity of fluid.

The intrinsic permeability of the porous medium is function of the shape and dynamic viscosity which is dependent upon water temperature. Fluid density is additionally dependent upon total dissolved solids. Hydraulic conductivity is governed by the size and shape of pores, effectiveness of the interconnection between pores and physical properties of the fluid. Darcy's Law is used extensively in groundwater studies. It helps to answer important questions such as what direction an aquifer pollution plume is moving in and how fast it is traveling. It is applied in describing the rate of flow through a porous medium. Like in treatment of groundwater with permeable reactive barrier (PRB) that is a permeable or porous medium. Darcy Law is applied in the treatment.

2.2 Groundwater Pollution Control

An understanding of the factors that affect groundwater quality can help you make decisions on well depth and the best water quality for a particular application. There are several factors that affect groundwater quality and they are; depth from surface, permeability and chemical makeup of the sediments through which groundwater moves, and climatic variations (Davies and De Wiest, 1996). Polluted water is determined through odour, taste, colour, bacterial analysis, and chemical analysis carried out to determine levels of chemicals present in the groundwater. There are three known pollutants in water which includes; Microbial/organic pollutant, Chemical pollutant or inorganic, and Solid sediment/geological pollutants. After identifying clearly the hazardous effects of pollutants in groundwater, it is clear therefore that a remediation action should be taken. Groundwater pollution control involves the reduction of the levels of individual pollutant in water, to a level that is permissible. Serious studies should be carried out on remediation technologies for groundwater pollution control. In groundwater pollution control options, there are two basic types which are; In-situ pollution control and Ex-situ pollution control method. Ex-situ method of treatment has been highly utilized over-time compared to in-situ method.

Ex-situ pollution control; this process involves the actual removal of water from the aquifer before pollution control measures are taken. The most common method of removing water from the aquifer is by pumping and once the water is removed it is treated. Therefore this method is called pump and treat method. This method can be subdivided into various aspects of pollution control which includes; physical pollution control after the water has been pumped out. The physical control method of ex-situ treatment involves screening, aeration, flocculation, sedimentation, and filtration. Another is chemical pollution control which involves the application of chemical control measures for the reduction of the levels of harmful chemical pollutants (Driscoll, 1987). This is carried out through coagulation, disinfection, water softening for reduction of the pollutants that causes hardness of water, and absorption.

Some disadvantages of Ex-situ pollution control option include; it is expensive on capital expenditure, and operation expenses, time wasting. It exposes the water to different chemical reagents. Other disadvantages include; high maintenance unlike the in-situ that can operate for long period without need for reagent substrate addition, high stringent control of operating condition, which makes management of such system high, natural filtration processes in the aquifer provide additional water quality improvement that is not found in ex-situ treatment, and it requires the use of pumps, moving parts or associated noise. It does not involve redox-based system that can often remove other contaminants e.g. chromate and organic chemical, if these are also present. It is less effective and inefficient.

In-situ treatment technique involves leaving the groundwater in place within the aquifer and adding the reagents to the aquifer. The reagents react with the inorganic contaminants within the aquifer and eliminate the problem. The treatment methods are divided into three main groups which are; Permeable Reactive Barrier (PRB) methods, Biological methods, and Electrochemical methods.

2.3 Overview of Permeable Reactive Barriers (PRBs)

Use of PRBs involve the physical placement of a barrier, consisting of reactive material, into a trench excavated in the aquifer. In other cases, a chemical reagent is injected into the aquifer to create the reactive barrier, for efficiency a primary aquifer is needed with well-defined, impermeable lower boundary. Zero-valent iron walls, are widely used for aquifer clean up operation in preference to pump and treat methods. A wide range of contaminants including arsenic, cadmium, chromium, copper, mercury, iron, manganese, molybdenum, nickel, lead, selenium, technetium, uranium, vanadium, nitrate, phosphate and sulphate, can be removed (EPA, 2003). PRB technology is a novel groundwater remediation method which enables physical, chemical or biological in-situ treatment of contaminated groundwater by means of reactive materials. The most commonly used processes/reactions are: redox-reactions, precipitation, adsorption, ion exchange and biodegradation. The reactive materials are placed in underground trenches downstream of the contamination plume forcing it to flow through them and by doing so; the contaminants are treated without soil or water excavation [Lin and Craig. 2004]. Generally, this cost-effective clean-up technology impairs the environment much less than other methods do. The arrangement of a PRB is illustrated in Figure 3.

The organic pollutants controlled by PRBs are; halogenated hydrocarbons which are found in deltaic zones due to oils spills which is removed by redox-reaction, aromatic compounds like benzene, toluene, ethylbenzen, xylene, and PAHs, etc., and nitro-aromatic compound, which can be reduced via nitroso and hydroxylamine form to the respective amino acids. Inorganic pollutant controlled by permeable reactive barriers includes; heavy metals controlled using precipitation process. Chemical precipitation is a process by which a soluble substance is converted into an insoluble form by a reaction with precipitant (. Frequently used precipitants are hydroxides, sulphides, phosphates, and carbonated. Examples of the heavy metals are, lead, chromium, uranium. PRBs are used also in the removal of non-metallic pollutants which include; nitrates, arsenate, and phosphate

Reactive material types used in the barriers are; those changing pH or redox potential, e.g. zero-valent iron: degradation of low chlorinated hydrocarbons, those causing precipitation, materials with high sorption capacity, and those releasing nutrients/oxygen to enhance biological degradation.

Positive results achieved so far are; reaction mechanisms and influences are well studied (especially for zero valent iron), reaction kinetics of many processes are understood enabling informed design, and Pilot test results suggest that large-scale application is feasible (EPA, 2003).

However, information on the long-term performance of PRBs is still required for a better understanding of the remediation processes. Also, construction techniques are in need of further development.

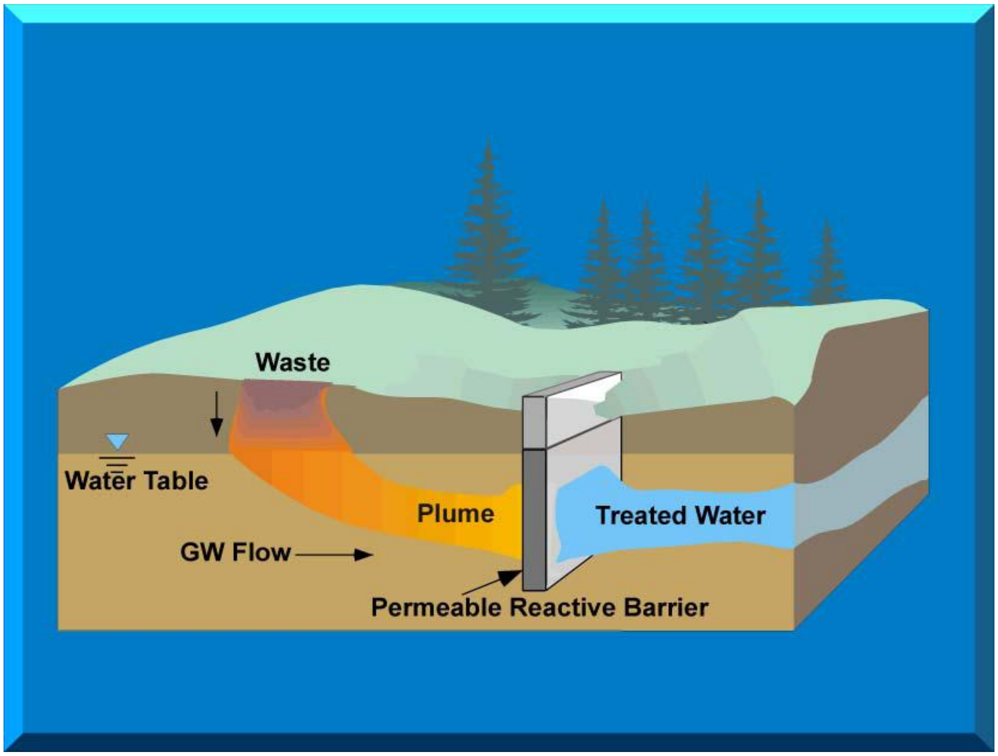

Figure 3: Permeable reactive barrier arrangement (EPA, 2003)

In Nigeria there is need to harness the advantages of this technology in establishing low cost groundwater pollution control systems. It is also important to note that presently in Nigeria, well water utilization is high and has become an important source of water supply in rural areas. Therefore the utilization of PRBs in Nigeria as a water pollution control alternative is viable. Typical examples of reactive media are (EPA, 2003), ion exchange resins for adsorption of metals and radio nuclides, zero valent iron for dechlorination of halogenated solvents, absorption of carbon disulphide or reduction of oxy-metal ions (e.g. chromate), limestone for precipitation of metals, activated carbon for absorption of organics, and sand/gravel beds with the addition of nutrients and oxygen to promote microbial degradation of organic contaminants.

2.3.1 Types of PRBs Design Systems

Two basic designs are used in full-scale implementations of reactive barrier are funnel and gate system, and continuous Trench.

Funnel And Gate System: basically requires an impermeable funnel typically consisting of inter locking sheet pilings or slurry walls is emplaced to encompass and direct the flow of contaminated water to a gate or gates containing the permeable zone of reactive (Fe) metal. The design must prevent the contaminant plume from flowing around the barrier. Due to directing large amounts of water through a much smaller cross-sectional area of the aquifer, ground water velocities within the barrier will be higher than those resulting from the natural gradient.

Continuous Trench: Simply a trench that has been excavated and simultaneously back filled with reactive medium allowing the water to pass through the barrier under its natural gradient.

2.3.2 Advantages and Disadvantages of PRBs

The advantages of PRBs include; actual in-situ contaminant remediation, rather than simple migration control as with impermeable barriers, passive remediation, reduced energy input and limited maintenance following installation, No required surface structures other that monitoring following installation, no alteration of the overall ground water flowing pattern as much as high volume pumping, remediates plumes even when the source term of plumes cannot be located, contaminants are not brought to the surface; i.e., no potential cross-media contamination, no disposal requirement or disposal costs for treated wastes, and avoids the mixing of contaminated and uncontaminated water that occur with pumping. Cost analysis conducted by United States Environmental Protection Agency (2003) shows that the initial cost of installation and use of PRBs is high when compared to that of pump and treat method. But the advantage of PRBs is that of reduced cost overtime. For instance according to that analysis, at the eight year, the present cumulative value of PRBs is $1,990,311, while that of Pump and Treat was $2,028,744.

For any process system, there must be the dark-side of using such system. Some of disadvantages are; the use of PRBS is currently restricted to shallow plumes, approximately 50 feet or less below ground surface, plume must be very well characterized and delineated, limited long-term field testing data is available and field monitoring is in its infancy stage, there is limited data concerning longetivity of wall reactivity or loss of permeability, and presently, initial cost of production of permeable reactive barriers is still high due to the fact that the technology is in its infancy stage. Overall, the United States Environmental protection Agency has supported the development of this innovative in-situ technology through collaboration with relevant research institutions to adequately provide the necessary backups for the proper implementation of this emerging technology.

2.4 Groundwater Pollutants in Nigeria

The regional categorization will be based on the geological features of the zone, agricultural practice, industrial location/mining activity, and deltaic/coastal features. The geological features of Nigeria include volcanic rock zones and sedimentary rock zones (like areas of Nasarawa, plateau, Benue state etc.) which form the underlying aquifers (Offodile, 1992). Due to ground water action most groundwater in these area are polluted with chemical that dissolved from minerals and rocks. In highly industrial areas of Nigeria like Port-Harcourt, Rivers state, and Lagos, there are serious possibilities of dangerous chemicals seeping or infiltrating into the aquifers cause serious ground water pH rise. The effect is higher acidity of ground water. Most dug wells in such areas are very unsafe to be used as source of domestic water resource point.

Mining zones like in Nasarawa, Benue, Enugu, Plateau, and Ogun etc, have ground water seriously polluted with nitrates from runoffs, and other chemicals with a lot of baterial build up. This is because there exist direct opening to the water tables due to mining activity. Most deltaic region have high water table, therefore there is a problem of infiltration of sewage and chemicals from fertilizers, and petro-chemicals into the ground water. This is because there is not much distance between the ground surface and the water table. Therefore, the situation where there is natural filtration through soil layers dose not actually exist. Wells dugs in such areas are seriously contaminated. Sometimes house hold sewage systems are dug near household wells, a situation that increases the contamination of such wells.

For coastal regions like Lagos, and Cross River, there are serious salt water intrusions into the groundwater. Most of the pollutants are therefore inorganic in nature, but in all cases ground water testing should be carried out to determine the pollutants present.

3. PROSPECTS OF USING PERMEABLE REACTIVE BARRIERS (PRBS) AS A WELL WATER POLLUTION CONTROL ALTERNATIVE

According to the United States Environmental Protection Agency (EPA) (2003), permeable reactive barriers stand to be just the right alternative for water pollution control. Once built, they have no moving parts, equipments or noise associated. The reactive materials placed in the permeable reactive material trench are not harmful to the ground water or to the people. The polluted ground water is cleaned underground, so there is no contact of clean up workers with the treated water. It offers water pollution control for different communities and households using well water supply systems.

Observations from different water pollution control points in Nigeria shows that the cost of pollution control measures are high, that is why most water pollution control operations are carried out by the federal and state agencies with less involvement of the private agencies. To alleviate the scarcity of pollutant free ground water, in areas with high water tables and well water utilization, there is need to introduce the utilization of PRBs. The involvement of extension workers who have been adequately trained in PRB services will be necessitated and increased, thereby creating rural employment opportunities for youths and others alike.

3.1 Consideration for PRB Installation

It requires information on contaminant concentration, contamination degradation rate in the presence of the reactive substrate and groundwater flow rate through the barrier be known. This allows determination of the required residence time in the zone needed to achieve remedial goals, hence allowing calculation of the required thickness of reactive zone. It will also enable the determination of the type of reactive barriers that will be used. The required site characterization tools will include; plume location, plume flow direction, concentration of contaminants, hydrologic changes with time, and aqueous geochemistry. Duration of the pollution control interval should be a tool that will be used during the modeling period. This therefore means that an accurate data is required to ascertain how long particular permeable reactive barrier are used before becoming ineffective.

3.2 Areas of Application of PRBs in Nigeria

There are various systems of harnessing groundwater, which includes well water systems, springs (natural harnessing system). In each of these systems, there is need for pollution control. For well water systems, it was noted that most rural areas in Nigeria that has high water table occurrence, utilizes shallow or dug wells for balancing their water needs. For instance in Nasarawa state, it was observed that almost each family or household visited there exist a shallow well that serves that household. Therefore it is necessary that most pollutant be controlled to a level that is safe for water utilization.

3.3 A Conceptual PRB System for Control of Well Water in Nigeria

The Conceptual model for pollution control in well water is the funnel and gate model. The funnel is the cylinder representing the well, and the gate is the PRB separating the untreated zone from the treated zone. The cylinder is divided into two layers made up of a PRBs that will control the polluted water coming by the side of the wall and the layer of impermeable barrier. The layer of permeable barrier is proposed to be above the water table and some distance into the saturated zone as shown in Figure 4 below.

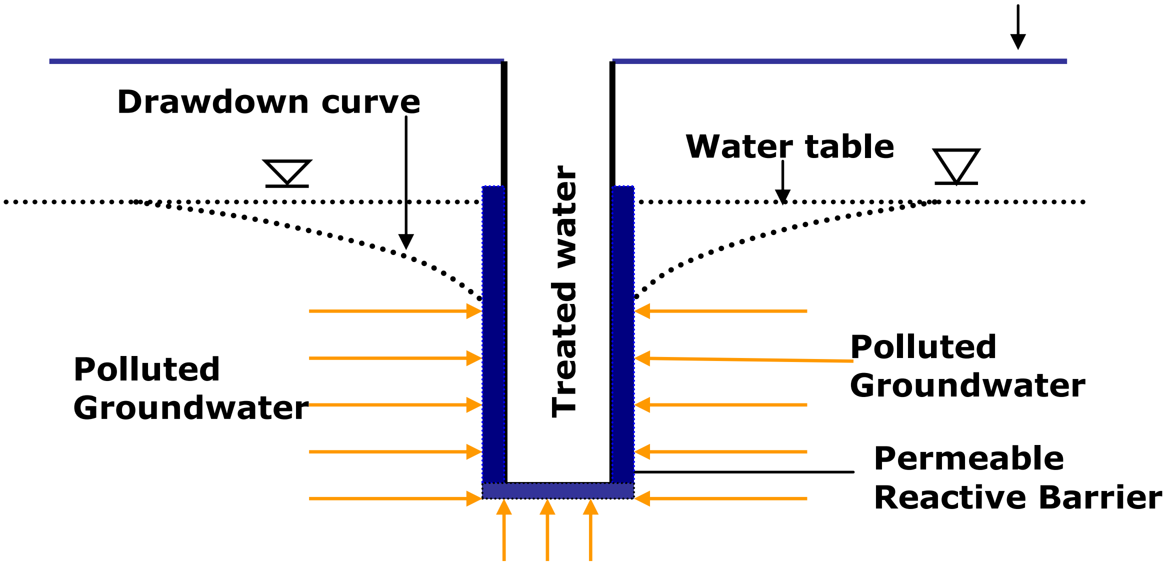

Figure 4: Model PRB design diagram for well water pollution control

The layer of impermeable barrier comprises of pipe made of concrete or asbestos materials adjoining the permeable cylinder. This arrangement is to ensure that ground water flow into the well must pass through the layer of PRBs.

3.4 Economic and Health Benefits of using Permeable Reactive Barriers

Economic benefits include the low operating and maintenance cost when compared to pump and treat method. The multi-treatment stage observed in other pollution control methods does not exist in PRBs. It is affordable and easily available, especially where adequate training on the production and use of such system has been done. The field of research provides more opportunity for business, attracting foreign investors in the area of permeable reactive barrier installation and production.

The health benefits of using PRBs include reduction in the changes that occur during mechanical handling of water which may affect users, and reduction in the risk of sickness as a result of high concentrations of hazardous materials in water.

4. CONCLUSIONS AND RECOMMENDATIONS

The world of research has continuously provided new innovations and technologies. These new innovations and technologies have continuously, in a positive way improved the lot of man on the earth. Most of these new innovations have focused on overall cost reduction in utilizing such system. Developing nations need to understand these emerging systems with a view of adapting and applying them to local systems and situations.

Permeable reactive barrier can be classified as an emerging water pollution control alternative. As analyzed so far, it was proved with salient points that permeable reactive barriers are an efficient system in ground water pollution control. The United States environmental protection agency has supported the development of this innovative in-situ technology through active collaboration with the National risk management Research laboratory and the National Exposure Research Laboratory of the United States and other relevant agencies. Existing research sites for permeable reactive barrier includes; Industrial Facilities Mountain View, California, Industrial Facilities, Belfast Northern Ireland (EPA, 2003), just to mention few. These examples prove that the technology is already in use. One thing of note is that most of these remediation sites are places where the water producing aquifers are nearer to the ground surface, and so the contaminated plumes are dug and the permeable reactive barrier laid. The use of permeable reactive barrier in well/ground water pollution control has been evaluated during the study so far, and was discovered to be a viable ground water remediation technology.

In Nigeria, ground water is the highest source of water supply for most domestic purposes. Against the backdrop of the consistent use of the pump and treat method, there is an urgent need to harness the opportunities provided as a water pollution control option. As a developing nation with lots of interest in low cost technologies, the use of permeable reactive barrier as a ground water pollution control alternative is viable and veritable. This is because this technology can be used for controlling both inorganic and organic pollutants in water. The proposed model for well water pollution control was designed to enable water pollution control technologies to reach remote villages and deltaic zones. This is to enable access to safe domestic water even in cases of oil spills.

Based on the above conclusions the following recommendations are made:

1. henceforth all efforts should be channeled into development of experimental sites where the proposed model can be simulated
2. government should partner with relevant agencies and researchers in developing a blue print for a successful exploitation of this technology
3. A detailed analysis and categorization of major pollutants of ground water in different zones of Nigeria should be done to help establish a data bank that will be used in production of different permeable reactive barriers for different pollutant in Nigeria
4. Funds should be made available for collaborative research studies on use of PRBs in Nigeria, in line with what was obtained in South Africa.

It is clear that there are serious health implications of using polluted ground water. Therefore proper pollution control measures should be utilized to ensure that pollutants levels are highly reduced. Thus it is not only important but highly necessary that critical effort should be made to harness the potentials of permeable reactive barrier as a ground water pollution control alternative in Nigeria, since it is viable.

REFERENCES

Alberta Agriculture Food and Rural Development, 2000. www.agric.gov.ab.ca/watercycle.html

Bouwer, H. 1978. Groundwater Hydrology. Mc Graw-Hill Book Company. New York, U.S.A. p.54-98.

David, K.T. 1959. Groundwater Hydrology. John Wiley and Sons Inc, New York, London. Pp. 44-53.

Davies, S. N and De Wiest, R. J.M. 1996. Hydrogeology. John Wiley and Sons Inc, New York, U.S. A. p.110-120.

Driscoll, F.G. 1987. Groundwater and Wells. Second Edition Johnson Division Saint Paul, Minnesota, U.S. A. p.89-91.

Lin Li, and Craig H. B. 2004. Impact of fouling on the long-term hydraulic behaviour of permeable reactive barriers. Department of Civil and Environmental Engineering, University of Wisconsin-Madison, Wisconsin 53706 U.S.A. p.56.

Offodile, M. E. 1992. An approach to groundwater study and development in Nigeria. Mecon Services Limited Jos, Nigeria. p.45.

Riley, M.S, and Parkin, G. 2000. Groundwater Hydraulics I: Flow through Porous Media. Water quality hydroinformatics and management systems, University of Newcastle England. P.34-67.

United States Environmental Protection Agency, Office of Research and Development 2003. Permeable Reactive Barrier Technologies for Contaminant Remediation. PA/600/R-98/125, US EPA, Washington DC 20460, U.S.A. www.epa.org/prb.html

OPTIMIZATION STRATEGY FOR LOW COST FARM BUILDING DESIGN IN NIGERIA

B. O.Ugwuishiwu[1] and B. O Mama[2]
[1]Department of Agricultural and Bioresources Engineering
[2]Department of Civil Engineering,
University of Nigeria, Nsukka, Nigeria.
E-mail: ugwuishiwubo@yahoo.co.uk

ABSTRACT

Fundamental criteria of economics are highlighted in this paper and applied to estimate the acceptable reliability level and optimal projected lifetime of farm buildings. For simple structures a very low safety class factor of safety of 10^{-2} is recommended. A developed life safety factor indicates that this safety level is acceptable, since for farm buildings the social consequences of structural failure are negligible. The most economical lifetime of farm buildings, based on Nigeria data is about 25 years. In special case a shorter projected lifetime is acceptable. Application of the adapted method results in a 5 - 10 percent cost of the total project cost.

1. INTRODUCTION

The farm tractor is one of the most important and easily recognizable technological components of modern agriculture in the world. Its development in the first half of the twentieth century fundamentally changed the nature of farm work, significantly altered the structure of rural areas of the world (White, 2000). The cardinal task of an engineer is to protect humans, animals, crops, property and the environment with structurally sound, functional, but cost effective, designs. He must consider many types of loading and must still make certain that the building serves its function properly (White, 2008).

Farm buildings commonly require engineering design for specific structural components (plates, post/stud sizes, bracing, footing sizes, etc). There are well known methods for computing the optimal dimensions of the load bearing structures, considering a target reliability level and a project lifetime (reference period). The reliability requirement may be prescribed by the expression [1]

$$P_f = \left[/ R(t) - S(t) / \leq 0 \right] \leq \frac{1}{r} \qquad (1)$$

$$0 < t \leq T_p$$

Where P_f is the failure probability, R(t) and S(t) are the time dependent resistance and stresses of the structure, 1/r is the risk of failure and T_p is the projected lifetime.[2]

Eq. (1) means that the time dependent probability of failure must not exceed a required minimum during the projected lifetime, i.e., for structural design it is necessary to presume an acceptable safety level and a reference period. The optional values both of P_f and T_p correspond to the minimum of the expected total costs.

To estimate the acceptable risk of failure, social consequences such as probability of loss of life, injury etc., also have to be considered. In case of farm buildings, when social consequences are negligible, the acceptable P_f can be determined by considering purely economic consequences.

The projected lifetime also has a great influence on the structural costs, since the adequate safety factors, corresponding to a certain target reliability level are less when the projected lifetime is the shorter [3]. For rural constructions, when the fast development of technology necessitates the cyclic exchange of fixtures and equipment, the physical and moral obsolescence of buildings is relatively quick. In this case, optimization of T_p is off great importance.

2. INVESTIGATION OF THE OPTIMAL PROBABILITY OF THE FAILURE

2.1 Economics

What level of P_f i.e. what design safety factors are the most economical? This can be determined by minimizing the expected total costs, C_T, including (i) the initial structural cost C_I, (ii) the maintenance cost C_M and (iii) the expected failure loss, P_fD, where D is the damage loss when failure occurs, i.e.

$$C_T = C_I + C_M + P_fD \tag{2}$$

Dependence of C_M on P_f is negligible; therefore the economical optimum of P_f can be obtained by minimization of

$$C_T = C_I + P_fD \tag{3}$$

It can be proved by regression analysis, that C_I is proportional to $\log_{10}\left(\frac{1}{P_f}\right)$

$$C_I = C_{I0} \Big/ 1 + a_1 \log_{10}\left(\frac{1}{p_f}\right) \tag{4}$$

Where C_{10} is the cost of structural component, which includes cost of material in place corresponding to a safety level, P_f of 10^{-3} or a safety index, β, of 3.09 and a_1 is a cost attenuation factor, which depends on the probability distribution of the basic variables (load, resistance, geometrical variables, etc), mainly on the coefficient of variation of resistance, V_R. Substituting Eq (4) in Eq (3) after minimizing, the most economical failure probability can be determined by equation.

$$\frac{1}{P_f} = \frac{\ln 10}{C_{I0}} . \frac{D}{C_{I0}} = \frac{2,3}{a_1}\delta D \tag{5}$$

Where δD is the ratio of the damage cost, D, to the cost of structural component, C_{I0}, explained above. In order to estimate an acceptable range of a_1 different structures were dimensioned [6] By calculations the cost attenuation factor considering the material consumption, a_{1m}, is within the range from 0.1 to 0.3. Assuming that cost of material on site, C_m is above 60 per cent of the initial building cost, C_I, (cp. Material, production, and assembling cost) an acceptable estimation of a_1 is

$$0.05 \le a_1 \le 0.12 \tag{6}$$

The lower values correspond to ductile materials with lower coefficient of variation ($V_R < 0.1$), while the higher ones are typical for brittle materials of $V_R > 0.15$. For practical purposes $a_1 = 0.08$ is suggested. Economical failure probabilities according to Eq. (5) are shown graphically in Fig. 1. It can be seen that P_{fQPT} is sensitive only to the order of magnitude of δD and increasing of total cost is slight above the optimum. The acceptable economical safety levels corresponding to = 25; 250; 2500; … are $P_f = 10^{-3}$; 10^{-4}; 10^{-5} respectively.

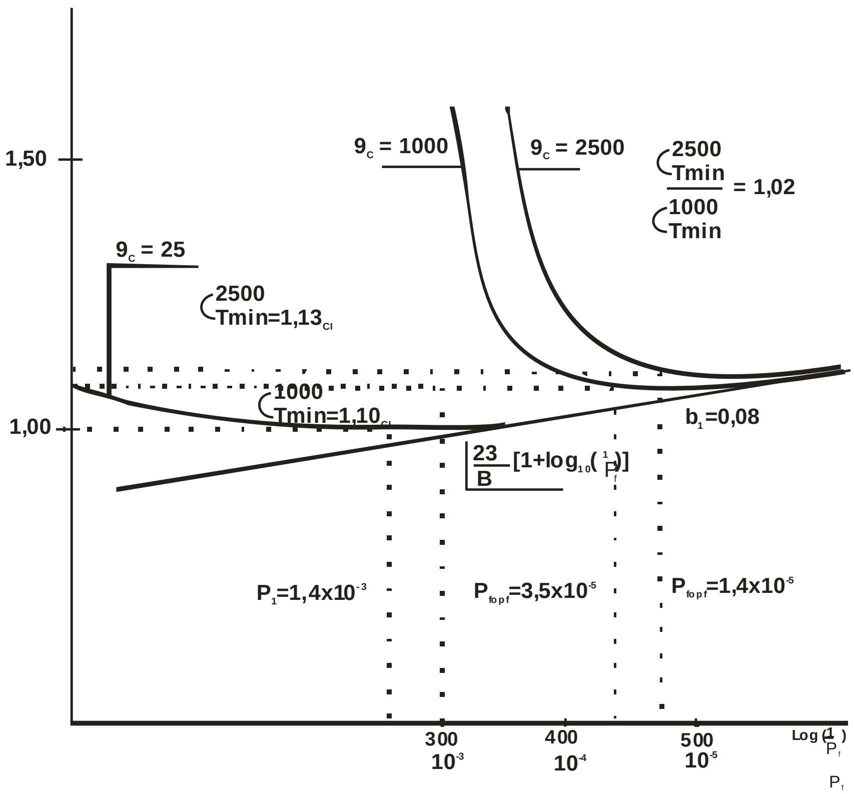

Fig. 1 Cost of safety (Source: Nagy, 1978)

2.2 Life Safety

Social consequences of structural failure, i.e. an acceptable risk to life can be estimated with the formula, suggested by [4]

$$P_{fs} = \frac{T_o A 10^{-5}}{W\sqrt{n}} \tag{7}$$

Where T_0 is the lifetime of the structure, which is assumed to be 50 years, A is the activity factor (A = 1.0 for buildings), W is a warning factor, n is the number of persons at risk and 10^{-5} is the annual failure probability. It is necessary to make difference between buildings on the basis of performance of human occupancy. For this purpose a duration factor is suggested.

$$H_D = \frac{T_H}{T_0 e} \tag{8}$$

Where T_H is the length of the human occupancy with relative values suggested in Table 1, and e is an escape factor with values suggested in Table 2. the developed life safety factor is

$$P_{fs}^{x} = \frac{P_{fs}}{H_D} \tag{9}$$

Table 1: The relative length of human occupancy (Source: Nagy, 1978)

Building	$\frac{T_H}{T_0}$
Working building (station, power plants)	1.0
Residential Building	0.7
Civic and industrial buildings	0.5
Farm buildings	0.2

Table 2: Values of the escape factor,e

Building	E
High building (n 10)[x]	0.1
Multi story living houses (n 5)[x]	0.7
Single storey living houses	1.5
Industrial buildings	2.0
Farm buildings	3.0

X n is the number of storey

3. DETERMINATION OF THE OPTIMAL LIFE TIME

The most economical value of the projected lifetime can be determined also by minimizing the expected total cost including C_I and C_M mentioned in part. 2.1 further increase the operating cost, C_{OP}. The building cost includes the cost of the permanent parts of the building, $C_{IP,}$ and cost of fixtures and equipment, designed for shorter lifetime, C_{IC}. The incurable maintenance expenditure can be divided into two parts such as cyclic maintenance cost, C_{CM}, continuous maintenance cost and surplus owing to obsolescence, C_{MO}. Each of these costs has to be considered with their discounted values. The most economical lifetime is obtained by minimizing the annual expected total cost.

$$\left[c(t) = \frac{1}{t} / \; pv\,(C_1; C_M; C_{OP}) \; / \right] \qquad (10)$$

Where Pv means present value, and t is the time.

It should be emphasized that in this case C_I signifies the cost of the building in running condition, while for optimizing the probability of failure that means the cost of the load bearing structures.
The discounted value of C_{OP} is approximately constant in time, therefore it can be neglected. The cyclic cost, C_{IC} and C_{CM} can be taken into account at the same time, in the end of the renewal cycle. The exponential increase of the cyclic costs is explained by the improvement of the technology and includes increase of pulling down, and repair costs.

A possible estimation (Nagy 1978) is

$$C_R^{(i)} = b_1 \exp\left(\frac{iT_1}{T_0}\right) C_{IC} \qquad (11)$$

Where $C_R^{(i)} = C_{IC}^{(i)} + C_{MC}^{(i)}$ is the discounted value of the reconstruction cost at the end of the i – th cycle, T_0 is the lifetime of the structure by the standards, which is assumed to be 50 years; T_1 is the length of the renewable cycle, C_{IC} is the initial cost of elements with lifetime T_1 and B_1 is a correction factor with values in Table 3.

Table 3: Values of the correction factor (b_1) (Nagy 1978)

Change of equipment without rebuilding	0.9
Change and partial rebuilding	1.0
Change and increased rebuilding	1.1

The continuous maintenance cost, C_{MO}, is also exponential in time, its average being proportional to the length of the renewable cycle. A practical estimation of the yearly average value of C_{MO} is 0.5 – 1.2 percent of the initial building cost. The moral obsolescence of the building can be considered by an increase of 15 – 30 percent, i.e., the acceptable range of C_{MO} is 0.6 – 1.5 percent of D_I.
Based on this the following formula is suggested.

$$C_{MO}(t) = \frac{T_1 \exp\left(\frac{2t}{T_0}\right)}{2\,T_0} \tag{12}$$

Where T_0 and T_1 are the same as in Eq.(11). If Eqs (11) and (12) substituted in Eq.(10), the most economical lifetime T_{OPT}, is obtained by minimization of

$$\frac{1}{t}\left(C_1 + \sum_{i=1}^{n} C_R^{(i)} C_{MO}\right) \tag{13}$$

Where n is the number of the renewable cycles, $n = \operatorname{int}\left(\frac{T_0}{T_1} - 1\right)$.

It should be noted that T_{OPT} depends on the ratio of C_{IC} to C_{IP}.

4. APPLICATION OF THE OPTIMIZATION METHODS OF FARM BUILDINGS

Farm buildings such as animal houses, horticultural buildings, storage buildings, etc., as it was mentioned above, are relatively simple constructions compared to industrial and civic buildings (cp. large rooms, simple structures, good escape roads, etc). The obsolescence of the technology necessitates the cyclic exchange of the equipment, which accelerates both physical and social obsolescence of the constructions.

4.1 Economical Failure Probability

Having the average value of the cost attenuation factor, a_1, suggested in 2.1, it is necessary to estimate δD. Damage cost, D, includes direct and indirect loss due to a structural failure. Direct loss, d, means the loss of the structure, equipment and goods (livestock, plants, stored materials etc.) in the building. Indirect loss d_i is the loss of income, i.e., the shortage of benefit during the rebuilding period.

Considering the usually uncomplicated equipment and fixtures in farm buildings, the production process can relatively easily be reorganized (e.g. in temporary buildings) the acceptable range of δD is 5-25. Substituting these values, and a_1 stated in Eq. (6) in Eq.(5), the range of economical failure probability of farm buildings is

$$10^{-2} \leq P_f \leq 10^{-3} \quad (14)$$

These values were calculated considering purely economic consequence of failure, and they suggest that the economical range of failure probability is greater by an order of magnitude than that is for "normal" buildings, i.e., the acceptable risk is about 10 times higher.

4.2 Life Safety of Farm Buildings

According to Nagy,1988, the expected maximum number of persons at risk in farm buildings is 2–20. The calculated value of H_D by Eq. (8) is 0.07 cp as shown in Table 1 considering the normal case when some warning is expected, i.e., W = 0.3, the safety levels based on Eq. (9) are

$$10^{-2} \leq P_{fs}^{*} \leq 10^{-3} \quad (15)$$

This also indicates that a lower safety level/safety class can be suggested for simple farm buildings.

4.3 Economical Lifetime

For farm buildings the length of the renewal cycle T_1, is about 5-10 years, on average it is 8 years. The ratio of C_{IP} to C_{IC} is 1:1 (50-50 percent) on average. This ratio is characteristic for buildings of intensive production. Considering above, Eq. (13) is shown graphically in Fig. 2. It is seen that the minimum of the average yearly total cost corresponds to $t \cong 25$ years. Further calculations show [5] that the length of the renewal cycle has hardly any influence on the optimal lifetime; furthermore that increase of the ratio of C_{IC} to C_I results in a decrease of the most economical lifetime.

These argument indicate that for buildings, where the total cost of the technology, C_{IC}, is more than 70 percent of the initial building cost in running condition, C_I, the projected lifetime of the structure can be chosen equal to the lifetime of the equipment, i.e. $T_P = T_1$.

4.4. Discussion

The basic criteria of economics can be applied to estimate the most economical values both of P_f and T for all kinds of structures, since the parameters, the optimal values depend on, can be determined. The values of failure probabilities, P_f, based on economics and P_{fs}^{x} based on life safety for farm buildings are about the same. By the calculations for simple constructions, such as hay storages, sheds etc. a lower safety class can be recommended. The economic based failure probability of farm building is greater by an order of magnitude than that is for "normal" engineering structures. Considering this greater P_f, a saving of 6-10 percent in material consumption can be expected. This corresponds to a 4-8 percent reduction in construction cost, C_I. For structures with higher cost attenuation factors, a_1, e.g. timber structures, and with very low failure loss, δD, the most economical failure probability can be extremely great (5×10^{-2}). In this case an over designing is suggested, since increasing of the total cost is slight above the optimum. The most economical lifetime of farm buildings was calculated on the basis of Nigerian experience. The values of different parameters are valid for constructions built for intensive agricultural production. In order to get more correct values, a detailed analysis of the total cost is necessary.

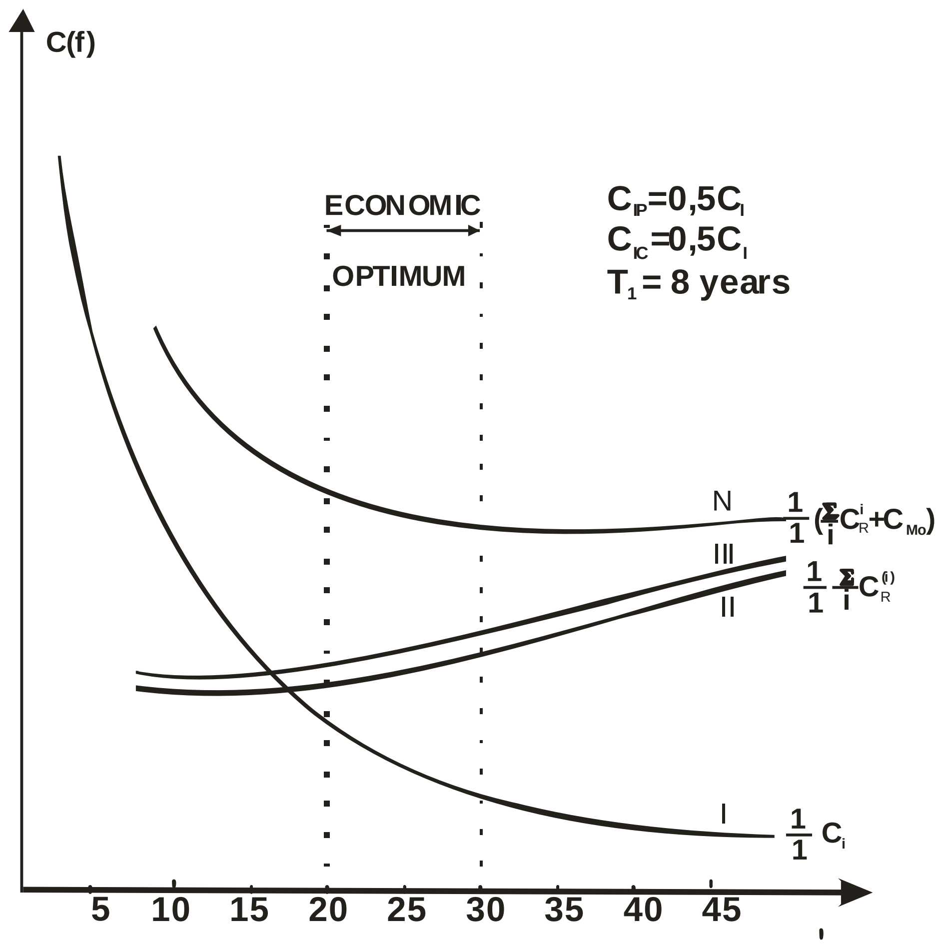

Fig. 2 Yearly Average Cost During the Lifetime (Source: Nagy, 1988)

Decreasing of the projected lifetime results in a saving of material consumption since the adequate design values of resistance increase while those of loads decrease when the projected lifetime is shorter (see part 1). Influence of the projected lifetime on building cost is the most characteristic for timber structures, where the time dependence of resistance is significant [4]. For example a timber construction projected for T = 30 years is able to fulfil the reliability requirement in a lower safety class until the age of 50. This can be considered when designing multi purpose constructions.

5. CONCLUSION

Application of the strategy introduced in the paper is suggested especially for prefabricated structures on serial production, when more accurate structural analysis and quality assurance is possible. Further research work is needed in the field of loads and structural safety of farm buildings with emphasis on: reliability analysis of typical existing structures; influence of the lifetime on the structural safety, especially for timber structures; determination of the adequate design values of special loads, such as animal loads, live loads of floors, wall pressure in horizontal bins etc.

REFERENCES

Allen, D.E. 1981. Criteria for Design Safety Factors and Quality Assurance Expenditure in T. Moan and M.Shinozuka (eds.) Structural Safety and Reliability. Van. Nostrand Co New York

John Johnson 2004. Engineering Requirements for Farm Structures, Order No. 93-009, Oxford University Press, New York

Misteth, E. 1977. Principles of Economical Dimensioning of Multi-purpose Constructions (Dissertation in Hungarian), Budapest.

Nagy, T. 1978. Principles of structural design of farm buildings Scientific Review of Civil Engineering 37.Wesley Pub. Co. New York

Nagy, T. 1988. Influence of the designed lifetime on the reliability of timber structures in C.M. Dolby (ed.) Documentation of the CIGR Section II Seminar.

White, W. J. 2008. “Economic History of Tractors in the United States". EH.Net Encyclopedia, edited by Robert Whaples. zURL

White, W. J. 2000. “An Unsung Hero: The Farm Tractor’s Contribution to Twentieth-century United States Economic Growth.” Ph.D. dissertation, Ohio State University, http://eh.net/encyclopedia/article/white.tractors.history.us

GUIDE FOR AUTHORS

Publication Schedule: The Journal of Agricultural Engineering and Technology (JAET) is published annually by the Nigerian Institution of Agricultural Engineers (NIAE), A division of the Nigerian Society of Engineers (NSE).

Manuscript: The manuscript should be typed double spaced on A4 paper (216mm x 279mm) on one side of the paper only, with left, right and top-bottom margins of 25.4mm. The original and three copies are required for initial submission. The paper should not exceed 20 pages including Figures and Tables.

Organization of the Manuscript: The manuscript should be organized in the following order; Title, Author's name and address including E-mail address and telephone number; Abstract; Keywords; Introduction; Materials and Methods; Results and Discussion; Conclusion; Notation (if any); Acknowledgements; References. The main headings listed above should be capitalized and left justified. The sub-headings should be in lower case letters and should also be left justified. Sub-sub headings should be in italics. All headings, sub-headings and sub-sub-headings should be in bold font. Headings and sub-headings should be identified with numbers such as 1; 1.1; 1.1.1 etc. For the sub headings, the first letter of every word should be capitalized.

Title: The title should be as short as possible, usually not more than 14 words. Use words that can be used for indexing. In the case of multiple authors, the names should be identified with superscripted numbers and the addresses listed according to the numbers, e.g. A. P. Onwualu[1] and G. B. Musa[2].

Abstract: An abstract not exceeding 400 words should be provided. This should give a short outline of the problem, methods, major findings and recommendations.

Keywords: There should be keywords that can be used for indexing. A maximum of 5 words is allowed.

Introduction: The introduction should provide background information on the problem including recent or current references to work done by previous researchers. It should end with the objectives and contribution of the work.

Materials and Methods: This section can vary depending on the nature of the paper. For papers involving experiments, the methods, experimental design and details of the procedure should be given such that another researcher can verify it. Standard procedures however should not be presented. Rather, authors should refer to other sources. This section should also contain description of equipment and statistical analysis where applicable. For a paper that involves theoretical analysis, this is where the theory is presented.

Results and Discussion: Results give details of what has been achieved, presented in descriptive, tabular or graphical forms. Discussions on the other hand, describe ways the data, graphs and other illustrations have served to provide answers to questions and describe problem areas as previously discussed under introduction.

Conclusion: Conclusion should present the highlights of the solutions obtained. It should be a brief summary stating what the investigation was about, the major result obtained and whether the result were conclusive and recommendations for future work, if any.

Notation: A list of symbols and abbreviation should be provided even though each of them should be explained in the place where it is used.

References: Follow the name-date system in the text, example: Ajibola (1992) for a single author; Echiegu and Ghaly (1992) for double authors and Musa et al. (1992) for multiple authors. All references cited must be listed in alphabetical order. Reference to two or more papers published in the same year by the same author or authors should be distinguished by appending alphabets to the year e.g. Ige (1990a, 1992b). All references cited in the text must be listed under section “References”. For Journal, the order of listing should be author’s name, year of publication, title of paper, name of journal, volume number, pages of the article: for books, the author’s name comes first followed by the date, title of book, edition, publisher, town or city of publication and page or pages involved. Examples are as follows:

Journal Articles: Ezeike, G. O. I. 1992. How to Reference a Journal. J. Agric Engr and Technology. 3(1): 210-205

Conference Papers: Echiegu, E. A. and Onwualu A. P. 1992. Fundamentals of Journal Article Referencing. NSAE paper No 92-0089. Nigerian Society of Agricultural Engineers Annual Meeting, University of Abuja, Abuja – Nigeria.

Books: Ajibola O. 1992. NSAE: Book of abstracts. NSAE: Publishers. Oba. Abakaliki, Nigeria.

Book Chapter: Mohamed S. J., Musa H. and Okonkwo, P. I., Ergonomics of referencing. In: E. I. U. Nwuba (Editor), Ergonomics of Farm Tools. Ebonyi Publishing Company, Oshogbo, Osun State, Nigeria.

Tables: Tables should be numbered by Arabic numerals e.g. Table 3 in ascending order as reference is made to them in the text. The same data cannot be shown in both Table and Figure. Use Table format to create tables. The caption should be self explanatory, typed in lower case letters (with the first letter of each word capitalized) and placed above the table. Tables must be referred to in the text, and positioned at their appropriate location, not at the end of the paper.

Figures: Illustrations may be in the form of graphs, line drawings, diagrams schematics and photographs. They are numbered in Arabic numerals e.g. Figure 5.m. The title should be placed below the figure. Figures should be adequately labeled. All Figures and photographs should be computer generated or scanned and placed at their appropriate locations, not at the end of the paper.

Units: All units in the text, tables and figures must conform to the International System of units (SI)

Reviewing: All papers will be peer reviewed by three reviewers to be appointed by the Editors. The editors collate the reviewers’ reports and add their own. The Editor-In-Chief’s decision on any paper is final.

Off Prints: A copy of the journal is supplied free of charge to the author(s). Additional reprints can be obtained at current charges.

Page Charges: The journal charges a processing fee of N1000 and page charges are currently N500 per journal page. When a paper is found publishable, the author is advised on the page charges but processing fee (non refundable) must be paid on initial paper submission. These charges are subject to change without notice.

Submission of Manuscript: Submission of an article for publication implies that it has not been previously published and is not being considered for publication elsewhere. Four copies of the manuscript and N1000 processing fee should be sent to:

The Editor-In-Chief
Journal of Agricultural Engineering and Technology (JAET)
C/o The Editorial Office
National Centre for Agricultural Mechanization (NCAM)
P.M.B. 1525, Ilorin, Kwara State
Nigeria.

Papers can also be submitted directly to the Editor-In-Chief or any of the sectional Editors (See address in a current volume of the journal). Those who have access to the internet can submit electronically as an attached file in MS Word to the Editor-In-Chief's e-mail box. (ponwualu@yahoo.com or ifeeolife@yahoo.com).