The First UNIUYO & GIST
Joint Programme Workshop

WATER SECURITY
FOR A SUSTAINED TRANSFORMATION

June 15 ~ 18, 2015
Abuja, Nigeria

Programme Coordinators:
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International Centre for Energy and Environmental Sustainability Research (ICEESR), University of Uyo, Uyo, Nigeria

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PROCEEDINGS OF THE FIRST INTERNATIONAL WORKSHOP ON WATER SECURITY FOR A SUSTAINED TRANSFORMATION

June 15 - 18, 2015

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WELCOME ADDRESSES

Welcome Address by the Director of ICEESR

It is with great excitement and gratitude to God that I welcome all participants to the First UNIUYO & GIST Joint Programme Workshop on "Water Security for a Sustained Transformation" held in the beautiful city of Abuja, Nigeria. It is a privilege that the International Centre for Energy and Environmental Sustainability Research (ICEESR), University of Uyo, Nigeria is able to host this event.

The University of Uyo and Gwangju Institute of Science and Technology (GIST) linkage programme commenced on May 6, 2013, after the signing and exchange of Memorandum of Understanding (MOU) between the two institutions. The linkage programme has over the past two years witness several activities in the areas of research and training. Five Nigerians in the 2013 batch of trainee participated in a training programme in GIST, Korea funded by the United Nations Office for South South Co-operation. The 2014 batch which includes participants from other African Countries including Ghana and Cameroun will proceed for the training this August while the 2015 batch will have their opportunity in October, 2015. These trainings are all geared towards building local capacities in sustainable water resources management. Today we are happy to be starting another activity, the Joint Programme Workshop with the aim of building international multi disciplinary network for advancing research in water science and technology for sustainability.

The topic for discussion during this workshop is apt at the moment as the United Nation's Millennium Development Goals (MDGs) to achieve "sustainable access to safe drinking water" reaches the target by the end of 2015. It is also pertinent to note that water is at the core of sustainable development and is critical for socio-economic development, healthy ecosystems and for human survival. Today, it is estimated that about 1.7 billion people live in water basins where depletion through use exceeds natural recharge, a trend that would see two-thirds of the world's population living in water-stressed countries by 2025. Furthermore, Africa is known to be the second-driest continent in the world after Australia and has the highest number of countries that will experience water stress and water scarcity. This challenge is further compounded by global climatic changes, insufficient and/or improper treatment of water and wastewater, rapid growth in population and urbanisation. To address these challenges and achieve water security, joint efforts are needed, including transforming to green

and sustainable technologies, promoting public participation, and establishing water quality standards that is in tandem with 21st century innovations. In all these, science and technology is pivotal.

The major aim of this workshop is to provide a platform for exchange of knowledge and research experiences from different disciplines and countries in order to address key issues relating to water security. It is hoped that the workshop programme will also present opportunities for networking and collaboration among participants, particularly between those from developing countries in Africa and a developed country South Korea as well as provide an avenue to engage in discussions about new trends in scientific research.

I use this opportunity to very specially thank International Environmental Research Centre, Gwangju Institute of Science and Technology, United Nations Development Programme, United Nations Office for South-South Co-operation in South Korea, University of Uyo, Vandrezzer Energy Services Limited, ICEESR, and others, whose efforts have contributed to the success of this workshop. Finally, I wish every participant a profitable and pleasant stay in Abuja!

Edu Inam, PhD
Director, International Centre for Energy and Environmental Sustainability Research (ICEESR) and Acting Director, Centre for Research and Development, University of Uyo, Uyo, Nigeria

Welcome Address by the Director of IERC

I am grateful for the opportunity that the International Environmental Research Center (IERC) is able to be a co-organizer for the UNIUYO and GIST Joint Programme Workshop, 'Water Security for a Sustained Transformation.' IERC has had a long standing tradition of developing international scientific collaborative networks, however primarily many of our past efforts have been in Southeast Asia. We are very excited to help in establishing a stronger relationship with our institute and partners in Africa. In this light of new endeavors for fostering collaborative research with developing countries, I sincerely hope that this workshop promotes engaging scientific discussion and lays the groundwork for further international collaboration.

Prof. Heechul Choi
Director, UNU & GIST Joint Programme
International Environmental Research Center
Gwangju Institute of Science and Technology, Korea

Preface

The United Nations Development Programme (UNDP) continually works towards achieving the eradication of poverty, and the long-reaching effects of inequalities and exclusion. UNDP works in more than 170 countries and territories by assisting with developing policies, promoting leadership skills and partnering abilities, improving institutional capabilities, and contributing towards sustainable development results.

In cooperation with the Korean Government, the Special Unit for South-South Cooperation under the UNDP is able to contribute support to the UNU & GIST Joint Programme. In turn we were able to host this special June 16-17 workshop with our regional partner, the International Centre for Energy and Environmental Sustainability Research (ICEESR), University of Uyo, in Abuja, Nigeria for 2015. One of the main functions of this program managed by UNDP is to provide opportunities and resources for local stakeholders, so that they can be active participants in solving issues related to the Millennium Development Goals. I feel that our outcomes from this workshop will certainly aid in fulfilling the mission goals of UNDP.

The topics discussed in this workshop address not only to improving sustainability, but also improving the well-being and public health of the region by tackling the difficult issues related to water resources in Sub-Saharan Africa. I sincerely hope that this workshop allows for an exchange of ideas and solutions, and can build a foundation where regional partners can work with Korea, UNDP, ICEESR, and IERC-GIST in achieving current and future Millennium Development Goals.

Kenneth Widmer
Research Assistant Professor
International Environmental Research Center
Gwangju Institute of Science and Technology, Korea

Workshop Programme

Day 1: Monday, June 15, 2015 (Arrival)

Day 2: Tuesday, June 16, 2015

Morning Session

08.30 – 9.30	Registration
09.30 – 9.50	Welcome Addresses: (i) Dr. Edu Inam, Director, International Centre for Energy and Environmental Sustainability Research (ICEESR), University of Uyo, Uyo, Nigeria; (ii) Prof. Heechul Choi, Director, UNU & GIST Joint Programme
09.50 – 10.05	Overview of the University of Uyo, Uyo –Prof. (Mrs) Comfort Ekpo, Vice Chancellor, University of Uyo.
10.05 – 10.25	Overview of International Environmental Research Center (IERC) –Dr. Kenneth Widmer
10.25 – 10.35	Coffee Break
10.35 – 10.50	Overview of the University of Benin, Benin City –Prof. Felix Okieimen, Director, GeoEnvironmental and Climate Change Adaptation Research Centre (GECCAR), University of Benin, Benin City, Nigeria
10.50 – 11.10	Goodwill messages and presentation by Mr. Joe Udofia, Managing Director, Vandrezzer Energy Services Limited.
11.10 – 11.50	Korean Science, Technology Innovation Development and UN Post-2015 Sustainable Development Goals –Dr. WooSung Lee, Director, Global Policy Research Center, Science and Technology Policy Institute, South Korea
11.50 – 12.10	Participants Expectations and Feedback –Dr. Edu Inam, Director, ICEESR
12.10 – 12.40	Group Photograph
12.40 – 13.40	Lunch Break

Session 1:
ADVANCES IN MONITORING AND RISK ASSESSMENT OF WATER POLLUTANTS

Chair: Prof. Joseph P. Essien (ICEESR) / Dr. Suil Kang (IERC)

TIME	TOPIC AND SPEAKER
13.40 - 14.00	Prevalence and Impact of E. coli in Southeast Asian Surface Waters – Approaches to Rapid Monitoring Methods – **Kenneth Widmer**, UNU & GIST Joint Programme, Korea
14.00 - 14.20	Chemical and Radiological Health Risks Assessment of Radionuclides in Water Sources in Akwa Ibom State, Nigeria – **Inime Udoh & Kufre Ite**, ICEESR, UNIUYO
14.20 - 14.40	Occurrence and Ecological Risk Assessment of Endocrine Disruptors, Pharmaceuticals and Personal Care Products in Ikpa River Basin, Nigeria – Nnanake-Abasi Offiong, ICEESR, UNIUYO
14.40 - 15.00	Physicochemical Quality of Surface and Ground Water from Municipal Waste Dumpsite Impacted Environment – Idongesit Ambrose, Akwa Ibom State Ministry of Environment and Mineral Resources, Uyo - Nigeria
Session 3:	Climate Change, Waterborne Diseases and Public Health
15.00 - 12.20	Impacts of Climate Variability on Wetland and Fishing Households in the Niger Delta Region, Nigeria – Valerie Solomon, Department of Agric. Economics and Extension, Faculty of Agriculture, University of Uyo, Nigeria
15.20 - 16.00	Discussions and Networking

DAY 3: WEDNESDAY, JUNE 17, 2015
SESSION 2: WATER AND WASTEWATER TREATMENT TECHNOLOGIES

Chair: Dr. Effiom Oku (UNU-INRA) / Dr. Kenneth Widmer (IERC)

Morning Session:

TIME	TOPIC AND SPEAKER
09.00 – 09.20	Opening Remarks –Dr. Kenneth Widmer
09.20 – 09.40	Biofiltration Potentials of two Saprophytic Fungi of a Brewery Effluent – **Adeniyi Sanyaolu**, Department of Botany and Ecological Studies, Faculty of Science, University of Uyo, Uyo, Akwa Ibom State, Nigeria
09.40 – 10.00	Enhanced Adsorption of Phenol on Bentonite Intercalated with Quaternary Ammonium Cation–**L.B. Okenwa & Felix Okieimen**, University of Benin, GeoEnvironmental & Climate Change Adaptation Research Centre, Benin City, Nigeria
10.00 – 10.20	Crude Oil – and PAH– Degrading Bacteria Isolated from Humic Freshwater Ecosystem of Eniong River, Nigeria – **G. E. Udofia,** Department of Microbiology, University of Uyo, Uyo, Nigeria
10.20 – 10.40	Treatment Performance of Waste Stabilization Ponds. The case of VRA treatment plant at Akosombo, Ghana –**Richard Amfo-Otu**, Department of Environmental and Natural Resources Management, Presbyterian University College, Ghana
10.40 – 11.00	Water Purification Process using Plant Extracts from *Acacia Nilotica* Pod Powder and *Eucalyptus Citriodora* Exudates as Coagulants –**Enoobong Sunday Nicholas,** Department of Pure and Industrial Chemistry, Faculty of Physical Sciences, University of Nigeria, Nsukka, Enugu State, Nigeria
11.00 – 11.20	Remediation of Water Works Supernatant Return Flow: Resource Recovery and Utilization Strategy for Sustainable Development –**N. V. Anyakora**, Research Unit, Federal Capital Territory Water Board, Abuja, Nigeria
11.20 – 11.40	Enhanced Biodegradation of PAHs Using Biosurfactant Producing Bacteria from a Humic Freshwater Ecosystem of Eniong River, Itu, Nigeria – **Nsikak Abraham** , Microbiology Research Unit, International Centre for Energy & Environmental Sustainability Research (ICEESR), University of Uyo, Uyo, Nigeria
11.40 – 12.40	Lunch Break

Afternoon Session:
Chair: Prof. Anthony W. Akpan (UNIUYO) / Prof. Felix Okieimen (GECCAR)

12.40 - 13.00	Treatment Technologies for Emerging Contaminants in Wastewaters –**Sanda Idiat Modupe,** Federal Ministry of Environment, Maitama, Abuja, Nigeria
13.00 - 13.20	Waste Water Tre atment and Emerging Waste Water Contaminants –**Obinna JohnPaul Opata,** Federal Ministry of Environment, Pollution Control & Environmental Health Department, Marine Contaminant Clean-up & Remediation Division, Abuja, Nigeria
13.20 - 13.40	Transforming Indus trial Wastewater Management in Africa with a Green Technology – **Effiom Oku**, United Nations University, Institute for Natural Resources in Africa (UNU-INRA), Ghana
13.40 - 14.00	Removal of Methylene Blue from Aqueous Solution using Calcined Cow Bone –**Patrick Akpan**, Department of Science Technology, Akwa Ibom State Polytechnic, Ikot Osurua, Nigeria

Session 4: "Speed Dating" Session

14.00 - 15.00	Networking Session
15.00 - 15.30	Closing Discussion: The Way Forward

Day 4: Thursday, June 18, 2015 (Departure)

CONTENTS

Introducing ICEESR

The International Centre for Energy and Environmental Sustainability Research is a newly created R & D centre in the University of Uyo, Uyo, Akwa Ibom State, Nigeria dedicated to generation and transfer of knowledge, strengthening individual and institutional capacities in furtherance of the mission and vision of the University of Uyo. ICEESR is envisaged to be a model research centre for international technological cooperation and has linkages with renowned International Research Centers like the Massachusetts Institute of Technology's Media Laboratory, USA, Strategic Energy Institute, Georgia Institute of Technology, USA, the International Environmental Research Centre at Gwangju Institute of Science and Technology, Korea, and the American Chemical Society. In ensuring sustainability of research and training excellence ICEESR brings in private ownership through a consortium of local, national and international businesses and governments. For partnership and collaboration opportunities please contact:

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IERC at a Glance

Situated on the campus of the Gwangju Institute of Science and Technology, the UNU Pilot Programme on Science and Technology for Sustainability was founded in 2001 and operated until 2003. In 2004, the Korean government committed larger financial support and the UNU & GIST Joint Programme on Science and Technology for Sustainability was established with the management of the Programme conducted by the International Environment Research Center. IERC has implemented three main aspects of the UNU & GIST Joint Programme:

- To carry out research and training in science and technology for environmental sustainability.
- To contribute to capacity building of developing countries in the area of sound environmental management and sustainable development.
- To disseminate the information and advisory services through an international environmental information network.

Since 2004, IERC has continued these mission goals and expanded its efforts of scientific research, international collaboration, and information dissemination (as both educational and professional development programs) continuously promoting work with developing countries. With a supporting budget of 1.5 mil USD/year, IERC is fully expecting to continue its mission and broaden our outreach with new partners and strive to address the pressing environmental and societal issues regarding future sustainability, particularly those challenges facing developing countries.

Overview of University of Uyo, Uyo, Akwa Ibom State, Nigeria

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VICE CHANCELLOR
Professor (Mrs.) Comfort Memfin Ekpo
BLS, Ed. M.Ed.(Zaria) Ph.D(Wales)

The University of Uyo was established on October 1, 1991 by the Federal Government of Nigeria. The University inherited students, staff, academic programmes and the entire facilities of erstwhile University of Cross River State, Uyo, established by the then State Government in 1983. Academic activities in the University of Uyo commenced in 1991/92 session.

Location: The University is located in the heart of Uyo, capital of Akwa Ibom State, Nigeria. Akwa Ibom is the largest oil producing state in Nigeria. Uyo is easily accessible by road and there are two international airports within 100 km radius, the Margaret Ekpo International airport, Calabar, and Ibom International airport, Uyo. Currently, the University operates from five campuses: Ime Umana Campus for Pre Degree Programmes, Medical Campus, the Town Campus as well as Town Campus Annexe and the Main Campus. These campuses are within 10km from the city centre.

Population: The University of Uyo has One thousand four hundred and six (1,406) academic staff of which one hundred and twenty five (125) are full professors. The number of senior non-academic staff is one thousand one hundred and seventy-five (1,175) while one thousand one hundred and sixty (1,160) are junior non-teaching staff. The university has a total student population of eighteen thousand seven hundred and twenty-four (18,724) comprising of two thousand four hundred and forty

(2,440) post graduate students and sixteen thousand two hundred and eighty four undergraduate students.

Academic and Research Directorates:

Academic Planning; Centre for Wetlands and Waste Management Studies; Clement Isong Centre for Development Studies; Centre for Skills Acquisition and Rural Development; Centre for Cultural Studies; Centre for Entrepreneurial Development; Institute of Education; Centre for Research & Development Studies; Centre for Gender and Women Studies; General Studies Directorate; Directorate of Pre-degree Studies

New Research Initiatives: International Centre for Energy and Environmental Sustainability Research (ICEESR), Institute for Biomedical Research and Innovation, and Institute for Agricultural Research and Innovation.

List of Faculties: The University of Uyo has a total of Sixty Six (66) full accredited programmes housed within twelve (12) faculties including Agriculture, Arts, Basic Medical Science, Business Administration, Clinical Science, Education, Engineering, Environmental Studies, Law, Pharmacy, Science, and Social Sciences.

OUR MISSION

To diligently pursue scholarship and deploy its output for human capacity development and economic growth in the society, with active participation in Information and Communication Technology, sensitivity to Nigeria's rich cultural heritage and responsiveness to global environmental changes

OUR VISION

To be a center of academic excellence by utilizing the available human and technological resources for teaching, research, community service and sustainable development

OUR CORE VALUES

Faith in God
Academic Excellence in Teaching and Research
Institutional Autonomy
Peer and Professional Review
Qualitative Service Delivery
Strong Work Ethics
Equal Opportunity
Creativity and Innovation
Integrity
Transparency and Accountability
Peace and Orderliness

Academic Programmes: The University of Uyo runs the following programmes:

- Regular Undergraduate programmes
- Regular Postgraduate programme
- Part-time diplomas and degrees coordinated by the School of Continuing Education in collaboration with the Postgraduate School
- Sandwich and undergraduate long vocation programmes strictly for Teachers already in Employment and coordinated by the Institute of Education in collaboration with the School of Continuing Education
- Pre-degree Programmes strictly for science students in the Faculties of Sciences, Agriculture and Education
- Basic studies programmes which prepares students for Advanced Level Examinations Papers through Cambridge/Joint Universities Examination bodies

Strides:

- One of the Nine Federal Universities in Nigeria selected for e-learning by the Federal Government of Nigeria
- The 10th most preferred university out of the 124 universities in the country by UTME Candidates. About 45,000 candidate choose UNIUYO as 1st Choice University
- One of the two universities in Nigeria selected for the study of Space Technology
- The only Nigerian University where Computational Language Documentation and Technology is studied at Masters and Doctorate degree levels in conjunction with Bielefield University, Germany.
- Has the largest number of programmes with full accreditation
- Honoured as the Information Technology School of the year 2012
- UNIUYO is a Fulbright affiliated institution visited by the AMERICAN Ambassador to Nigeria, Mr. Terence McCulley and parades eight Fulbright scholars at the moment

UNIVERSITY OF BENIN, BENIN CITY, EDO STATE, NIGERIA – AN OVERVIEW

University of Benin Main Campus Gate

The University of Benin, Benin City was established in 1970 as a specialized regional (Midwest) Institute of Technology with a mandate to train high level manpower in the areas of science and technology. The foundation campus is located in the premises of a provincial teacher's college on the southwestern flank of the city along the Ekenwan road. The Institution was taken over by the Federal Government in 1975 and renamed University of Benin and a subsequent introduction of liberal arts and social science courses was to complement the Institution's growth into a conventional University. The University's main campus in the Ugbowo area is located on the North-west fringe of the city, originally extending from the Benin-Lagos road to the Benin-Auchi road. The University has continued to grow over the years from a foundation enrolment of 100 students to a current full-time student population of over 30,000 and a teaching Staff of 1,800. The University of Benin is about the most diverse, multi-ethnic institution of

higher learning in Nigeria, with students and Staff from all the geo-political zones, and from a majority of the federating states of the nation.

The University of Benin, Benin City is grouped into 16 faculties/schools: Agriculture, Arts, Basic Medical Sciences, Dentistry, Education, Engineering, Environmental Studies Law, Life Sciences, Management Science, Medicine, Pharmacy, Physical Sciences, Social Sciences and Veterinary Medicine, Institutes and Specialized Research Centres including the African Centre for Mushroom Research and Technology Innovations, Centre for Gender Studies, Centre of Excellence for Geoscience and Pollution Studies, National Centre for Energy and Environment and the GeoEnvironmental and Climate Change Adaptation Research Centre (GECCAR).

In its mission statement, the University of Benin makes clear its aim to develop the human mind to be creative, innovative, research oriented and competent in areas of specialization, knowledgeable in entrepreneurship and dedicated to service. The University seeks diverse approaches to actualize these objectives including building partnerships through the establishment of linkages for continuous professional and competence development of Staff, student exchange programmes and joint/collaborative research.

Professor F.F.O. Orunmwense
Vice Chancellor, University of Benin, Benin City

GECCAR centre evolved from the postgraduate teaching and collaborative research activities of what was then the Water and Environmental Science and Technology (WEST) group. The Centre is dedicated to capacity building/strengthening in the core areas of research (fundamental and applied) activities: the environmental, water and air pollution, and in the generation and sharing of knowledge in line with the University's motto: knowledge for service. The Centre's lead scientists include:

- Professor Felix E. Okieimen, Consultant Environmental Chemist with more than 35 years postdoctorate teaching, research and consultancy experience and more than 400 published scholarly journal articles in additional to six textbooks and several monographs.
- Dr. Daniel U. Okuonghae, Associate Professor, Mathematical Modelling.
- Dr. Dan I. Olorunfemi, Associate Professor, Molecular Biology/Toxicology.
- Dr. Doris F. Ogeleka, Senior Lecturer, Ecotoxicology.
- Professor Gabriel E. Imeokparia, Consultant Geochemist.
- Professor James M. Okuo, Consultant Air Pollution Monitoring/Modeling.
- Dr. Andrew N. Amenaghawon, Lecturer, Process Engineering.
- Dr. Theresa O. Egbuchunam, Associate Professor, Pollution Studies

The Centre is awaiting approval for full autonomous status.

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Academic Presentations

Prevalence and Impact of *E. coli* in Southeast Asian Surface Waters –Approaches to Rapid Monitoring Methods

Kenneth Widmer
International Environmental Research Center, Gwangju Institute of Science and Technology, Korea

ABSTRACT

Microbial indicators can be related with fecal contamination of water from humans and warm blooded animal sources, and their presence in surface waters may also signal the presence of pathogenic organisms. Microbial quality of surface waters can be reliant on the detection, and enumeration, of bacterial fecal indicators based on cultivation and/or molecular analysis. This talk will highlight surveys of surface waters in various South Asian countries. The approach of detection and enumeration utilizing real-time PCR techniques will also be discussed including the advantages and limitations of these methods. Additionally, routes of fecal contamination of produce due to surface water irrigation and its potential impact on public health will also be discussed.

Keywords: water quality, *E. coli*, PCR, fecal indicators, surface water

Chemical and Radiological Health Risks Assessment of Radionuclides in Water Sources in Akwa Ibom State, Nigeria

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ABSTRACT:

Introduction: Radionuclides are ubiquitous in the environment and elevated levels of uranium, thorium and their daughter products might be present in water in areas that are rich in natural radioactivity or through human activities including oil and gas operations. Recently, considerable attention has been given to low-level exposure arising from naturally occurring radionuclides, particularly ^{238}U, ^{232}Th, their decay products and ^{40}K. Nigeria like many countries in sub-saharan Africa still face challenges in availability of clean and portable water to its ever increasing population. Most of the rural and semi-urban populations depend on raw surface and ground water for domestic and drinking purposes. The situation with the residents in the oil and gas producing communities in the Niger Delta Region of Nigeria is particularly severe as available natural water resources are threatened by pollution. There are no data on the radiological and chemical health effects of ^{238}U, ^{232}Th, and ^{40}K in drinking water and domestic supplies in communities hosting oil and gas exploration activities in Akwa Ibom State. This study aims to provide data and information on the concentrations of ^{238}U, ^{232}Th, and ^{40}K in the surface and underground waters and the associated radiological and chemical risks they may pose to the population. The selected communities in Akwa Ibom State include Eastern Obolo, Eket, Esit Eket, Ibeno, and Ikot Abasi known as the oil and gas producing areas while Uyo a non-oil producing is used as control.

Materials and Methods: Water samples were collected from underground and surface water sources, pretreated and transported to the laboratory using standard procedures (IAEA, 1989; Tchokossa *et al*., 2011). A Geographical Positioning System (GPS) was used for coordinate measurement. Gamma ray spectrometric system coupled with a NaI (Tl) scintillation detector was employed for the analysis of ^{40}K, ^{238}U, and ^{232}Th in the water samples. This was carried out at the Radioactivity Measurement Laboratory, Centre for Energy Research and Development (CERD), Obafemi Awolowo University, Ile-Ife.

Results and Discussion: The summary of location, sample size and concentrations of radionuclides ($Bq.l^{-1}$) in the study area are presented in Table 1.

Table 1: Summary of location, sample size and concentrations of radionuclides ($Bq.l^{-1}$) in the study area

Location	Sample Size	^{40}K		^{238}U		^{232}Th	
		Average	Range	Average	Range	Average	Range
Esit Eket	20	181.70 ± 34.53	110.12 – 289.52	11.96 ± 3.72	6.42 – 15.76	14.76 ± 4.46	8.92 – 18.42
Eket	20	189.83 ± 36.25	133.54 – 289.09	13.66 ± 4.74	8.33 – 17.64	16.58 ± 5.01	10.34 – 20.26
Eastern Obolo	17	195.71 ± 35.23	139.95 – 271.30	10.81 ± 3.49	5.29 – 14.13	12.90 ± 3.54	8.89 – 17.38
Ibeno	10	33.43 ± 10.65	17.45 – 66.94	5.52 ± 1.52	0.73 – 10.74	6.11 ± 2.13	2.65 – 10.17
Ikot Abasi	10	38.3 ± 11.53	14.2 – 134.41	2.54 ± 1.14	0.6 – 4.81	3.52 ± 1.26	0.12 – 10.22
Uyo	5	34.11 ± 10.49	15.29 – 93.05	6.27 ± 2.12	3.76 – 8.86	4.04 ± 1.36	0.57 – 7.24
Average		112.18 ± 23.11		8.46 ± 2.79		9.65 ± 2.96	

The overall average activity concentrations of ^{40}K, ^{238}U, and ^{232}Th were found to be 112.2; 8.5; and 9.7 $Bq.L^{-1}$, respectively. The results for the following communities Eket, Esit Eket and Eastern Obolo revealed concentrations higher than acceptable safe limits, while those of Ibeno, Ikot Abasi and Uyo were lower or within safe limits. The radiological risks for cancer mortality and morbidity for the three nuclides were in the range of 10^{-3} to 10^{-4}, respectively. Chemical toxicity ranged from 36 to 216 $\mu g.kg^{-1}.day^{-1}$ for ^{40}K, 3 to 216 $\mu g.kg^{-1}.day^{-1}$ for ^{238}U and 4 to 18 $\mu g.kg^{-1}.day^{-1}$ for ^{232}Th. Similarly, values for Eket, Esit Eket and Eastern Obolo were found to be higher than the recommended acceptable safe level by various international organizations, while those of Ibeno, Ikot Abasi and Uyo were below.

Conclusion: The overall results reveal that there are health risks associated with the presence of ^{40}K, ^{238}U, and ^{232}Th in water used for drinking and domestic purposes by these communities mainly attributable to chemical toxicity. It was shown in the study that the radioactivity concentration in water sources used for drinking and domestic purposes by the populace of the studied area is in the following order of magnitude; Ikot Abasi < Uyo < Ibeno < Eastern Obolo < Esit Eket < Eket. There is urgent need for actions to protect public health in the affected communities.

Keywords: Water quality**,** human health protection, cancer mortality and morbidity risk.

References:

International Atomic Energy Agency, IAEA (1989). Measurement of Radionuclides in Food and the Environment – Guidebook. Technical Report Series No 295, pp. 1 – 182.

Tchokossa, P., Olomo, J. B. and Balogun, F. A. (2011). Assessment of Radionuclide Concentrations and Absorbed Dose from Consumption of Community Water Supplies in Oil and Gas Producing Areas in Delta State, Nigeria. *World Journal of Nuclear Science and Technology*, 1, 77 - 86.

Occurrence and Ecological Risk Assessment of Endocrine Disruptors, Pharmaceuticals and Personal Care Products in Ikpa River Basin, Nigeria

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ABSTRACT:

Introduction: Contaminants of emerging concern (CECs) are a class of newly detected compounds in the environment with potential detrimental effects like cell mutation, endocrine disruption, and sexual disruption amongst others. Unlike most well characterised pollutants, CECs are not commonly regulated with challenges of trade-offs due to their uses as active pharmaceutical ingredients (APIs) or personal care products (PCPs). CECs get into the aquatic environment as a result of human activities like wastewater and sewage discharges into nearby water bodies. This class of contaminants have received great attention in developed countries and as such some of them have received priority screening and preliminary regulatory guidelines proposed. However, due to the requirements of highly sophisticated analytical instruments research on this subject in developing countries like Nigeria is almost non-existent. The aim of the present study was to determine the occurrence of selected endocrine disrupting compounds (EDCs), pharmaceuticals and personal care products (PPCPs) in water samples of Ikpa River Basin in Southern Nigeria as well as in leachates and storm water of a nearby landfill also used as a hospital dumpsite. The ecological risks of some of the compounds detected were evaluated.

Materials and Methods: Water samples were collected using amber glass bottles between 2013 and 2014 during raining seasons. Field grab samples were preserved by adding 250mg/L sodium thiosulphate ($Na_2SO_3S_2$) and transported to the laboratory in an ice box and stored at 4°C. Sample preparation, extraction followed modified procedure according to Canada method (Hao, 2008). Target compounds were extracted using the solid-phase extraction (SPE) system and analysed by liquid chromatography/tandem mass spectrometry (LC-MS/MS).

Results and Discussion: Seven antibiotic drugs (acetamidophenol, chloramphenicol,

ciprofloxacin, erythromycin, lincomycin HCl, roxythromycin, and sulfamethoxazole), three antimicrobial agents or bactericides (sulfathiazole, triclosan and triclocarban), an antiepileptic drug (carbamazepine), an analgesic drug (diclofenac sodium), a resin precursor (bisphenol A), a sunscreen product (oxybenzone), a hormone (equilin), an insect repellent (DEET), and a stimulant (caffeine) were detected at nanogram per litre levels. Bisphenol A, triclosan, triclocarban and oxybenzone were among the most frequently detected compounds (Figure 1). In order to evaluate the ecological risk of some of the selected compounds, their predicted no-effect concentrations (PNECs) derived from toxicity data reported for green algae, fish and invertebrate in the literature were compared with the maximum measured environmental concentrations (MECs); MECs/PNECs ratios, to obtain risk quotients (RQs). The potential risk levels (RQs) were low for most of the compounds except bisphenol A and chloramphenicol with RQs (0.044 and 0.07, respectively) approaching medium risk levels. More so, the potential risk level for triclosan and erythromycin reached the medium risk level (HQ>0.1) for the considered organisms. The highest potential risk levels were estimated for triclocarban with RQ values above unity for the aquatic organism –algae, fish and invertebrate.

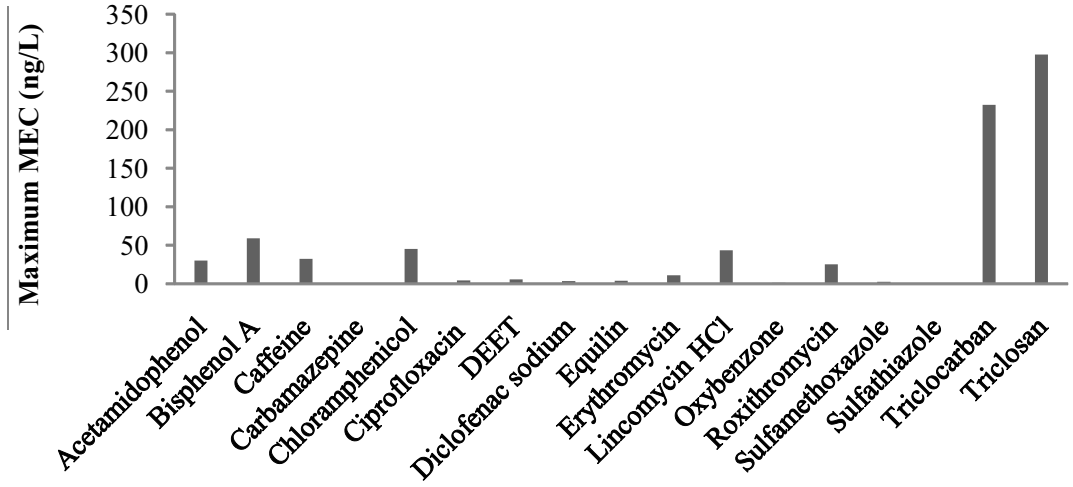

Fig. 1: Occurrence and distribution of emerging pollutants in the study area

Conclusion: The occurrence of contaminants of emerging concern (CECs) in the study area indicates inputs from human activities, presumably from the nearby landfill and hospital dumpsite. Some CECs were frequently detected indicating continuous inputs. Since the water resource of the river basin is used for domestic applications and irrigations, humans may unknowingly be exposed to these contaminants. This is also

true for other non-targeted organisms in the aquatic ecosystem. Bisphenol A, triclosan and triclocarban were found to pose high risks to the ecological environment of the study area.

Acknowledgement: This study was supported by the Ministry of Science and Technology in South Korea through the Institute of Science and Technology for Sustainability (UNU & GIST Joint Programme).

Keywords: Ikpa River Basin, Nigeria, endocrine disruptors, pharmaceuticals, hormones, personal care products, risks

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Biofiltration Potentials of Two Saprophytic Fungi of a Brewery Effluent

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ABSTRACT

Introduction: Aggressive push towards industrialization is often accompanied by the problem of pollution in a number of the developing nations of the world. In the Industrial nerve centres of Nigeria, there are many industries that discharge their effluents untreated into the water bodies (Odeigah *et.al*., 1997, Bakare *et.al*., 1999 and 2000). Untreated effluent poses a major risk to human health, destroys aquatic ecosystems and threatens human livelihood (Pruss-Ustun, 2008). Mycofiltration as a form of biological treatment of waste water involves the use of fungal mycelia as a membrane for filtering out microorganisms, pollutants, and silt (Stamets, 2005). The aim of this research was to investigate the ability of some filamentous fungi at remediating industrial effluent in a timely and cost effective manner.

Materials and Methods: The soil from which fungi were isolated was collected from Shomolu market, Lagos State, Nigeria while effluent sample was collected from Nigerian Brewery (Sona Brewery), Ijako-Ifo, Ogun State, Nigeria. The pure culture of each of the fungus was placed in the self-fabricated mycofilter (Plate 1). Here, each of the fungus acted as a mesh through which the effluent drained to the different layers before finally collecting in the filtrate collector (Plate 1). The control samples were the raw unfiltered effluent samples. The final filtrates were taken under aseptic conditions to the laboratory for analysis of some physicochemical parameters present before (raw i.e. control) and after the filtration process (filtrate).

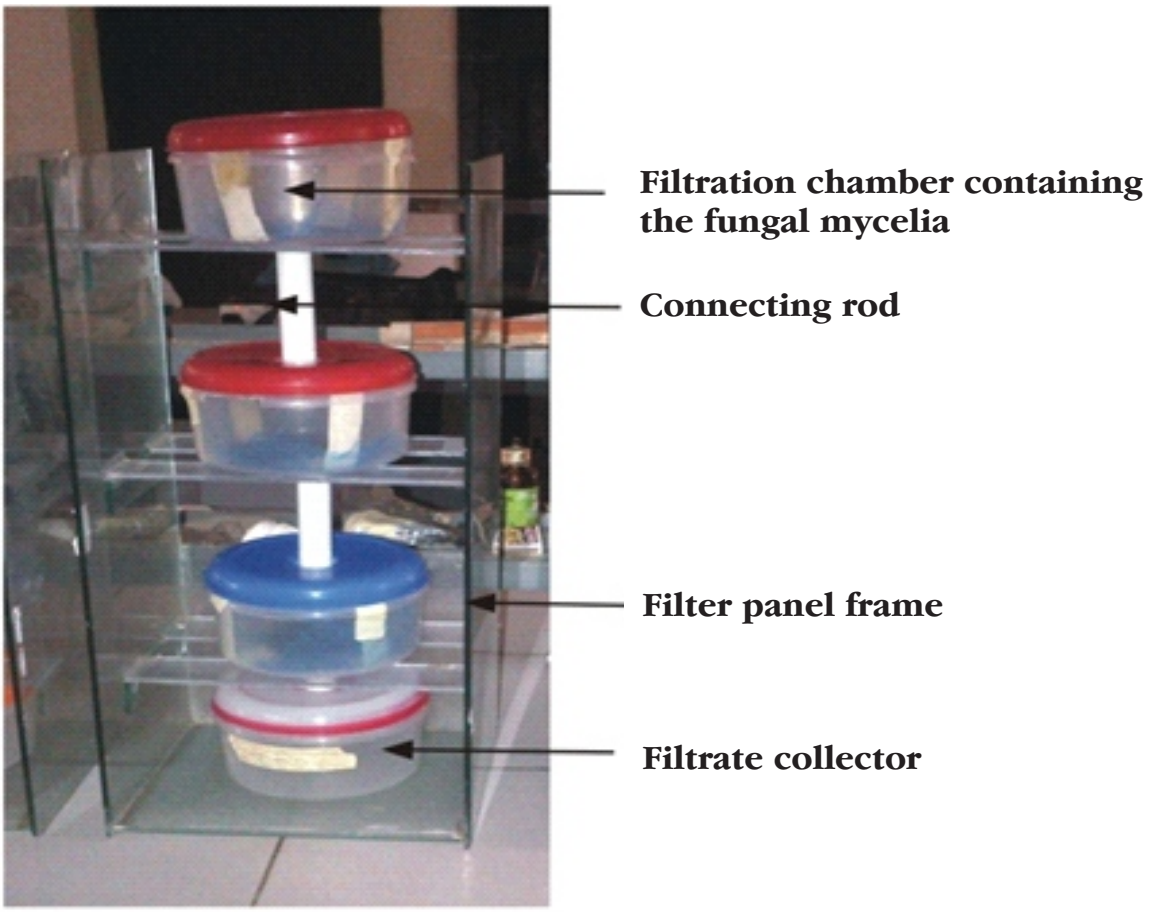

Plate I. Picture showing the complete filtration apparatus

Physico-chemical parameters such as BOD, COD, chloride, sulphate, heavy metals, total acidity, total alkalinity, total hardness, pH**,** EC, TDS, and TSS were determined using standard analytical methods and equipment. Three Treatments A, C and E which were Untreated effluent (Control), effluent filtered using *A. niger* and effluent filtered using *A. flavus* respectively were used.

Results and Discussion: The results of the Isolation Studies showed most of the fungi encountered from the soil as belonging to the genus *Aspergillus*, essentially *Aspergillus niger* (*A. niger*) and *Aspergillus flavus* (*A.flavus*). Results of the physic-chemical analysis as indicated in Figs 1 and 2 below showed that both fungal species caused a significant (P=0.01) improvement in most of the physicochemical parameters considered in this effluent when compared to the Control, and some approved benchmarks. The values for the BOD in the 2 mycofiltered effluent samples were found to be below the FEPA and LASEPA standards of 50mg/l and 30mg/l respectively (FEPA, 1991 and LASEPA, 2011). Although both fungi were able to achieve a significant reduction in the amount of COD in the effluent sample; the values were however higher than the FEPA and LASEPA standards of 150mg/l and 60mg/l respectively (FEPA, 1991; LASEPA, 2011). The results also showed (Fig. 1) an excessively high COD value in Treatment A, thereby suggesting that the Industry considered in the present study probably did not treat the

effluent before discharging same into the environment. The concentration of nitrate in all the effluent samples were higher than the 20mg/l and 10mg/l standards specified by FEPA (FEPA, 1991) and LASEPA (LASEPA, 2011) respectively.

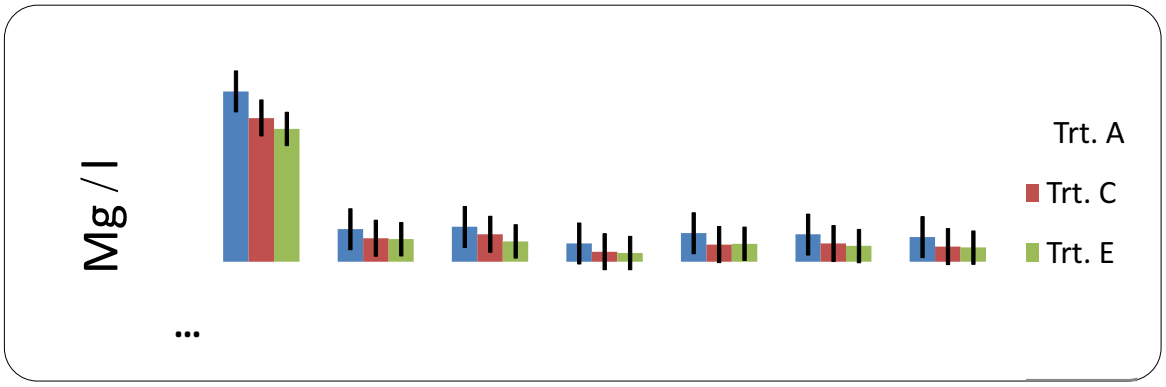

Fig. 1: Level of some chemical parameters in the effluent samples

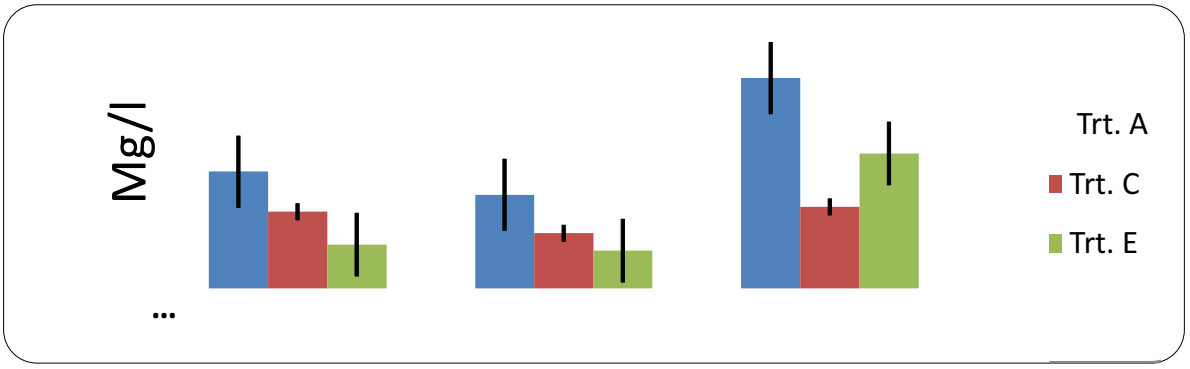

Fig 2: values for some physical parameters in effluent samples.

Conclusion: The results from the present studies show that the unfiltered (Control) effluent samples are polluted as they contain significantly higher levels of some important chemical indicators such as nitrates, phosphates, chlorides and sulphates, compared to the mycofiltered samples. Filtering the Control effluent sample through each of the fungal mycelia caused a significant improvement in most of the parameters investigated, thus showing the ability of *A.niger* and *A.flavus* to clean up some important physicochemical indicators of water pollution.

Keywords: Fungi, effluent, mycofiltration, *Aspergillus niger*, Aspergillus flavus

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Enhanced Adsorption of Phenol on Bentonite Intercalated with Quaternary Ammonium Cation

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Increasing concern about the pollution of environment by organic chemicals arising from naturally occurring ecological events and industrial processes has created a need for the search for innovative techniques for the removal of these contaminants. Phenolic compounds are common contaminants in wastewaters, being generated from petroleum and petrochemical, coal conversion and other phenol producing industries: and are on the basis of their potential to be harmful to organisms at low concentrations classified as hazardous pollutants (Fang and Chen, 1997). Different water treatment technologies are available for the removal of phenolic pollutants including destructive oxidation with ozone, hydrogen peroxide or magnese oxide (Hoigne, 1985; Kochany and Bolton, 1992; Ukrainczy and McBride, 1992), solvent extraction (Eahart *et al*., 1977) membrane separation (McGray and Ray, 1987) and adsorption onto porous solids. Although literature on the adsorption of activated carbon for the removal of phenolic compounds from aqueous effluents abound (Hisch and Teng, 2000; Roostael and Tezel, 2004; Abdo *et al*., 1997; Furuya *et al*., 1997). Due to the high cost of activated carbons there have been attempts to utilize low-cost, naturally occurring adsorbent to remove trace organic and inorganic contaminants from wastewaters. One of the natural materials that can be used in such processes is clay. Termitaria and laterite are other "earthy" materials that have been applied to remove/reduce the levels of trace contaminants in wastewaters (Anoduadi *et al*., 2009). Bentonite consists essentially of smectic (montmorrilonite) group that has a wide range of industrial applications. On account of the hydration of inorganic cations on the exchangeable sites, the clay mineral surface is hydrophobic in nature which makes natural clays ineffective sorbent for organic compounds. When the exchangeable inorganic cations are replaced by surfactants, e.g. quaternary ammonium cations, organophilic clay (organoclay) with potential enhanced capacity to absorb organic molecules is formed.

In this study organoclay prepared by exchanging hexadecyltrimethyl ammonium cation (HDTM) with exchangeable cations (at a level corresponding to 100% CEC) in bentonite in dimethylsulfoxide medium and characterized by FTIR and XRD was tested for phenolic pollutants, using phenol as a model component adsorption. Infrared absorption bands at 3019cm^{-1}, 2924cm^{-1} and 2856cm^{-1} assigned to C-H asymmetric

streatching, CH_2 – symmetric stretching and CH_3 – symmetric stretching respectively together with the increase in basal spacing provided evidence of the presence of HDTM molecules in the interlayer spacing of the organoclay. Laboratory batch kinetic and equilibrium studies were conducted using various conditions of contact tine, initial adsorbate concentrations, pH and temperature, to evaluate any enhancement in adsorption capacity of the quaternary ammonium cation treated bentonite for phenol. It was found that the adsorption capacity of the modified clay for phenol was markedly enhanced (by more than 100%) by the intercalation of HDTMA in the clay. The observed reduction in the adsorption capacity, q_e ($mg.g^{-1}$) by more than 60% and in the phenol removal efficiency, %R, from about 85 to 30% with increase in temperature from 30 – 50°C allowed the thermodynamic parameters: K (0.4232 – 0.1504 $l.mg^{-1}$); G ($2.17x10^{3}$ – $5.27x10^{-3}$ $kJmol^{-1}$); H (0.082 $kJmol^{-1}$) and S (– 19.82 JK^{-1} mol^{-1}) of adsorption process to be determined. These values suggest that the uptake of phenol on the organoclay is endothermic and dominated by physical adsorption. To predict the adsorption isotherms and to determine the characteristic parameters for process design, four isotherm models: Langmuir, Freundlich, Temkin and Dubinin-Kagana-Radushkevic (DKR) models were applied to the experimental data. The results revealed that the adsorption models filled the data in the order Temkin = Freundlich > Langmuir > DKR isotherms (Table 1).

Table 1: Isotherm parameter* for phenol on raw and HDTMA cation exchanged bentonite

Isotherm		Parameters	Bentonite	
			Raw	HDTMA cation exchanged
Freundlich	$q_e = K_f C^{1/n}$	K_f	0.72	0.67
		n	1.42	1.48
		R^2	0.9899	0.9946
Langmuir	$qe = \frac{qK_L C_e}{1 + K_L C_e}$	Q_{max} ($mg.g^{-1}$)	25.64	46.94
		K_L ($l.g^{-1}$)	0.0161	0.0209
		R_L	0.55	0.49
		R^2	0.9892	0.9013
Temkin	$q_e = B \ln A C_e$	A ($l.g^{-1}$)	0.15	0.25
		B ($J.mol^{-1}$)	443.75	276.85
		R^2	0.9921	0.9321

** Parameters for DKR isotherm omitted because of poor fit of experimental data.*

The value of R_L, the separation factor for Langmuir and the n value for Freundlich isotherms showed that phenol is favourably adsorbed by the quaternary ammonium cation modified bentonite. Adsorption of phenol onto the modified clay was well

described by the pseudo-first-order reaction kinetics and gave value of $1.10 \times 10^{-2} \pm 0.001$ min^{-1}; $R^2 = 0.9657$, for the apparent rate constant of sorption of phenol on the quarternary ammonium cation intercalated bentonite.

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Crude Oil - and PAH - Degrading Bacteria Isolated from Humic Freshwater Ecosystem of Eniong River - Nigeria

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ABSTRACT

***Introduction*:** Crude oil exploration and exploitation of its refined products in Nigeria has resulted in massive degradation and deterioration of soil, water, sediment and the atmosphere due to pollution. This is posing great threats and danger to environmental and public health (Urum *et al.,* 2000) resulting in biodiversity losses especially in the Niger Delta region. Although various options for remediation abound, their applications are limited by high costs and eco-unfriendliness due to formation of more toxic intermediates (Debarati *et al.,* 2005). One potential method for managing petroleum and other organic pollutants contaminated farmlands is to use indigenous microbial biocoenosis to biodegrade and contain the pollutant plume. In search of active microbial strains that could be of relevance in bioremediation of petroleum and its complex polycyclic aromatic hydrocarbons contaminated environment study was conducted on the petroleum hydrocarbons degrading potentials of indigenous strains of bacteria from "blackwater" ecosystem of Eniong River – Nigeria.

Materials and Methods: The study area (Figure 1) is a humic freshwater or blackwater ecosystem of Eniong River, a tributary of the lower Cross River traversing Itu through Okopedi. The area is located between the coordinates $05^{o}12^{I}0.54^{II}$ N and $007^{o}\ 58^{I}\ 48.6^{II}$ E (downstream); $05^{o}\ 16^{I}\ 0.54^{II}$ N and $007^{o}\ 57^{I}\ 28.7^{II}$ E (midstream) and $05^{o}\ 22^{I}\ 56^{II}$ N and $007^{o}\ 54^{I}\ 59.1^{II}$ E (upstream). The wetland of the ecosystem is persistently farmed and there are reported cases of oil spills within the vicinity.

Figure 1:Map of humic freshwater Eniong River, Itu, Nigeria

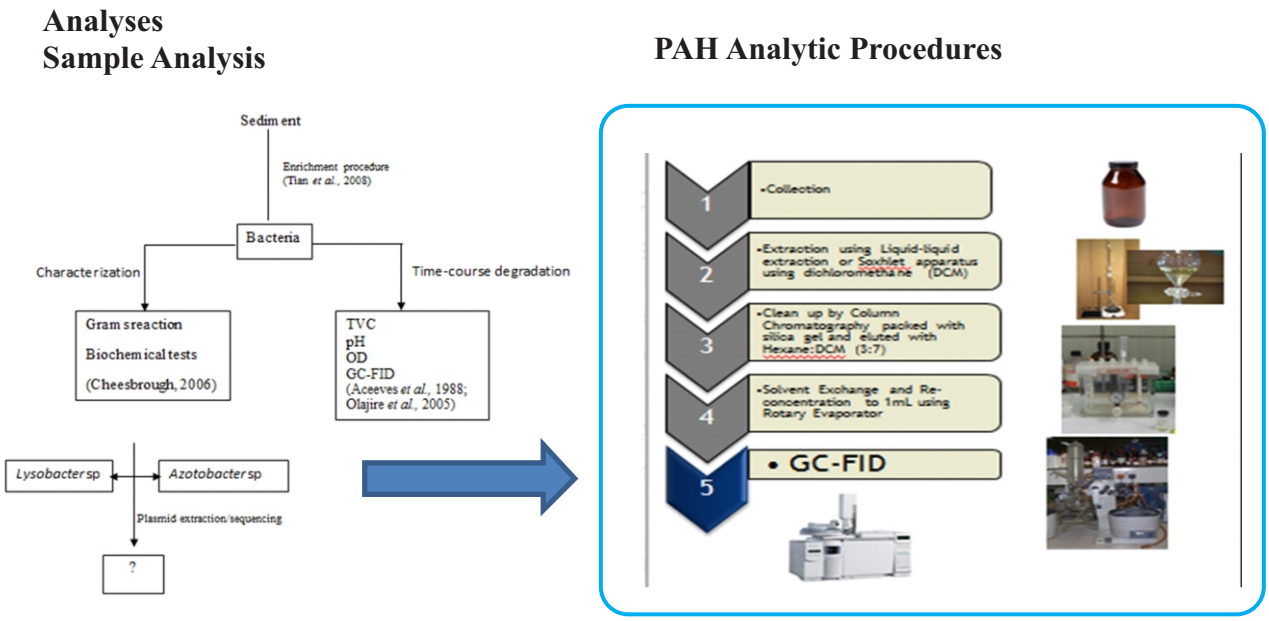

Figure 2:Flow Chart of Procedure Adopted for the Research

Results and Discussion: The selection of bacterial species mainly the Gram positive from humic freshwater Eniong river sediment with capabilities of degrading crude oil and anthracene is evident in this study. The results have revealed the potentials of the bacteria *Azotobacter* HSC_2 as strong crude oil degraders. Result in Table 1 shows the components and the concentrations of the crude oil degraded by the test organism. While some fractions were poorly degraded others including the high carbon chain components (C_{14}, C_{15}, C_{25}, C_{26} and C_{31} – C_{37}) however showed high percentage degradation (Figure 3). Novel organism *Lysobacter* HSA_1 was also discovered to efficiently biodegrade anthracene after 20 days of incubation exhibiting 41% reduction level (Table 2). The ability to degrade might be attributed to the modulating effects of humic substances originally present in the ecosystem (Semple, 2015).

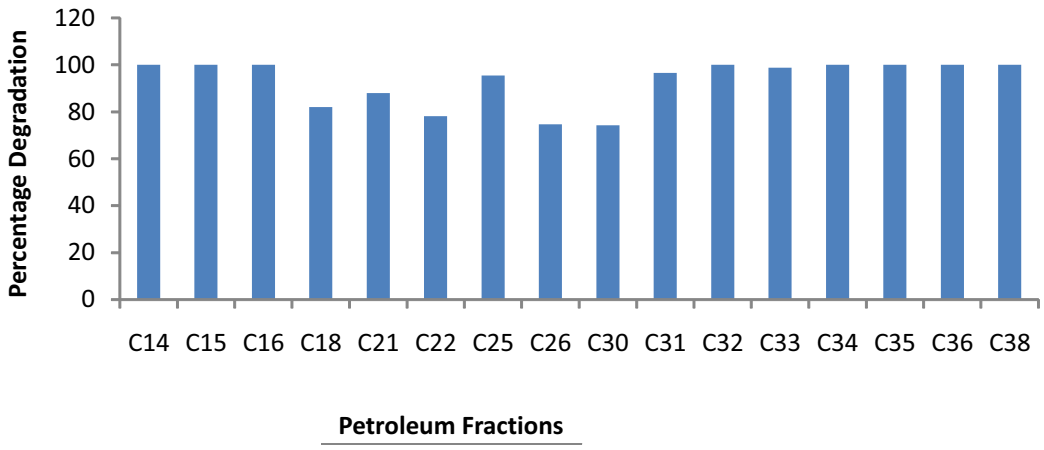

Figure 3: Efficiency of Degradation of Crude Oil Components by *Azotobacter* HSC_2

Table 1: Concentrations of Petroleum hydrocarbon factions in control and test samples after degradation by *Azotobacter* HSC_2 (mg/L)

Organism ID	TPH Components	Control Sample	Test Sample (% degradation)
Azotobacter HSC_2	C_{14}	0.010	0.00 (100)
	C_{15}	1.0145	0.00 (100)
	C_{16}	1.0365	0.00 (100)
	C_{17}	1.1022	0.8568 (22)
	C_{18}	0.5688	0.1022 (82)
	C_{19}	4.6522	3.1225 (32.8)
	C_{20}	1.2562	1.1247 (10)
	C_{21}	1.1265	0.1257 (88)
	C_{22}	0.0568	0.0124 (78.17)
	C_{23}	1.5638	1.0211 (34.61)
	C_{24}	1.4522	1.2314 (15.20)
	C_{25}	1.9856	0.0887 (95.53)
	C_{26}	1.0225	0.2587 (74.69)
	C_{27}	2.0145	1.1255 (44.13)
	C_{28}	1.0258	1.0224 (0.33)
	C_{29}	1.0699	0.7560 (29.34)
	C_{30}	0.9856	0.2541 (74.22)
	C_{31}	0.6225	0.0214 (96.56)
	C_{32}	0.5210	0.00 (100)
	C_{33}	0.4552	0.0052 (98.86)
	C_{34}	0.5114	0.00 (100)
	C_{35}	0.4120	0.00 (100)
	C_{36}	0.3245	0.00 (100)
	C_{37}	-	-
	C_{38}	0.1524	0.00 (100)
	C_{39}	-	-
	C_{40}	-	-
Total		19.887	11.124

Table 2: Concentration of Anthracene in Control and test sample after degradation with *Lysobacter* HSA_1

Organism	Parameter	Control	Test sample (% degradation
Lysobacter HSA_1	Anthracene	0.0195	0.0115 (41)

Conclusion: The research findings indicate that *in situ* or on-site bioremediation using inoculated with *Lysobacter* – HSA_1 and *Azotobacter* – HSC_2 would be feasible technology for cleanup of crude oil and polycyclic aromatic hydrocarbons contaminated agricultural soils in Nigeria. It will be useful in designing a scale up *in situ* or on-site pollutant bioremediation system for field application.

Keywords: Biocoenosis, blackwater, remediation, enrichment, degradation

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Treatment Performance of Waste Stabilization Ponds: The Case of VRA Treatment Plant at Akosombo, Ghana

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ABSTRACT

Key Words: Waste Stabilisation Ponds, Waste water, Treatment Efficiency, Nutrient Removal, Akosombo

Introduction

The global population explosion has contributed to the generation of high volumes of waste water in the developed and developing economies. Efficient and effective treatment of such waste water before discharging into the environment is critical for protecting the life of flora and fauna. The aquatic environments are likely to be under siege if untreated waste water released into them. Mara, (2003) indicated that less than 15% of the collected wastewater is treated in developing countries before discharge into the environment. Prevention of disease infection, improving hygiene and health are important global objectives of the Million Development Goals (MDGs) (Tsuzuki, 2012). Waste stabilisation ponds (WSP) system is one of the wastewater treatment technologies which is thought to be suitable for developing countries because of ease of construction, low cost of operation and maintenance, low technical capacity requirement and treatment efficiency (Ghazy et al., 2008). In Ghana, only 20 % of 44 waste water treatment plants were working in 2008 across the country (International Water Management Institute, 2008). This implies that most waste water produced is discharged into the environment untreated. The current study examined the physico-chemical quality of waste water from waste stabilization ponds treatment plant.

Methodology

Akosombo is a community established by the Volta River Authority Development Act of 1961 (Act 46) and is located in the Eastern Region of Ghana. The waste stabilization ponds consisted of two ponds, namely facultative and maturation ponds. The facultative and maturation ponds has retention period, depth and area are 24 days, 1.7 m, 9.6 ha and 3 days, 0.8 m and 2.5 ha respectively (Hodgson, 2007). Grab samples of raw sewage, facultative pond effluent and maturation pond effluent (final effluent)

amounting to 15 samples were taken in five consecutive months for laboratory analysis. The following parameters were analysed: pH, Total Suspended Solids (TSS), Turbidity, total dissolved solids, Electrical conductivity (EC), Dissolved Oxygen (DO), Biochemical Oxygen Demand (BOD), Chemical Oxygen Demand (COD), Total Nitrogen, Total Phosphorous and total coliform. All the analysis followed the procedures outlined in the standard method for the examination of water and wastewater (APHA, 2003).

Results and Discussion

The mean pH of the raw sewage obtained was 6.7 which fell within the acceptable limit given by EPA of Ghana as 6-9. The mean pH for the raw sewage, facultative and maturation ponds was 6.99, 7.80 and 8.01 respectively. This gives a trend of increased pH, implying that the waste water becomes more basic in the process of treatment. TSS had a mean value of the influent was 50.2 mg/l whilst the effluent value was 35.2 mg/l. The mean overall TSS removal efficiency of the pond system was 30.0 per cent which is very low, however the final effluent is satisfactory compared to the Ghana Environmental Protection Agency (EPA) guideline value of 50 mg/l except the high value recorded for January. Presence of significant levels of total suspended solid in the treated effluent might have been due to the presence of algal cells. The mean dissolved oxygen (DO) level of the influent (2.06 mg/l) is low compared to the effluent (7.96 mg/l) quality. This implies that there is addition of oxygen to the wastewater after treatment; therefore it is safe to discharge it into the receiving water body. The BOD of the raw sewage had mean value of 55.4 mg/l whilst that of the treated effluent was 10.0 mg/l. The mean overall BOD removal efficiency was 82 per cent. This means the reduction in BOD in the wastewater is significant, emphasising the treatment capabilities of the WSPs especially when sufficient water is added and adequate retention time is allowed. The COD of the raw sewage had a mean of 263 mg/l, whilst the final effluent had a mean of 64.9 mg/l as in Table 1. The mean overall COD removal was calculated to be 75.0 per cent which is appreciably high, which satisfied the EPA guideline value of 250 mg/l. The ammonia concentration of the raw sewage ranged from 16.9 to 57.8 mg/ with a mean value of 28.2 mg/l. The ammonia concentrations of the final effluent were between 0.842 and 7.41 mg/l with a mean value of 2.32 mg/l. The mean ammonia removal efficiency was 92.0 per cent which is high yet the final effluent was found to be unsatisfactory compared to the EPA guideline value of 1 mg/l. The mean concentration of phosphate in the raw sewage was 8.33 mg/l and the final effluent was 1.35 mg/l. This gives about 84.0% of phosphate removal efficiency. The final effluent concentration is within the established standard for effluent disposal by EPA Ghana of 2.0 mg/l.

Table 1: Mean concentration for the sampling points

Sampling Points	**pH (pH Units)**	**COD (mg/l)**	**BOD (mg/l)**	**TSS (mg/l)**	**TDS (mg/l)**	**NH_3-H (mg/l)**	**PO_{4-P} (mg/l)**	DO **(mg/l)**
Raw	6.99	263	55.4	50.2	283.4	28.2	8.33	0.26
Facultative to Maturation	7.80	97.6	27.3	41.6	119	4.48	2.38	-
Effluent	8.01	64.9	10.0	35.2	118.4	2.3	1.4	7.96

Conclusions

It can be concluded that the treated effluent from the waste stabilisation ponds at Akosombo met both the environmental and health criteria set by the Ghana Environmental Protection Agency (GEPA) except the ammonia concentration and total Coliforms load which were above the set limit. The strength of the raw sewage had BOD concentrations less than 200 mg/l and therefore it can be classified as weak. Most of the BOD reduction occurred in the facultative pond which may be due to the long retention period of 24 days. The final effluent quality in terms of BOD concentrations will not have any adverse effect on the Lower Volta River into which it is discharged. The 82.0% BOD, 75.0% COD, 92.0% ammonia and 84.0% phosphate treatment efficiencies implies the plant is working well in ensuring high level of pollutant removal. Considering this treatment capabilities of the plant, it is important to construct such plants in a decentralised fashion for the various Municipal and District Assemblies to deal with wastewater challenges in the sub-region. The quality of the final effluent which is rich in ammonia can be used in agricultural fields or farmlands to retain the nutrient capacity of the waste into the environment for productive use.

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Water Purification Process using Plant Extracts From *Acacia nilotica* Pod Powder and *Eucalyptus citriodora* Exudates as Coagulants

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ABSTRACT

This research work was carried out to find whether an eco-friendly water purification process using plant extracts from *Acacia nilotica* and *Eucalyptus citriodora* exudates could be achieved. These plants are readily available in most urban and rural areas in Africa. The aim(s) and objective(s) of this research work is to investigate the use of *Eucalyptus citriodora* and *Acacia nilotica* pod powder as coagulants for water treatment and to compare the effectiveness of these plants extracts as coagulants to alum (standard conventional coagulant). This was done using Completely Randomized Design with loading doses from 0.02 g - 0.1 g of the extracts and alum as standard coagulant. Turbidity, pH, TDS and conductivity of the pond water used were determined before and after coagulation. The *Acacia nilotica* extract showed coagulation efficiency of 90% reduction in turbidity at optimal dosage of 1.0 g compared to 92.2% and 94.44% of alum at optimal dosage of 0.08 g and 0.10 g respectively. The pH values (7.4-6.6) obtained for the treatment were in the recommended range set by World Health Organization.

KEYWORDS: Coagulation, *Eucalyptus citriodora exudates, Acacia nilotica,* Alum, Antimicrobial properties.

Remediation of Water Works Supernatant Return Flow: Resource Recovery and Utilization Strategy for Sustainable Development

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ABSTRACT

Poor management of supernatant return-flow (SRF) and its contributory adverse effect on water security has necessitated this research. Qualitative analysis of SRF from lower Usuma Dam Water Treatment Plant (LUDWTP), Abuja, Nigeria, was undertaken for sustainable development through resource recovery and utilization. The result revealed that reuse and recycling of SRF is a sustainable approach to water reclamation, water supply reliability, potable water conservation and reduction of pollution from waste flow into the immediate environment. An indication of technical feasibility of recycling supernatant from LUDWTP is presented as a model, as well as recommendations for further study. This paper presents the necessary, but adequate information to assist developing countries in attaining long-term approach in managing the risk of water security towards the actualization of the sustainable development goals (SDGS) agenda in the area of water and sanitation.

***Key words*:** Supernatant Return-Flow, Resource recovery, Utilization, Water security, Sustainable development, Remediation.

Introduction: The paradigm shift from Millennium Development Goals (MDGs) to Sustainable Development Goals (SDGs) in the year 2015 has necessitated increase in research in neglected areas such as utilization potentials of SRF. This is as an unprecedented approach to actualize the concept of the transformation mission. Of interest is the number 6 of the proposed SDGs, "ensure availability and sustainable management of water and sanitation for all" (ICSU 2015), which is the basic responsibility of water utilities worldwide.

Exploration of natural resources and discharge of untreated effluents into the environment are some of the major causes of environmental degradation. To remedy this situation, exploration of new materials through waste- to-wealth initiative is sought for sustainable development.

Sludge is a by-product generated during the production of potable water. Its quantitative analysis showed that it consists of 3-10% of the raw water supply in the water works with only 0.1 -1% solid. The major contaminants in sludge are suspended solids, dissolved solids, trace metals, amongst others (Syed, 2002). Sludge residue and supernatant are the outputs of various sludge treatment processes with supernatant returned to the water course as SRF.

Some researchers reported the utilisation of water treatment sludge residue as soil substitute (Cornwell et al., 1987; Dayton et al., 2001; Anyakora, 2012) and as clay substitute in brick making (Anderson et al., 2003; Mohammed et al, 2008; Anyakora, 2013).
Presently, little has been mentioned about the resource recovery and utilisation potentials of the SRF which is also a major component of sludge. Addressing this issue becomes expedient because it gives a holistic approach to the complete management of sludge in the water works environment towards the actualisation of SDGs agenda.

Materials and Methods*:* The qualitative analysis of SRF from LUDWTP was undertaken using various instrumental analytical techniques.

Results and Discussion: The physic-chemical characteristic of SRF from LUDWTP is presented in Table 1.

Table 1: Physico-chemical Characteristic of SRF from LUDWTP

Parameter	Unit	LUDWTP-SRF
pH	-	6.39
Temperature	^{o}C	27.5
Total Hardness	mg/l	18
Total Dissolved Solids	mg/l	78.2
Turbidity	NTU	22
Conductivity		146.2
Chloride	mg/l	BDL
Nitrate	mg/l	1.22
Colour	-	Not acceptable
Smell	-	Not acceptable
BOD^{5}	mg/l	16
COD	mg/l	976
MPN	/100ml	1200
Aluminium	mg/l	1.3521
Cadmium	mg/l	0.0052
Chromium	mg/l	0.0382
Iron	mg/l	0.3621
Manganese	mg/l	0.0256
Nickel	mg/l	0.0022
Lead	mg/l	0.0132
Zinc	mg/l	0.0321

***Conclusion*:** The result of physic-chemical characteristics of SRF from LUDWTP showed that it met the requirement for both recycling and reuse in agriculture in accordance to relevant National and International Standards (NESREA, 2009; USEPA, 1996). Actualization of the SDGs through resource recovery and utilization of SRF will help reduce pollution from untreated waste water discharge, increase water use efficiency and ensure sustainable withdrawals and supply of fresh water to address water security, improve agricultural systems and raise rural prosperity.

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Enhanced Biodegradation of PAHs Using Biosurfactant Producing Bacteria from a Humic Freshwater Ecosystem of Eniong River, Itu-Nigeria

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ABSTRACT

Introduction: Polycyclic Aromatic Hydrocarbons (PAHs) are amongst the known components of petroleum that is of much concern during spills. Its recalcitrant nature, ease of biomagnification along food chain and health risk are attributed to its hydrophobicity, lipophilic nature and low water solubility (Clements *et al.,* 1994; Urum *et al.,* 2000; Essien *et al.,* 2012). These concerns have led to the development of various remediation technologies including bioremediation – which mainly depends on microorganisms to degrade, transform, detoxify or breakdown the contaminant. Despite the advantages of bioremediation, its efficiency is limited majorly by the limited bioavailability of PAHs to microorganisms. This is attributed to the low solubility and strong and/or irreversible sorption to soil matrix (Rockne *et al.,* 2002). To solve this problem, several methods have been developed to enhance the bioavailablity of PAHs and the use of surfactants (biological or synthetic) is one, with preference to biological sources. This study aimed at scavenging for indigenous bacteria as sources of biosurfactants to increase solubility and apparent biodegradation of PAH compounds.

Materials and Methods: Sediments samples were collected from the humic freshwater ecosystem. PAH utilizing bacterial species were screened for using enrichment technique while biosurfactant producing capabilities of the isolates was determined using the Haemolytic, Emulsification index, Oil spread and Drop collapse tests (Youssef *et al.,* 2004). Isolate with the greatest biosurfactant producing potential was subjected to plasmid profiling to determine if the potential is plasmid mediated. Best isolates obtained were then used to degrade PAH components of crude oil using the monoculture (best crude oil utilizer) and mixed culture (best crude oil Utilizer and best biosurfactant producer). After 21 days of incubation, the rate of degradation was then determined using Gas chromatography coupled with Flame ionization Detector (GC-FID).

Results and Discussion: Preliminary characterization of the strong biosurfactant

producing ($EHSA_4$) and Crude oil utilizing ($EHSC_1$) bacterial isolates revealed *Micrococcus* luteus and *Bacillus subtilis* respectively. *M. luteus* had the highest biosurfactant producing capacity while *B. Subtilis* demonstrated the strongest ability to utilize crude oil and its PAHs components as carbon and energy source for growth. Degradation using monoculture of the oil degrader (*B. Subtilis*) and culture consortium comprising the oil degrader *(B. Subtilis*) and biosurfactant producer (*M. luteus*) shown enhanced degradation when *B. Subtilis* was mix-cultured with *M. luteus* Crude oil degradation by *Bacillus* sp alone resulted in 19.65% degradation by reducing the total petroleum hydrocarbon (TPH) from 20.3467 mg/l to 16.3082 mg/l within 21 days while the bacterial consortium enhanced degradation by 46.06% within the same duration by reducing the TPH to 10.9755 mg/l. This may be attributed to the activity of the biosurfactant produced by *M. luteus* Enhanced degradation of the crude oil induced by biosurfactant producing bacteria population also had effect on the residual PAH content of the crude oil.

Table 1: Biosurfactant Producing and Hydrocarbons Utilization Potentials of the Bacterial Isolates

Isolate Code	Biosurfactant Producing Potentials	Crude Oil Utilization Rate	Naphthalene Utilization Rate	Anthracene Utilization Rate
$EHSC_1$	+	++++	++	+
$EHSC_2$	-	+++	++	+
$EHSC_3$	++	++	+	-
$EHSC_4$	-	+	-	-
$EHSA_1$	-	+++	-	-
$EHSA_2$	-	++	+	-
$EHSA_3$	++++	++	-	-
$EHSA_4$	-	+	-	-
$EHSA_5$	-	++	+	-
$EHSN_1$	-	++	+	+
$EHSN_2$	-	+	-	+
$EHSN_3$	++	++	+	-
$EHSN_4$	-	+++	+	+

Key - = no growth, 1- 5 mm (weak) = +; 6 – 10 mm (moderate) = ++; 11 – 15 mm (strong) = +++; 16 – 20 mm (Strongest) = ++++

Table 2: Summary of Percentage PAH Suites Remaining After 21 days Degradation

Code	Parameters	Monoculture	Mixed Culture
a	Naphthalene	100	100
b	2-methylnapthalene	81	95.8
c	Acenapthene	90.9	95.9
d	Acenapthylene	89.6	99.4
e	Fluorene	97	97
f	Phenanthrene	85.6	59
g	Anthracene	100	99.8
h	Fluoranthene	44.4	43.3
i	Pyrene	94.4	93.4
j	Benz(a)anthracene	98.9	99
k	Benzo(b)fluoranthene	70.7	94.3
l	Chrysene	97	76.9
m	Benzo(k)fluoranthene	99.9	87.5
n	Benzo(a)pyrene	98.8	99.8
o	Dibenz(a,h)anthracene	54.5	52.9
p	Benzo(g,h,i)perylene	72.5	70.5
q	Indeno(1,2,3-cd)pyrene	72.7	83.5

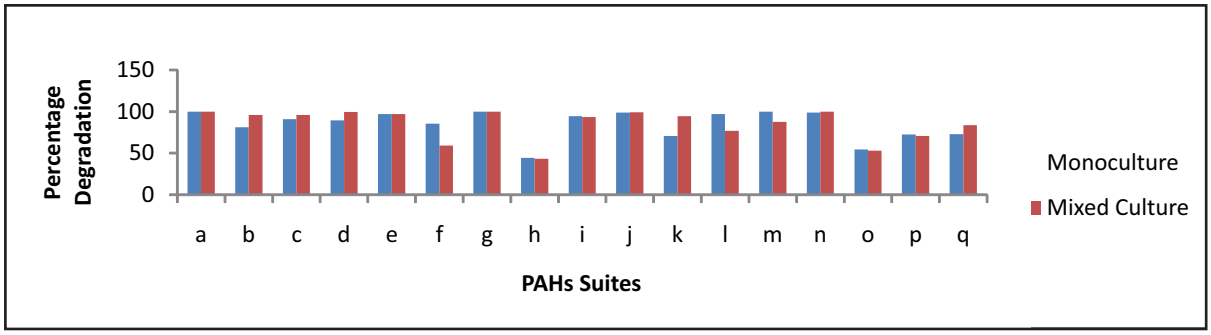
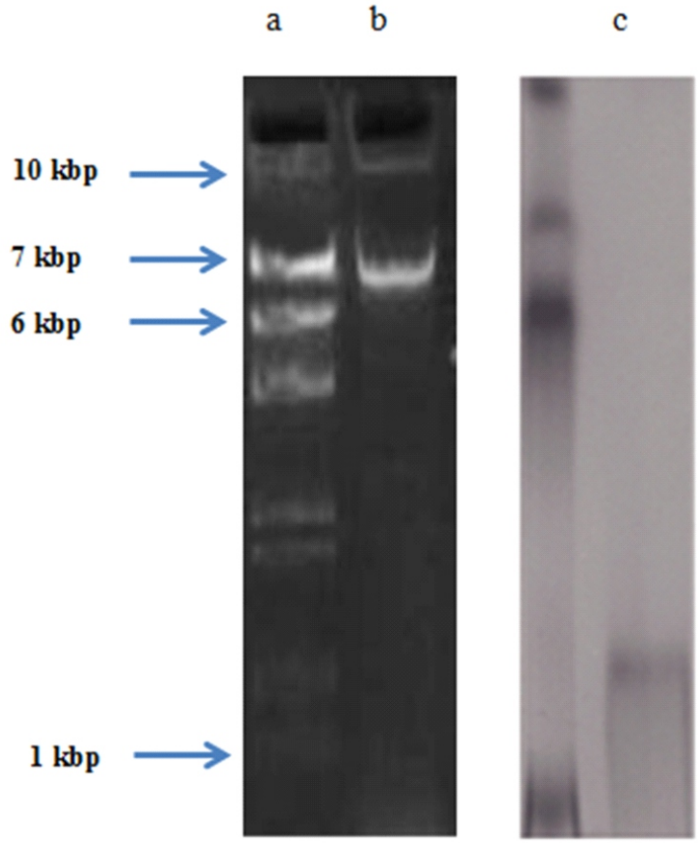


Figure I: PAHs Suites Degradation Rates

After 21 days of degradation, the residual PAH in the degraded crude oil using *B. Subtilis* alone was 2.4547 mg/l while that enhanced with biosurfactant producing *M. luteus* was 2.1833 mg/l. The most degraded PAHs suites were Benzo(b)fluoranthene followed by 2-methylnapthalene and Indeno(1,2,3-cd)pyrene. Isolation, curing and re-screening of the isolates for biosurfactant production revealed that it is plasmid mediated as the bacterium (*M. luteus*) lost its 7kbp plasmid (Figure II) as well as its bio-surfactant producing potential.



Key: a - Marker, b - Plasmid DNA, c - Cured Plasmid DNA

Uncured and Cured Plasmid DNA bands of Micrococcus

***Conclusion*:** The results revealed the selective degrading potential of the *B. Subtilis* and *M. luteus* consortium against Benzo(b)fluoranthene, 2-methylnapthalene and Indeno(1,2,3-cd)pyrene. It is believed that the biosurfactant produced by the *M. luteus* facilitated the degradation activity of the *B. Subtilis* by reducing the interfacial tension between the hydrophobic crude oil and the bacterial cells via its amphiphilic property. The potentials of these bacterial communities can be explored for broader use in remediating Crude oil polluted environment and farmlands, a condition which is inherent and of high concern in the oil producing Niger Delta region of Nigeria.

Keywords: Biosurfactant, PAHs, Plasmid Profile, *Bacillus*, *Micrococcus*

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Treatment Technologies for Emerging Contaminants in Wastewaters

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ABSTRACT: This study is to ascertain the efficiency of the effluent treatment plant available in intercontinental Distillers Limited Sango Ota, Ogun state using the aerated-biochemical system. The efficiency of the system is dependant on 2 factors which are the relationship between the amount of pollution indicators parameter (TSS, BOD, DO) that enters the system with raw wastewater & the amount that leaves the system with the clean effluent and the frequency of evacuation of sludge generated. The results generated shows that the technology adopted by the company is highly efficient and is inconformity with effluent quality to set limits as represented in table 1, the results of the effluent samples from the treatment plant for 13 months.

Introduction: Waste water is any water that has been adversely affected in quality by anthropogenic influence (Akter *et al*., 2000). Wastewater can originate from a combination of domestic, industrial, commercial or agricultural activities, surface runoff or storm water and from server inflow or infiltration (Tilley *et al*., 2001).

Water pollution cannot be overlooked as it is commonly results from factory operations such as wastewater generated from raw materials mixing in production, equipment washing and domestic purposes activities such as in products, filling, spill washing, laboratory, backwashing of the borehole water treatment facilities, underspec flushing and vessel washing were given adequate treatment at the bio-chemical treatment plant described below prior to discharge. Most of the treated effluents are re-used for sprinkling of the lawns/open field within the factory premises, while the excesses is periodically discharged into the environment through the public drains.

Industrial wastewater treatment covers the mechanisms and processes used to treat wastewater that is produced as a by product of industrial or commercial activities. The various types of contamination of wastewater require a variety of strategies to remove the contaminations and the disposal of wastewater from an industrial plant is difficult and costly problem. Most petroleum references, chemical and spectrochemical plants have onsite facilities to treat their wastewater comply within the local/national regulations regarding disposal of wastewater into community treatment plant or into rivers, lakes or ocean constructed (Beychok, 1967) (Tchnobanoglous, *et al.,* 2003). Other industrial processes that produce a lot of waste water such as paper & pulp production has created environmental concern leading to development of processes to recycle water use within plants before they have to be cleaned & disposed (Bryd *et al*., 1984). Waste water generated from agricultural and food operations has distinctive characteristics that set it

apart from common municipal wastewater managed by public or private sewage treatment plants throughout the world, it is biodegradable and nontoxic, but has high concentration of biochemical oxygen demand(BOD) and suspended solids (SS) (European Environmental agency, 2001). The objective of this research is to evaluate the efficiency of the aerated biochemical system used in Intercontinental distillers limited, Sango Ota, Ogun state as a type of waste treatment technology used in developing countries. The treatment of wastewater is not only important for our own health but also to keep our environment clean and healthy. Without the proper wastewater treatment many ecosystem would be severely damaged once the treated water gets recharged back into the environments.

Materials and Method: The effluent treatment plant available in the company is an aerated-biochemical system designed in sequence designed with two processes; surface aeration and sedimentation. In the surface aerated system, the waste water is brought in contact with activated charcoal/sludge in the presence of atmospheric oxygen. Under these circumstances, the organic matter in the raw waste water is broken down by the activities sludge- a consortium of diverse microorganism. Critical elements are organic matter and oxygen.

The second step, which is sedimentation, implies the separation of the sludge flocs from the clear effluent by gravity. This is achieved in sequential chambers (4 numbers) of 500m3 capacities each. The supernatants liquid is thereafter discharged from the last chamber. The designed capacity of the ETP is 300mg/l BOD5 loading, 350mg/l COD and 250m3/d average flow. To achieve a better effluent quality, soda ash is often added of PH stabilization as well as alum and polyelectrolyte to aid chemical coagulation, followed by dissolved air floatation as a result of microbial metabolism, the sludge mass will constantly grow. Hence to avoid sludge accumulation in various settling chambers, the sludge is constantly removed. Samples were then taken from the ETP plant for analysis in the laboratory.

Result and Discussion: The recorded respective ranges for the various pollution indicator parameters within the 13 month are as shown in the table below:

Table 1**: Pollution Indicator Parameters Analyzed in Wastewater for 13 months**

S/N	PARAMETERS	OBSERVED RANGE WITHIN THE 13 MONTHS	AVERAGE	SPECIFICATION/LIMIT
1.	TSS	30.0mg/l-292.0mg/l	109.0mg/l	30.0mg/l
2.	BOD5	2.0mg/l-200.0mg/l	67.9mg/l	50.0mg/l
3.	COD	5.0mg/l-320.0mg/l	100.0mg/l	90.0mg/l
4.	DO	0.67mg/l-5.45mg/l	3.36mg/l	>=2.0mg/l
5.	PH	6.6-8.9	7.5	6.0-9.0

The table above clearly indicates occasion of conformity of effluent quality to set limits. From the established, cause of the variation of the efficiency of the treatment plant being developed, are measures that will enable conformity of issuing wastewater on continuous basis. Such measures include ensuring that the treatment plant is not overloaded beyond the designed capacity as well as more frequent dislodgement which no doubt contributes to occasional high TSS/TS.

Conclusion; From the results obtained it was discovered that all the results are in compliance with the statuary requirement section 3(2)of the FMENV regulations S.I.8 and the maximum contaminant level. It is also good for the general public to be aware of the effects (Organic Pollutant) to human and take caution against future exposure.

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Waste Water Treatment and Emerging Waste Water Contaminants

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ABSTRACT

Waste water is one of the day-to –day concerns of humans and the environment in general, due to its importance to the environment. This is because of the presence of various contaminants that are involved in waste water. Waste water treatment can be defined as the proportion of wastewater that is treated, in order to reduce pollutants before being discharged to the environment, by level of treatment. This work discusses waste water treatment, its contaminants as well as the technologies involved. The major focus is to analyze Okomu Oil Palm Company Plc, their effluent treatment facility. Okomu Oil Palm Company is based in Nigeria, which is one of the developing countries of the world. Okomu Oil Palm Company uses aquatic treatment technology for their effluent treatment and applies the physcio-chemical level of advanced chemical treatment of waste water treatment process. This work will discuss the outcome of the laboratory sample taken on the 30th January, 2015 and analyzed between 30th January- 4th February, 2015.

Keywords: Waste water Treatment, Contaminants, Physcio-Chemical Process, Okomu Oil Palm.

Introduction : Wastewater may be classified into four categories - Domestic: wastewater discharged from residences and commercial institutions and similar facilities; Industrial: wastewater in which industrial waste predominates; Infiltration/inflow: extraneous water that enters the sewer system through indirect and direct means such as through leaking joints, cracks, or porous walls and Storm water: runoff resulting from flooding due to rainfall.

Waste water treatment process are – conventional process, preliminary treatment, primary treatment, secondary treatment and advanced treatment process.

The three waste water treatment technologies are – mechanical, aquatic and terrestrial treatment methods.

Materials and Methods: Okomu Oil Palm Company uses an effluent treatment facility. In this facility, there are two basic systems namely- the effluent sedimentation pit and the pond system. The waste water and the effluent from the factory process are initially discharged into a sedimentation pit. The pit has four (4) compartments.

however, solid waste and dirt are further recovered from the pit. Furthermore, the recovered waste is sorted in the green, orange and red bins for good rubber, bad rubber and dirt respectively. While the sludge that is recovered from the pit is taken to the plantation and applied as manure.

The pond system is where the lagoon systems will be used to treat the factory effluent. The system will comprise two(2) ponds and one(1) pond/basin in series designed to receive, hold and treat the factory effluent for a predetermined period of time. The ponds will be constructed and lined with clay material that will prevent seepage to the groundwater below. While in the lagoon, the effluent will receive treatment through a combination of physical, biological and chemical process. Much of the treatment will occur naturally. Essentially, the treatment shall involve a combination of anaerobic and aerobic sequentially.

Results and Discussions:

Table 2.1 Physico-chemical test characterization of industrial effluent analyzed

	PHYSCICO-CHEMICAL TEST									
EFFLUENT	pH	TemppH oC	Cond. (µs.cm-1)	Turbidity	TDS (mg/L)	Sulphate (mg/L)	Nitrate (mg/)	BOD (mg/L)	COD (mg/L)	Chloride (mg/L)
Stream Effluent	7.76	25	3060	76	2100	80	50.0	1.07	87	265
Effluent from Treated Plant	6.62	25	6330	1100	4200	92	100.6	3.62	320	475
Effluent From Rubber Factory	6.76	25	647	220	440	60	81.0	0.60	278	12.5

From the laboratory sample analyzed by Searchgate Laboratories Limited , the results shows that the pH at 25° C for the Stream Effluent and the Treated Effluent is 7.76 and 6.72 respectively, it is still within WHO standard for pH tolerance limit of 6.00-9.00 and 6.76 for Effluent from the Rubber factory . Chemical Oxygen Demand (COD) is the measure of amount of oxygen required by both potassium dichromate and concentrated sulphuric acid to breakdown both organic and inorganic matters. The COD for the Stream Effluent and the Treated Effluent is 87 and 320 respectively, it is lower than WHO standard of COD of waste discharge of 1000mg/L and 278 for the Effluent from the Rubber factory . Biological Oxygen Demand (BOD) is the measure of the oxygen required by microorganisms whilst breaking down organic matter. The BOD for the Stream Effluent 1.07 , 3.62 for the Treated Effluent, and 0.60 for the

Effluent from the Rubber factory. This is still within the WHO standard which is 50mg/L. The TDS for the Stream Effluent is 2100, 4200 for the Treated Effluent and 440 is for the Effluent from the rubber factory. The TDS for the Stream Effluent and treated Effluent are higher than WHO standard, which is 2000mg/L. Conductivity of water which is a useful indicator of its salinity or total salt content is high in the wastewater from the Stream Effluent and that of the Treated plant. The conductivity for the Stream Effluent and that of the Treated plant- 3040 and 6330 μs.cm-1 respectively is higher than WHO standard of 1000μs.cm-1,but the conductivity from the rubber factory is 647 μs.cm-1 which is far less. The WHO standard for Nitrate is 45mg/L while that for the Stream Effluent, Treated Effluent and Rubber factory are -50 mg/L,100.6 mg/L and 81 mg/L respectively. This is above the WHO standard.

Conclusions: From the data collected from this research, the physicochemical parameters monitored in the Stream Effluent, the Treated Effluent and the Rubber Factory Effluent shows low level of some major parameters – COD, BOD and pH but the substances have high conductivity and TDS. This shows that there is high amount of dissolved salts and presence of a lot of dissolved solids present in the Stream Effluent, the Treated Effluent and the Rubber Factory Effluent. This justifies the stages of operation. Thus, the effluent treatment technology applied by Okomu Palm Oil Plc meets international Standard and as a result is recommended for global best practice.

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Physicochemical Quality of Surface and Ground Water from Municipal Waste Dumpsite Impacted Environment

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ABSTRACT

Physicochemical properties and heavy metal content of water supply in relation to Mfang-mfang and Ibaoku streams, and groundwater around unregulated waste dumpsite in Uyo urban of Akwa Ibom State, Nigeria were assessed to determine their pollution profiles. Surface and ground water samples were collected and analyzed for physicochemical properties and heavy metal content using methods as described by APHA, 2005. Parameters such as pH, dissolved oxygen, biochemical oxygen demand, chemical oxygen demand, total dissolved solids, total suspended solids, nitrate, sulphate, phosphate, total iron, cadmium, lead, etc., were determined. High values of BOD (2.18mg/l – 6.20mg/l for groundwater samples and 8.00mg/l – 9.20mg/l for surface water) show the availability of nutrients in groundwater and surface water samples. pH values for groundwater ranged between 5.42 and 5.87, while pH for surface water ranged between 6.97 and 7.36 respectively. High values of COD are an indication that chemical effluent is constantly discharged into the site. The surface water is highly turbid owing to constant deposition of leachate through surface run-off. The surface water quality around the study area was most affected by the dumpsite. TDS and electrical conductivity were above the given regulatory limits in both groundwater and surface water.

Introduction

Enormous amounts of solid waste produced in and around Uyo urban areas are dumped at the old stadium site ravaged by gully erosion. This municipal solid waste normally termed as "garbage" is an inevitable byproduct of human activity which is disposed through dumping. Solid waste land filling is the most common method of solid waste disposal. The landfill site is open dumpsite, because the open dumpsite is low operating costs and lack of expertise and equipment provided no systems for leachate collections (Abbas *et al*., 2009). Open dumps are unsightly, unsanitary, and generally smelly. They attract scavenging animals, rats, insects, pigs and other pests. Surface water percolating through the trash can dissolve out or leach harmful chemicals that are then carried away from the dumpsites in surface or subsurface runoff. Among

these chemicals heavy metals are particularly insidious and lead to the phenomenon of bioaccumulation and biomagnifications. These heavy metals may constitute an environmental problem, if the leachate migrates into the ground water. The presence of bore well around the open dumpsites to draw ground water threatens to contaminate the ground water (Kumar and Alappat, 2003; Raman and Narayanan, 2008). The people in and around the dumping site are depending upon the ground water for drinking and other domestic purposes. The Contamination of ground water is the major environmental risk related to unsanitary land filling of solid waste. The study of impact of solid waste on water quality of Old Stadium Road and surrounding areas in Uyo urban reveals that the streams are heavily polluted (Dinesh *et al.*, 2005).

Impacts of solid waste on health: The group at risk from the unscientific disposal of solid waste include – the population in areas where there is no proper waste disposal method, especially the pre-school children (located about 200m away); waste workers; and workers in facilities producing toxic and infectious material. Other high-risk group includes population living close to a waste dump and those, whose water supply has become contaminated either due to waste dumping or leakage from landfill sites. Uncollected solid waste also increases risk of injury, and infection. In particular, organic domestic waste poses a serious threat, since they ferment, creating conditions favourable to the survival and growth of microbial pathogens. Direct handling of solid waste can result in various types of infectious and chronic diseases with the waste workers and the rag pickers (scavengers) being the most vulnerable. Exposure to hazardous waste can affect human health, children being more vulnerable to these pollutants. In fact, direct exposure can lead to diseases through chemical exposure as the release of chemical waste into the environment leads to chemical poisoning (Pretti *et al.*, 2009).

Materials and Methods

Geographical Setting of the Study Area

The study area is in equatorial West Africa, which comprises the region lying between latitude 05° 01'North of the equator, and longitude 007°55' on the Atlantic Coast of Africa. Tropical wet and semi-hot equatorial climate with high solar radiation that is mostly diffused due to cloud cover heavy precipitation, light winds and low atmospheric pressure are the major climatic characteristics of the study area. The area falls into the Equatorial Monsoon (Udosen, 2006). Although temperatures are moderated by the cloud cover and by the generally damp air, mean annual temperatures are as high as 24°C - 32°C with little variation in monthly means. The

lowest monthly temperatures (25^{0}C) are recorded in the rainy season months of June to September while the highest temperatures (27.0C - 33.50C) are recorded in February and March. Rain falls every month of the year with a short dry spell in the months of January to March in some parts. Highest temperatures are between March and April and lowest between July and September. The effect the harmattan wind has on temperature in the area is limited. The wet season last from March to October (and in some wet years it may extend to early November when the inter-tropical discontinuity (ITD) moves southwards). Dry season takes three – four months (November to February).

Description of the Environment

This was Uyo Sports Stadium before being engulfed by gully erosion several years back. Government then adopted several erosion control measures to reclaim it, but the entire attempt proved abortive and finally resorted to what we are seeing today as dumpsite. The environmental components sampled include groundwater and surface water bodies (*Mfangfang* and Iba Oku stream along Uyo village road). The site is located in the heart of the city and surrounded by residential quarters and government office complex. The waste consists of domestic, industrial, sewage and hospital waste. All these are lumped together without form of segregation or de-contamination. A total of 3 surface water samples and 4 groundwater samples with 2 control stations were studied. The samples were preserved prior to physical, chemical and biological characteristics analyses. Also, *In situ* measurements were taken on fast-changing parameters. The locations of the sampling sites were established using a Garmin 76S Global Positioning System (GPS).

Surface Water Sample Collection

Sampling of the stream was done according to methods of AS (1998). Three composite samples resulting from the combination of five sub-samples were collected from three randomly selected points in the Mfang-fang and Ibaoku streams. The bottles were tightly closed immediately after sampling and stored in a cooler at 4 ^{o}C for laboratory analysis. Amber bottles were used for the collection of samples for biochemical oxygen demand (BOD). Samples for total hydrocarbon content (THC) were acidified with sulfuric acid, while heavy metal content samples were fixed with nitric acid. All the samples were analyzed for selected relevant physico-chemical parameters, heavy metals. The testing process was performed according to the procedures mentioned in the Standard Methods for Examination of Water and Wastewater (APHA, 2005). Various physico-chemical parameters examined in surface water samples includes, pH, DO,

BOD, COD, Turbidity, Sulphate, Phosphate, Nitrate, Electrical conductivity(EC), Total Dissolved Solids(TDS), Total hardness(TH), Calcium(Ca), Magnesium(Mg), Chloride(Cl), Zinc(Zn), Cadmium(Cd), Nickel(Ni), Iron(Fe), Copper(Cu), Chromium(Cr), Lead(Pb).

Groundwater Sample Collection

In an effort to study the extent of the groundwater contamination 4 sampling sites were selected near the dumpsite from where the samples were taken with 2 control samples. Collection of water from the stand pipes: the tap was allowed to run for three minutes before samples were taken to avoid contamination inside the pipe. The samples were collected in one litre capacity polythene bottles. Prior to the collection, bottles were thoroughly washed and rinsed with sample to avoid any possible contamination in bottling and every other precautionary measure was taken. After the sampling, the samples were immediately transferred to Laboratory Services Division, 84 Obio Imoh Street, Uyo and were stored and transported in an ice pack cooler (at 4°C). All the samples were analyzed for selected relevant physico-chemical parameters, heavy metals. The testing process was performed according to the procedures mentioned in the Standard Methods for Examination of Water and Wastewater (APHA, 2005). Various physico-chemical parameters examined in groundwater samples includes, pH, DO, BOD, COD, Turbidity, Sulphate, Phosphate, Nitrate, Electrical conductivity(EC), Total Dissolved Solids(TDS), Total hardness(TH), Calcium(Ca), Magnesium(Mg), Chloride(Cl), Zinc(Zn), Cadmium(Cd), Nickel(Ni), Iron(Fe), Copper(Cu), Chromium(Cr), Lead(Pb).

Results and Discussion

In Table 1, the pH of both surface and ground water samples were not within the internationally recommended standard (WHO) [pH for surface water systems 6.5 – 8.5; for ground water systems 6.0 – 8.5]. The groundwater and surface water quality were contaminated by incessant percolation and surface run-off of leachate. High values of BOD show the availability of nutrients in groundwater and surface water samples. When this happens, there is proliferation of aerobic bacteria to oxidize the organic matter. High values of COD are an indication that chemical effluent is constantly discharged into the site. The surface water is highly turbid owing to constant deposition of leachate through surface run-off. The surface water quality most affected by the dumpsite. Total dissolved solids (TDS) are the aggregate of dissolved mineral salts in water. Excess TDS is of concern due to their potential for causing unfavorable physiological reactions in humans and livestock. TDS is a good indicator of the mineralized character of water (KWW, 2001).

Table 1: Physico-chemical Characteristics of Water from the Study Area

Parameter		Groundwater						Surface Water			WHO Limit
		GW_1	GW_2	GW_3	GW_4	$CTRL_1$	$CTRL_2$	SW_1	SW_2	SW_3	
General Appearance		Clear	Clear	Clear	Clear	Clear	Clear	Turbid	Slightly Turbid	Turbid	Clear
pH		5.42	5.87	5.69	5.80	7.05	6.90	7.36	6.91	7.03	6.5-8.5
Turbidity (NTU)		1.03	1.25	1.76	0.55	0.21	0.13	115.01	98.61	100.00	5.0
Total Dissolved Solids (mg/l)		1462.5	1551.0	1475.0	1160.0	5.0	7.0	1439.9	1497.0	1369.6	1000
TSS (mg/l)		0.43	0.52	0.73	0.23	0.09	0.05	47.92	41.09	41.67	
Conductivity (µS/cm)		925.0	1102.0	950.0	320.0	15.0	21.0	1130.0	710.0	528.0	1000
Salinity (mg/l)		0.4625	0.551	0.475	0.160	0.005	0.007	0.4399	0.497	0.3696	-
Total Hardness (mg/l)		444.8	435.9	330.0	428.5	28.1	38.7	437.1	510.2	526.0	-
Oil and Grease (mg/l)		<1.00	<1.00	<1.00	<1.00	<1.00	<1.00	3.10	2.21	1.18	10.0
Biochemical Oxygen Demand (mg/l)		6.20	3.25	4.48	2.18	1.51	1.28	8.30	8.00	9.20	-
Chemical Oxygen Demand (mg/l)		18.0	12.0	18.0	14.0	<10.0	<10.0	88.0	79.0	82.0	-
Chloride (mg/l)		25.00	17.00	21.00	20.41	2.14	2.33	82.50	94.60	100.24	-
Total Alkalinity (mg/l)		332.4	220.2	327.9	224.0	34.0	23.2	428.8	455.1	352.7	250
Dissolved Oxygen		2.8	2.6	2.2	2.5	2.8	2.7	6.3	6.8	7.1	-
Nutrients (mg/l)	Nitrate	0.56	0.48	0.31	0.25	0.14	0.18	10.24	9.33	11.46	10.0
	Phosphate	4.11	2.58	3.15	2.85	0.18	0.32	35.10	32.18	36.28	-
	Sulphate	1.10	0.33	0.61	0.72	0.02	0.08	52.13	65.23	70.14	250
Calcium (mg/l)		35.00	24.20	28.00	25.10	4.12	3.15	85.00	77.00	96.00	70
Magnesium (mg/l)		12.20	13.43	12.28	10.48	0.14	0.10	132.00	37.00	40.00	30
Potassium (mg/l)		28.1	15.2	11.8	6.2	0.34	0.15	11.29	16.28	12.18	-
Sodium (mg/l)		266.41	248.31	224.33	110.21	14.28	13.19	328.12	332.10	344.28	200
Heavy Metal Content (mg/l)	Arsenic	0.0212	0.0165	0.0120	0.0113	<0.001	<0.001	0.240	0.210	0.301	0.01
	Mercury	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	0.001
	Selenium	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.036	0.031	0.035	0.01
	Lead	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.011	0.018	0.012	0.05
	Zinc	0.015	0.023	0.014	0.017	0.03	0.002	0.150	1.020	1.200	3.0
	Total Iron	0.46	0.63	0.55	0.29	0.18	0.11	1.21	1.23	1.31	0.36
	Copper	0.26	0.08	0.05	0.13	0.01	0.02	0.42	0.34	0.37	1.0
	Manganese	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.29	0.37	0.45	0.5
	Cadmium	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	0.003	0.002	0.001	0.003
	Total Chromium	0.070	0.041	0.021	0.037	<0.001	<0.001	0.250	0.217	0.263	0.05

Source: Fieldwork Laboratory Analysis (2014)

TDS and electrical conductivity were above the given regulatory limits in both groundwater and surface water (**Table 1**). Total alkalinity is a measure of the concentration of alkalis present in the water sample. It aids in monitoring the pH of the sample. The alkalinity of natural or treated water is the capacity of some of its components (bicarbonates, carbonates, and to a lesser extent hydroxides, silicates and phosphates) to neutralize an equivalent amount of a strong acid (GEMS, 1992). This equivalent amount of strong acid gives the total alkalinity. The hardness of water is

caused by dissolved metallic ions, primarily calcium and to a lesser extent magnesium ion, and is often expressed as an equivalent quantity of calcium carbonate. Magnesium in association with he sulphate ion may have laxative effect, to which the human body can adapt to in time (WHO, 1984; Cotruvo and Bartram, 2006). The heavy metals (As, Cu, Fe, Pb, Mn, Hg, Ni, V, Zn) constitute a large class of organic and inorganic compounds that are both essential and toxic to human and the environment. They are also known to accumulate in plants and animal tissues where they cause various physiological problems. The phenomenon by which they accumulate in tissue is known as bio-accumulation, and this process is of utmost importance in environmental management. Some case studies on bio-accumulation include the early 1970's Minamata disease, which revealed the potential for bio-magnification of mercury and other heavy metals in living tissues (Acha and Szyfres, 2003), and Ita-ita disease caused by accumulation of cadmium in human tissue, also O'Halloran and Duggan in 1984 showed that some spent lead shot ingested by swans in Ireland ended up in the nucleus of the kidney cells (ATSDR, 2005).

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Figure 1: Unregulated Dumpsite

Figure 2: D-5 Machine got stuck while land filling the waste

Figure 3: Field worker sampling

Figure 4: *Mfang-mfang* Stream

Transforming industrial wastewater management in Africa with a green technology

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ABSTRACT

It is a common practice in Africa to see untreated industrial wastewater being discharged into the environment without due diligence. In the quest to find a cost effective means of addressing the growing wastewater menace on the continent, a study was conducted in Nigeria to assess the effectiveness of an African endemic species of vetiver grass (*Chysopogon nigritana*) in removing wastewater contaminants. Effluents were collected from quarry, fertilizer and cassava processing company, as well as untreated leachate from public refuse dumpsite, among others. Pre and post treatment properties assessed were BOD, COD, pH, N, P, Cd, Pb, Zn, Ar, Ni, Fe, Mg, among others. All the pre-treatment contaminants levels exceeded the WHO/FAO and USEPA safe levels. Treatment using the African bio-resource for 2, 4 and 6 days in some case completely removed contaminants and in some, significantly reduced the levels; bringing the wastewater quality to acceptable standard. This green technology can be applied globally for commercial and micro wastewater treatment.

Keywords: sickwater, African bio-resource, climate resilient technology, safe level

Introduction

Treatment of industrial wastewater to a standard level is not a common practice in Africa. Industries usually discharge untreated effluents into water bodies, despite the implications on humans and the ecosystem. Untreated industrial effluents have become a major source of pollution of water bodies, soil and air globally (Hossain *et al*., 2010). Frequencies of outbreaks of sicknesses relating to contaminated water are high and in most cases, this outstretches national healthcare facilities in Africa. The situation is similar in Asia as reported by Hossain *et al*., (2010) and Ivy *et al*., (2015). Wastewater still poses a threat even in developed countries, as treatment systems comparatively process only small volume of wastewater (RUAF, 2008). The discharge of untreated textile factories effluents by industries in Ghana and the well documented destruction of livelihoods and ecosystems by oil and gas industry in Niger Delta in Nigeria and elsewhere in other developing countries (Mariano and Rovere, nd; Pyagbara, 2007) are

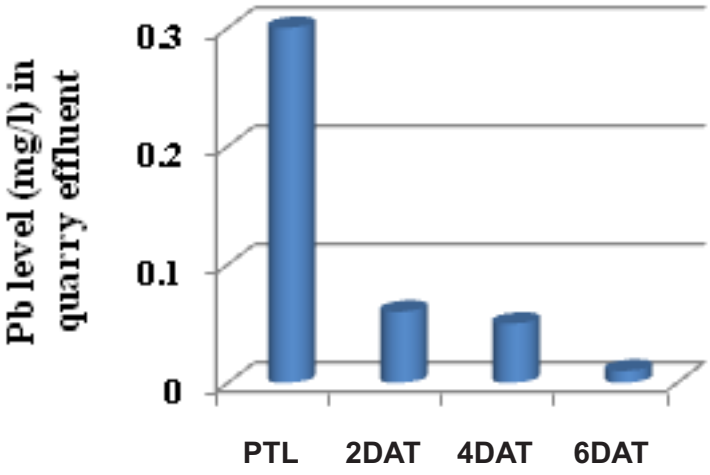
few examples of improper wastewater management which have negative impact on people and the environment. Industrial wastewater is reported to contain most hazardous heavy metals such as Cadmium (Cd), chromium (Cr), Nickel (Ni), Arsenic (As), Lead (Pb), and Zinc (Zn), with these elements being highly soluble in water and readily absorb into human bodies (Barakat, 2011). Unfortunately, strict monitoring and enforcement of environmental regulations is lacking in many African countries. As a result, industries are unwilling to invest in wastewater treatment infrastructure and human capital.

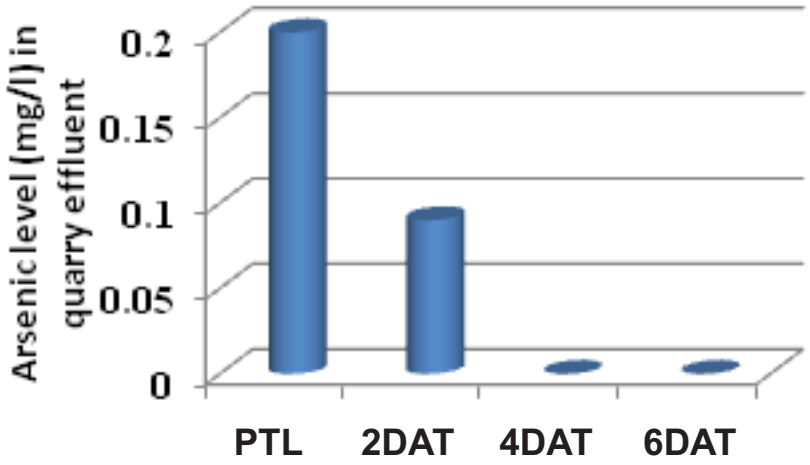
In Uganda, Zambia, Libya, Ghana, Nigeria, Senegal, Ethiopia, stabilization pond system was identified as being used for wastewater treatment (Wang, *et al*., 2014). Post treatment effluent from the pond indicated that, the water quality was still unsafe for discharge into the environment. Conventional practices for removal of heavy metals in wastewater have been reported in literature (Barakat, 2011 and Wang *et al*., 2014). However, these conventional systems are not being adapted for treatment of large volumes of wastewater. These systems also increase environmental risk as a result of the high fossil fuel (energy) demand, resulting in greenhouse gases (GHGs) emissions, hence the quest for a green technology that suits African unique characteristics and meets global standard. A green technology that is economical, ecologically acceptable, socially inclusive and technically suitable for commercial and micro scale usage could help in solving the wastewater challenges in Africa. This paper therefore aims at sharing the results of wastewater treatment with an African endemic species of vetiver grass (Chysopogon nigritana).

Methodology

The study was conducted in Abakaliki, Ebonyi State, Nigeria, using an African endemic vetiver grass (*Chysopogon nigritana*) to treat industrial wastewater. Effluents were collected from a quarry site, fertilizer and cassava processing companies, untreated leachate collected from public refuse dump, among others. Heavy metals and some properties determined were BOD, COD, pH, N, P. Cd, Pb, Zn, Ar, Ni, Mg, among others. Pre and post-treatment analyses were done using standard methods prescribed by APHA, (2005) and Udo *et al*., (2009). Vetiver plants were first raised hydroponically for 10 weeks to enable the establishment of roots and shoots (Truong and Hart, 2001). The bio-engineering set-up (treatment system) was a floating hydroponic vetiver, which was immersed in the industrial effluents. Samples were collected after 2, 4 and 6 days for laboratory analysis and compared with WHO/FAO/USEPA safe levels for wastewater before discharge or re-use.

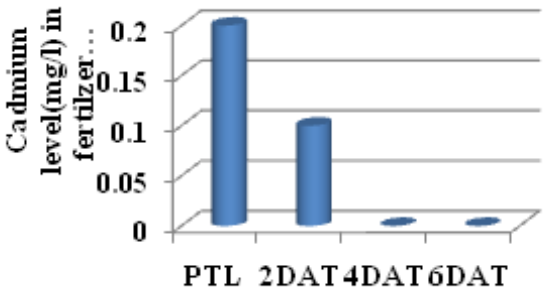
Results

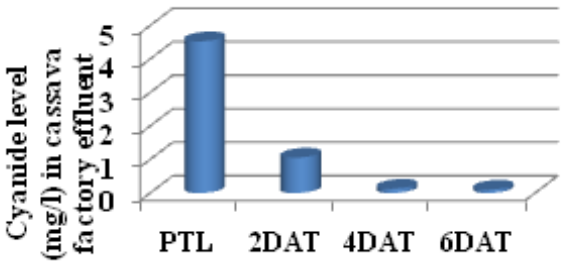




PTL=pretreatment level; DAT=days after treatment

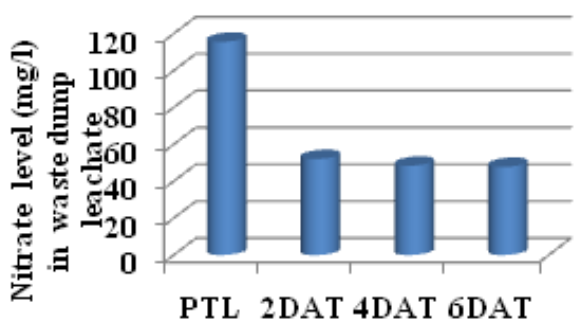
Figures 1 and 2. Pre and post treatment levels of Pb and As of quarry effluent using African vetiver *spp*.

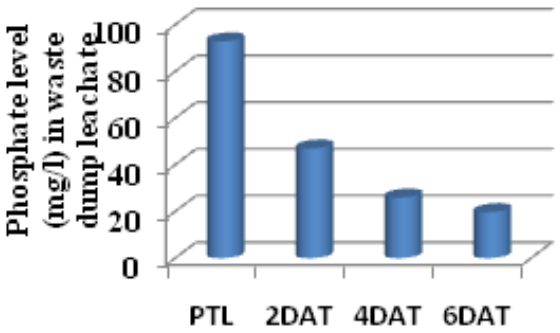




PTL=pretreatment level; DAT=days after treatment

Figures 3 and 4. Pre and post treatment levels of Cd and HCN in fertilizer and cassava factory effluents respectively using African vetiver spp.





PTL=pretreatment level; DAT=days after treatment

Figures 5 and 6. Pre and post treatment levels of N and P in untreated public waste dumpsite effluent using African vetiver spp.

Discussion

Pb and As contaminants are common pollutants of water in mining communities, however, treatment with African vetiver grass removed Pb by 80-83 %. Vetiver removed 55 % of As after 2 days treatment and by the 4th day of treatment, the pollutant was completely removed in the effluent. Cadmium and cyanide levels in fertilizer and cassava factory effluent were reduced from unsafe levels of 0.2 mg/l and 4.53 mg/l to safe levels of 0.01 and 0.20 mg/l, respectively (USEPA, 2012). Nitrate and phosphate, major contaminants responsible for eutrophication of aquatic environment and suffocation of marine lives were reduced to safe levels of < 50 mg/l and 30 mg/l, respectively. This implies that this treatment system could prevent eutrophication of water bodies.

Conclusion

African endemic vetiver grass was effective in healing the sampled "sickwater". This presents a unique climate resilient technology option to revolutionize wastewater management. It is recommended that African governments and other stakeholders invest in this technology to address the wastewater management challenges on the continent.

Acknowledgement

The authors gratefully acknowledge the United Nations University Institute for Natural Resources in Africa (UNU-INRA) in Ghana for sponsoring this research.

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Removal of Methylene Blue from Aqueous Solution using Calcined Cow Bone

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ABSTRACT

Introduction: Industrial wastewater containing dyes is considered as one of the major pollutants of the environment. To the environmentalists, dye removal from effluents of chemical industries such as plastics, dyestuffs, textile, pulp and paper has remained a problem of increasing concern (Phillips, 1996). The presence of dyes in water, even at very low concentrations, is highly visible and undesirable; Colour interferes with penetration of sunlight into waters; retards photosynthesis; inhibits the growth of aquatic biota and interferes with gas solubility in water bodies (Garg *et al*., 2004). Many health related problems such as allergy, dermatitis, skin irritation, cancer, and mutations in humans are associated with dye pollution in water (Bhattacharyya and Sharma, 2004). In order to remove dyes from industrial effluents, several processes have been adopted by researchers worldwide. Among several chemical and physical methods available are: Precipitation and coagulation, ion exchange, membrane processes and electrolytic technologies (Deniz and Saygideger, 2011). But current research has shown that treatment technologies like precipitation and coagulation become less effective and more expensive when situations involving high volumes and low metal concentrations are encountered (Kapoor, 1998). Carbonized cow bone has aroused much attention from wastewater treatment industry due to its advantages over other adsorbents (Aklil *et al*., 2004)

Materials and Methods: Preparation of dye stock solution and serial dilution was done according to Etim *at el* (2012). Characterization of cow bones was done according to method described in Mohammed *et al* (2012). Adsorption parameters like pH, adsorbent dosage, contact time and initial dye concentrations were conducted following the method described by Cheung *et al*. (2000). Different adsorption and kinetic models were employed to study the mechanism of adsorption according to the method described by Etim *at el* (2012).

Results and Discussion: Characterization of cow bones revealed the moisture content, ash content, bulk density, pore volume, as 2.85 %, 18.18%, 0.97 g/cm^3, 0.30 respectively. For effect of contact time, result revealed that at 1min the percentage dye removal was 84%, at 10 minutes it was 93.6%, and that at 15mins, it increased to 98% where it attained a constant value at equilibrium. For the effect of pH on the adsorption efficiency of CBC, percentage dye removal increased from 80.84% at pH 2.0 to 93.62% at pH 6.0. On adsorbent dosage an increase from 92.1% to 99.2% was observed when the dosage was increased from 0.05 to 0.10 g. When the adsorbent dosage was doubled from 0.10 to 0.20 g, dye removal did not increase, indicating that adsorption was almost complete with 0.10 g of the adsorbent. The application of the Langmuir, Freundlich and Temkin models to the adsorption isotherms revealed the correlation coefficients R^2 of 0.997 for Freundlich adsorption isotherm (Figure 1) as the best model. For the kinetics studies evaluated with the pseudo first-order and pseudo second order models, results of data analysis revealed that the pseudo first-order kinetic model does not fit well with the MB adsorption onto CBC ($R^2 = 0.44$) but the adsorption of this dye complies with the pseudo second-order (Figure 2) kinetics because the coefficient of this model is higher than 0.99.

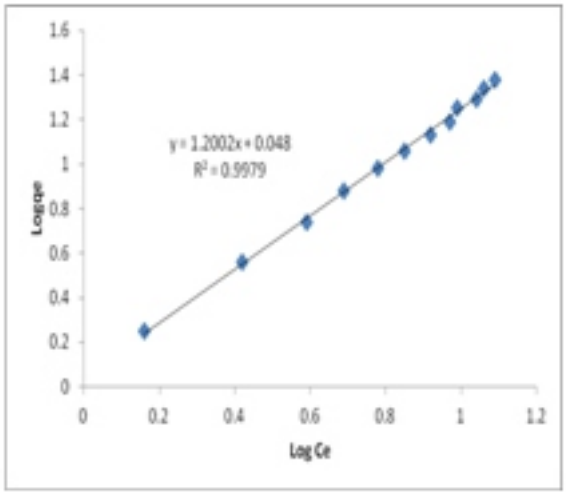

Figure 1 Freundlich isotherm for the adsorption of MB dye onto CBC

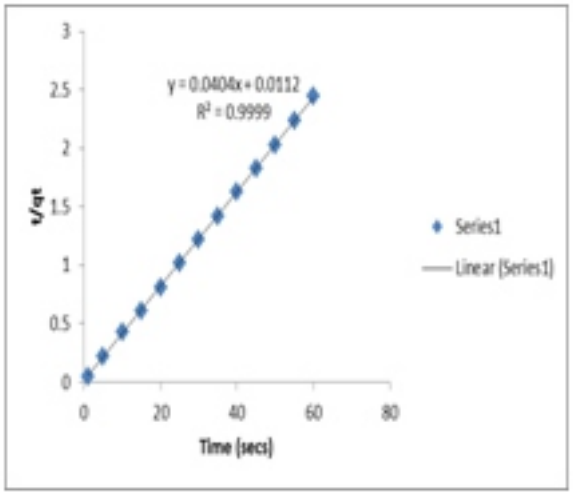

Figure 2 Pseudo- second order kinetic model

Conclusion

The results obtained from this work revealed that cow bone charcoal (CBC), a cheap and readily available agricultural waste material, is an effective low cost adsorbent for the removal of MB dye from aqueous solutions. The adsorbent had good adsorption

capacity for methylene blue and showed strong adsorption as the initial concentration of the dye was increased. The adsorption kinetic data were best described by the pseudo-second order kinetic model. Thus, the adsorbent (CBC) could find industrial applications for the treatment of industrial wastewater containing dyes before it is discharged into the aquatic environment.

***Keywords*:** Cow bone, Adsorption, Dye, Industrial Wastewater

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Impacts of Climate Variability on Wetland and Fishing Households in the Niger Delta Region, Nigeria

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ABSTRACT

The study assessed the impacts of climate variability on wetland and fishing households in the Niger Delta region, Nigeria. Three hundred and twenty four respondents were selected using multi-stage sampling technique. Primary data were collected using questionnaire, in-depth interview and focus group discussion, while secondary data was collected from literature. Descriptive statistics including frequency and percentage were used for data analysis. Climate variability has brought about drought, flood, sea level rise and erosion. These have adversely impacted on farm households in various ways including loss of farmland and farm produce, displacement of residents and loss of property including residential buildings and fishing gadgets. Other adverse impacts include health problems, conflict, increased expenditure, poor yield and loss of income. Gender analysis of the impacts of climate variability shows that both men and women are equally impacted upon. Adaptation strategies should be developed to help in reducing the impact of climate variability on farm households.

Introduction: The Niger Delta region of Nigeria is a complex, yet fragile environment consisting of upland, wetland and fishing communities. Almost all oil production activities in Nigeria, with their attendant negative effects on the environment take place in this region. The area is highly degraded due to oil exploration and exploitation activities, oil spills and gas flaring. Farming and fishing are the major livelihood activities of inhabitants of the region. Records (National Bureau of Statistics, 1997 and Central Bank of Nigeria, 2006) reveal that not less than 70% of the population depends on agriculture and fishing for its livelihood, producing food and fiber for human consumption and industrial use respectively. Agriculture is largely rain-fed and crop cultivation as well as livestock production depends on the availability of water from rainfall. Thus, agriculture in the Niger delta region is highly influenced by annual and inter-annual variations in rainfall and other climatic factors.

While drought is a recurring problem in northern Nigeria, floods cause serious damages to livelihoods and agriculture in the Niger delta (NEST, 2004). These

problems are aggravated by climate variability and long-term climate change, posing serious threats to agricultural production and to the livelihoods of a great number of people (Zabbey, 2007). Studies (Umoh, 2000; Umoh 2008) have shown that farmers in the Niger delta region, particularly the wetland farmers operate between two extreme conditions- flooding and drought. These are associated with variability/changes in climatic conditions of the region. Data from the National Bureau of Statistics (NBS - Nigerian data gathering agency) indicate obvious variations in such climatic elements as rainfall and temperature. For instance, mean annual rainfall in Akwa Ibom, Ondo and Rivers States was as high as 2,618.6mm, 1,699.5mm and 1,644.8mm respectively in 1994. This went as low as 180.2mm, 121.2mm and 203.1mm respectively in 2004 (NBS, 2005, 2007). This has grave effects on the timing of planting, pest and disease control, harvesting and crop yield.

The impacts of climate variability are cross-cutting, with several direct impacts on agriculture, water resources, and natural vegetation and indirect effects on health, the economy, and institutions. In the Niger Delta region, these are confounded by environmental degradation occasioned by sesamic activities and their fallouts, soil erosion, water pollution, and deforestation. These activities have impacted negatively on the social-economic activities and health of the inhabitants of the region in various ways. Livelihoods are destroyed; where fish catch as well as crop yield is low. Various diseases like skin rashes and cancer are increasing while acid rains are observed as destroying roofs of buildings. Variability in climatic conditions interact with other forms of stress associated with agricultural production and affect crop yields and productivity in different ways, depending on the types of agricultural practices and system in place (Watson *et. al*, 1997). In the Niger Delta region, these are impacted upon through direct changes in temperature, precipitation, length of growing season, and timing of extreme or critical threshold events relative to crop development (Oyekale, 2008).

It is therefore obvious that adaptive measures have to be taken to maintain agricultural production and productivity. According to Speranza (2010) at the level of practice, adaptation is a continuum of practices which ranges from activities that are predominantly developmental to those that focus on reducing climate change. The study further asserted that no single measure is sufficient to adapt to climate variability or long term change, rather, a mix of measures is required which targets the various farm variables – water, soil, micro-climate, seeds and crops as well as labour and capital. It concludes that for adaptation to be sustainable, local knowledge should be combined with other knowledge systems.

Many proponents (IPCC, 2001 and Nhemachena and Hassan, 2007) of climate

change argue that it is necessary to focus on current problems and adaptation to climate change in order to develop strategies that will adequately respond to anticipated changes in climatic conditions. The IPCC (2001) for instance, maintains that adaptation to current climate variability and extremes often produces benefits as well as forming a basis for coping with future climate change. A fair knowledge of the impacts of climate variability and long term change on farming and fishing households in the region is therefore necessary. This is required for informed policy formulation, programme planning and implementation on adaptation and mitigation of the impacts of climate variability/change, not only in the Niger Delta region and Nigeria, but in other regions with similar attributes as the area. However, information on the impacts of climate variability on farming and fishing households in the Niger Delta is scanty. To bridge the information gap therefore, the study assessed the impacts of climate variability in the Niger Delta, Nigeria.

The specific objectives of the study were to:

I) Assess the effects of climate variability on fishing and wetland households in the Niger Delta

ii) Examine ways by which men and women in the various communities are affected by impacts of climate variability in the Niger Delta.

iii) Identify the gender most affected by climate variability related hazard among fishing and wetland households in the Niger Delta

Materials and Methods

The study was conducted in the Niger Delta region of Nigeria comprising over 20 different ethnic groups which are spread over nine states. These states are Abia, Akwa Ibom, Bayelsa, Cross River, Delta, Edo, Imo, Rivers and Ondo. It is located along the Atlantic Coast and lies within latitude 04° 49o 60?o? N and longitude 06° 00? 00? ? E. The Niger Delta occupies an area over 70,000 Km^2 and is among the three largest wetlands in the world (Ikporikpo, 1998 and Constitutional Right Project, 1999). About 2,370 Km^2 of the Niger Delta area consist of rivers, creeks and estuaries, while stagnant swamp covers about 8600 Km^2 (Constitutional Rights Project, 1999).

The region falls within the tropical rain forest zone and is characterized by two seasons: the dry and rainy seasons. The rainy season stretches from March to October and the rainfall could be as high as 3800mm to 4500mm. The dry season is only experienced for a few months in some coastal sections of the region. The Niger Delta is richly endowed with mineral-rich sedimentary formations, with petroleum as the major mineral. Its exploitation accounts for over 90% of the federal government export revenue. Intense petroleum exploration and production in the Niger Delta region

result in gas flaring, with adverse effects on the environment (Ibeanu, 2000). Crop farming, livestock rearing, fishing and petty trading are major livelihoods of the people.

Akwa Ibom, Rivers and Ondo States were selected for the study using simple random sampling technique. Two wetland and one fishing community from each of the 3 states were purposively selected making a total of 9 communities. Disproportionate sampling technique was used to select 108 respondents from each of the 3 states, making a total of 324 respondents. Due to non-availability of documented information at the community level on climate variability/change related disasters, the study relied on secondary sources and oral testimonies from participants in Focus Group Discussions (FGDs) and In-Depth Interviews (IDIs) of key informants. Questionnaire was also used to obtain quantitative data. Data were analyzed using frequencies and percentages.

Results and Discussion:

Effects of climate variability in the Niger Delta

Table 1 contains impacts of sea level rise in the Niger Delta (Awosika, *et al*, 1992). The report reveals that 26-45 meters of land area is lost to erosion per year. This is 15% of the total area of the Niger Delta. A total of 50 villages are impacted and 0.15 million people are displaced. It is projected that 2-3million people could be displaced by sea level rise. The implication is that unless practical steps are taken to check sea level rise, a large portion of the Niger Delta can be washed off and millions of people would be displaced. Such practical approaches to checking impact of sea level rise include construction of embankments to protect the coastal environment, tree planting and grassing of fields. Awareness creation and building the capacity of the farmers to take climate change adaptive measures can assist in reducing the impact of sea level rise.

Table 1: Impact of Sea level Rise in the Niger Delta

Type of Impact	Unit of Measure	Present	1m SLR	2m SLR
Erosion rate	m/year	10-15	16-19	20-25
Area lost to erosion	Km2	26-45	55-120	130-230
Inundation and erosion	Km2	3,000	7,000	15,000
Percent of area lost	%	15	35	75
Villages impacted	No	50	200	350
People displaced	Million	0.15	1-2	2-3

Note: Total area of Niger Delta is about 2 million hectares
Source: Awosika et al 1992

Besides sea level rise, flooding has also impacted adversely on households in some communities in the area. The impacts come in different forms and severity and have been the subjects of concern and discussion in the print, electronic as well as social media. An example is the report of the impact of flooding in the newspaper quoted below. Again, flooding has taken new dimensions in the Niger Delta in recent years. Heavy down pour is more frequent, rainfall volume is unusually high and the impact, devastating. Usually, the first to be affected is fresh water, followed by road transportation. Movement is usually grounded and economic activities adversely affected. All these show that individuals as well as institutions including Ministry of Environment are yet to take adaptive measures to the impacts of climate change.

Floods: Displaced A'Ibom victims want to return home
(The Punch Newspaper November 17, 2010)

Indigenes of Itak Abasi community in Akwa Ibom State, who were displaced by floods in August, have expressed their desired to return home. The floods were caused by surging waves of the Atlantic Ocean. One of their leaders, Mr. Inyang Itrechio, who spoke to the News Agency of Nigeria in the community on Wednesday said they were yet to see any effort by the government to address the ecological problem caused by the floods. He, therefore, appealed to the state and federal governments to take urgent steps to reclaim the portion of their land submerged by the ocean surge, to enable them to reoccupy the community. He also appealed to the Ministry of Niger Delta Affairs to assist the community by reclaiming the land, saying that all fishing settlements in the area were swept away by the flood. "The greatest need of the affected people now is to have access to their ancestral land where they have lived for decades. We know that if there is the will by government, the land can be reclaimed. "We passionately appeal to the government to reclaim the land for us," he said. Itrechio recalled that some ecological experts, who visited the area after the incident attributed it to the effects of global warming. He said they claimed that the floods displaced more than 4,000 fishing settlements. He told NAN that the water blocked the creeks and made navigation impossible. Itrechio pointed out that if the situation was not reversed, many communities accessible only by canoe would be cut off. He commended Ibeno Local Government, the state government and the National Emergency Management Agency for their visit to the area and the donation of relief materials to them. The community leader urged NEMA, the state government and the council to find a lasting solution to the problem. Itrechio said the Chairman of the local government, Mrs. Regina Egbe, had constituted a committee to assess the problem and prepared a blueprint for tackling it.

Fig. 1: Debris of Brick Building Destroyed by Sea Level Rise in Ibaka, Mbo LGA, Akwa Ibom State

Going by the testimonies of participants at the FGDs, the variations in climate have varying degrees of effects on the farmers as well as the fishermen. Participants from farming communities noted that late onset of rains has brought about reduced level of sprouting/germination of seeds and poor yield. They also reported that high temperatures result in wilting and death of crops particularly banana and plantain. Yam tubers are also said to rot either in the soil or in storage due to extreme heat/temperatures. The overall effects of these are low crop yield, low farm income and food insecurity of farming households. Flooding is reported to "sweep off" farmland leading to loss of crops and income. Buildings, particularly thatch houses are often destroyed by flood and sea level rise in fishing and wetland communities. Livestock are not spared from the adverse effects of climate variability. Outbreak of livestock diseases are said to be common during periods of temperature extremes. Discussants in Amalem, Rivers State specifically reported appearance of new species of plants which is fast replacing indigenous ones. In addition, they also reported attack of coconut trees by non-indigenous species of bird which defecates on young coconut leaves. The leaves are said to wither and die and the entire tree follow suit subsequently.

Participants in FGDs in all the communities made the point that the health of households/families has also come under the adverse impact of climate variability. They reported that the population of malaria causing mosquitoes seems to have increased, leading to more cases of malaria attack on household members. Skin diseases are now

more common and households now spend more on medical bills. These, coupled with loss of income arising from climate related hazards have rendered households more vulnerable to poverty. Female respondents in Ifiayong Usuk, Akwa Ibom State observed that climate variability is affecting women's ability to procreate. They claimed that the number of children a woman can give birth to has reduced. In addition, new born babies are no more having characteristics that used to be identified with the new born such as folding of the hands, rhythmic beating of the center of the head and the characteristic cry of babies. Both key informants and discussants at the FGD were of the opinion that the impact of climate variability is more severe on female headed households than the male headed ones. This is said to be engendered by women's limited sources of income and access to resources such as land and farm input.

Ways by which men and women are affected by impact of climate variability/change.

`The distribution of respondents based on their observations on ways by which men and women are affected by climate variability/change related hazards in wetland and fishing communities are presented in Tables 2 and 3.

a) **Ways by which men and women in wetland communities are affected by climate variability**: Respondents' views of the ways by which climate variability affects farming households in wetland communities (Table 2) in Akwa Ibom State differ between male and female respondents. While as much as 34% of the male farmers reported no effect, only 7.4% of the females reported same. Loss of income was reported by 55.6% of the female respondents, while only 15.1% share in this opinion. However, conflict seems to be a common view of both male and female respondents (Table 2). Conflict as impact of climate variability is also common in Rivers State, but is less a problem in Ondo State. Another impact of climate variability that runs through all the States studied is loss of income. In Ondo State, 63% of the female and 50% of the male respondents are affected by loss of income. While more than a half (55.6%) of the female respondents in Rivers State is affected by loss of income, only 15.1% view this as one of the ways that they are affected by variation in climate. This means that men and women are not affected in the same way. Therefore, programmes designed for adaptation or mitigation of the impact of climate variability and long term climate change should consider these differences.

Table 2: Percentage distribution of respondents according to their views on ways men and women are affected in wetland communities

Ways households are affected	Akwa Ibom		Ondo		Rivers	
	Male (%)	Female (%)	Male (%)	Female (%)	Male (%)	Female (%)
None	34	7.4	4.6	0	34.0	7.4
Loss of properties	11.3	0	13.8	35.7	11.3	0
Health problems	1.9	0	7.7	0	1.9	0
Increase expenditure	0	0	10.8	14.3	0	0
Loss of income	15.1	55.6	63.0	50	15.1	55.6
Loss of output & poor yield	9.4	3.7	0	0	9.4	3.7
Conflict	28.3	33.3	26.7	0	28.3	33.3
Total	**100**	**100**	**100**	**100**	**100**	**100**

Source: Field data, 2011

a) **Ways by which men and women in fishing communities are affected by climate variability**:

Given the peculiar occupation of fishermen, it would be expected that the ways by which variations in climate affect the fishermen would be different from the wetland communities. Indeed, the result in Table 3 reveals an additional dimension which is the impact on the health of the respondents. In Akwa Ibom State, 30% of the female and 15% of the male respondents identified health problems as one of the ways that they are affected by variation in climate. Moreover, 20% and 40% of the male and female respondents in Rivers State respectively singled out health problem as a way in which they are impacted upon by climate variability. On the contrary, respondents in fishing communities of Ondo State did not identify this as a problem. More than a half (56.3%) of the male respondents in Akwa Ibom State identified low catch as one way that they are affected by climate variability. Loss of income is also one of the ways by which fishermen are affected by climate variability as a total of 60% of both the male and female respondents in the fishing communities observed that climate variability adversely affects their income.

These differences in the ways that fishing and wetland communities are impacted by climate variability implies that climate variability and long term climate change adaptation measures need to address these differences which may, to some extent, be influenced by the peculiarities of the livelihoods and the micro-environment of the respondents.

Table 3: Percentage distribution of respondents by their views on ways men and women are affected in the fishing communities

Ways households are affected	Akwa Ibom		Ondo		Rivers	
	Male (%)	Female (%)	Male (%)	Female (%)	Male (%)	Female (%)
None	13.7	0	6.7	0	13.3	0
Loss of properties	0	14	33.3	80	0	0
Health problems	15	30.0	0	0	20	40
Increase expenditure	0	10.7	0	0	0	0
Loss of income	10	45.3	33.3	0	60	60
Low catch	56.3	0	0	0	0	0
Conflict	5	0	26.7	20	6.7	0
Total	**100**	**100**	**100**	**100**	**100**	**100**

Source: Field data, 2011

Gender most affected by climate change related hazards

Table 4 shows that both men and women are equally affected by climate variability. In Ondo and Rivers States, the opinion of both male and female farmers is that men and women are equally affected. The trend seems to be that both men and women are equally affected across the communities and states (Table 4). While the percentage of respondents taking this position differs across communities and states, this group still forms the majority in each location and state. The findings seem to differ from the popular opinion in climate change literature which suggests that the women are more vulnerable (Speranza, 2010). The result as obtained may be attributed to insufficient gender analysis skills of most rural people. Being gender blind makes it difficult for the respondents to see the specific gender divide of the impacts of climate variability, as a male discussant in Amalem, Rivers States euphemistically explained: *If I am affected, my wife is affected. And, if my wife is affected, I am affected. Therefore, both men and women are equally affected.*

However, most discussions on the gender dimensions of climate change impacts and vulnerability seem to be inferences drawn from women's well known disadvantage position in the society. For instance, Tshikata and Awumbula (2004) posited that in Ghana, women's livelihoods depend on areas that are vulnerable to impacts of climate change. Nigerian Environmental Study/Action Team (NEST) (2004) also painted similar picture of gender dimension of climate change impacts and vulnerability in Nigeria. Citing example of water and water-related impacts, NEST pointed out that "when water crises sets in, women and young girls will be the most vulnerable in view of their need for water and hygiene (compared to males). It thus concluded that women continue to affect climate change and are most affected by it.

Table 4: Percentage distribution of respondents by their perception of the gender more affected by climate change hazards

Community type	Gender `	Akwa Ibom		Ondo		Rivers	
		Male (%)	Female (%)	Male (%)	Female (%)	Male (%)	Female (%)
Wetland	Men	70.3	12.8	1.5	0	20.0	3.8
	Women	11.1	52.8	6.2	0	21.0	46.2
	Both-men &women	18.6	34.4	92.3	100	59.0	50.0
	Total	**100**	**100**	**100**	**100**	**100**	**100**
Fishing	Men	60	0	15.0	20	54.6	0
	Women	30	0	65.0	0	34.3	0
	Both men &women	10	100	20.0	80	11.1	100
	Total	**100**	**100**	**100**	**100**	**100**	**100**

Source: Field data, 2011

Conclusion: Communities in the Niger Delta are adversely impacted by climate variability and long term climate change. However, each community type tends to experience different kind of climate risks. Wetland farming households are vulnerable to flooding, drought and erosion leading to poor health, loss of property, poor yield and loss of income, while the wetland and fishing communities are, in addition to these climate hazards, exposed to sea level rise. Men and women are equally impacted upon by climate variability. Therefore policies and programmes to reduce the impacts and help farming and fishing households adapt to climate variability should be developed.

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