Report on COMSATS International Thematic Research Group on Mathematical Modeling and Simulation

Prof. Benjamin O. Oyelami

Team Leader of the ITRG, National Mathematical Centre, Abuja, Nigeria

The 19th Meeting of COMSATS Coordinating Council, hosted by the COMSATS Institute of Information Technology (CIIT), Islamabad, Pakistan (17-18 May, 2016)

Background information on the Project

- On 2nd December 2015,the Director and Chief Executive of National Mathematical Centre (NMC),Abuja inaugurated the International Thematic Research Group(ITRG) on Mathematical Modeling and Simulation jointly with the International Conference on Mathematical Modeling and Simulation on Climate change which was held at NMC on 1-2 December 2014.
- The International Thematic Research Group (ITRG) at the inaugural meeting agreed to work upon the Project and developed a three years developmental plan. The team resolveed to seek research Grant Under ISESCO-COMSATS Joint Research Grants Programme for 2014-2015 period This was however approved.
- The ITRG discussed the viability of the components of the project, produced final working document for the project containing action plans including actors saddled with specific responsibilities and timeline for the actions.
- Mémorandum of Understanding (MoU) were signed among the Researchers and the Representatives of all Centres of Excellence present at the meeting.

Executive Summary of the Project

- The Project is specifically designed to determine to what extent the pollution in air and water will have impact on agricultural production, human health and global ecology and economy of South-South including the possibility of substantial population displacement in the region.
- Come up with some effective models for predicting/ controlling pollution of air and water.
- Provide intellectual resources to the Environmentalists, Educationalists, Researchers, Students and Field workers to understand the effects of air and water pollutions and possible ways of controlling pollutions.

Brief information About NMC-COMSATS-ISESCO Conference 2015

- National Mathematical Centre (NMC), Abuja in collaboration with the Commission on Science and Technology for Sustainable Development in the South (COMSATS), Islamic Educational Scientific and Cultural Organization (ISESCO) ,the entire Mathematical Modeling Community in Nigeria comprising: COMSATS International Thematic Research Group (ITRG) and the National Thematic Research Groups (NTRGs) in Mathematical Modeling in Nigeria as well as the Government of Federal Republic of Nigeria organized the **International Conference on Mathematical Modeling and the Second COMSATS International Thematic Research on Mathematical Modeling meeting** for Researchers, Scientists, Students and Policy Makers.

NMC-COMSATS-ISESCO Conference 2015

- The events were targeted to attract Mathematical Scientists, Engineers and Environmentalists all over the world.
- The Conference area of coverage, were on Modeling and Simulation in the following areas:

- Pollutions of Air and Water
- Population dynamics of bacteria, fungi, zooplankton and phytoplankton
- Terrestrial and marine biodiversity
- Multiscale hierarchical modeling
- Complex systems modeling and simulation
- Medical and biomedical systems and surgical modeling
- Bimolecular simulation and metamodeling techniques
- Climatic, reservoirs design and vehicle routine problems
- Oil spillages and corrosion problem in the marine and terrestrial environments.
- Engineering systems and telecommunication network
- Nano fluid and nanotechnology
- Quantitative models and financial models
- Applications in the Industry and other human endeavors
- Complex Atmosphere-Ocean General Circulation problem
- Ecological risk assessments
- Renewable and non-renewable energies
- Nuclear safety problem
- Energy efficient batteries
- Remote sensing and Satellite imagery
- Impact Assessments
- Geographic Information Systems (GIS)
- Quality control of water and air
- Determinations of benchmarks for clean air and water quality.
- Transportation of contaminants in air and water.

GOODWILL MESSAGES

- The conference was well attended by many scholars in Nigeria and international ones from COMSATS member states
- We received goodwill messages from:
- Dr. Imtinan Elahi Quereshi, the Executive Director, COMSATS was given by Dr. Farhan Ansari,
- His Excellency, Dr. Abdulaziz Othman Altiwijry, the Director General of the Islamic Educational Scientific and Cultural Organization, ISESCO was delivered by Dr. Ismail Abdelhamid.
- Professor Mohammed O. Ibrahim, President Mathematical Association of Nigeria (MAN) similarly gave a goodwill message.

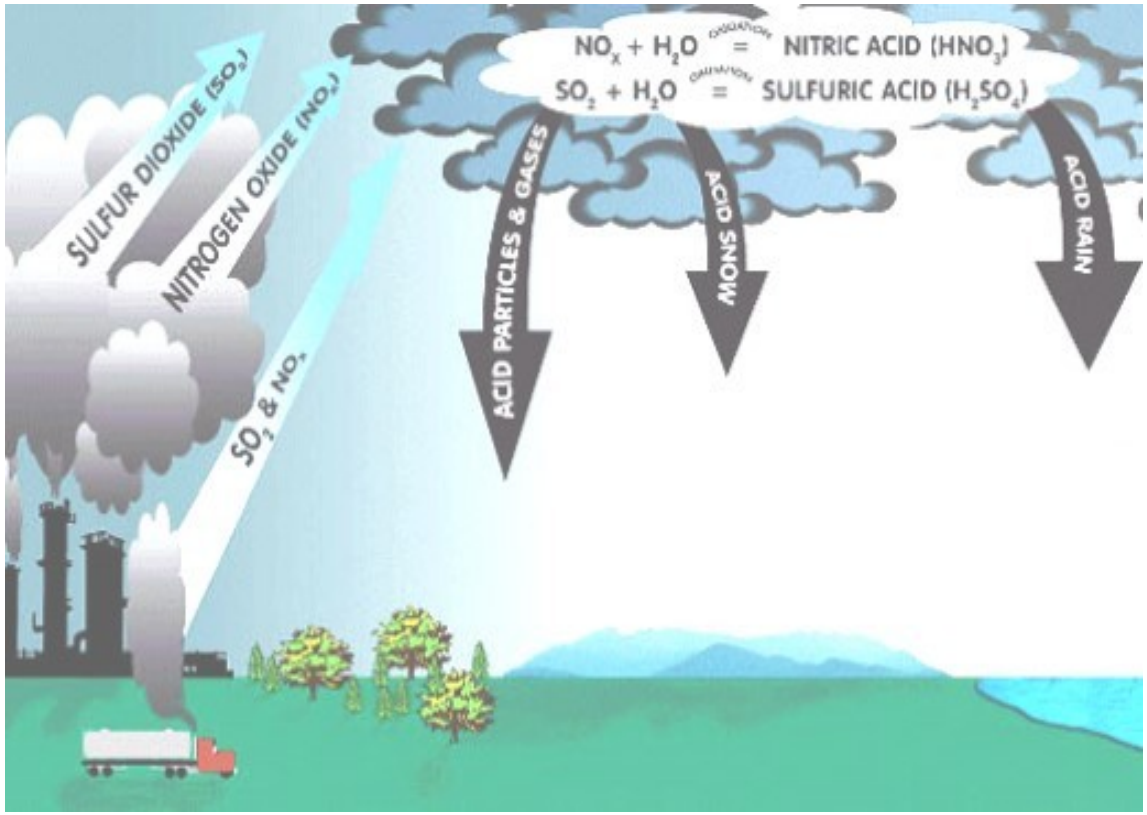
SIGNING OF MEMORANDUM OF UNDERSTANDING

- Memorandum of Understanding (MoU) between the member institutions participating in the COMSATS' International Thematic Research Group on "Mathematical Modeling" and Commission on Science and Technology for Sustainable Development in the South, Pakistan on Scientific collaboration in Mathematical Modeling was signed at the end of the meeting. The members of institutions of International Thematic Research Group on Mathematical Modeling include:
- National Mathematical Centre (NMC), Nigeria (Lead Centre)
- Tanzania Industrial Research and Development Organization (TIRDO) Tanzania
- COMSATS Institute of Information Technology (CIIT), Pakistan
- Bangladesh Council of Scientific and Industrial Research (BCSIR), Bangladesh
- University Cheikh Anta Diop (UCAD), Senegal
- Royal Scientific Society (RSS), Jordan
- Obafemi Awolowo, Nigeria
- University of Ilorin, Nigeria

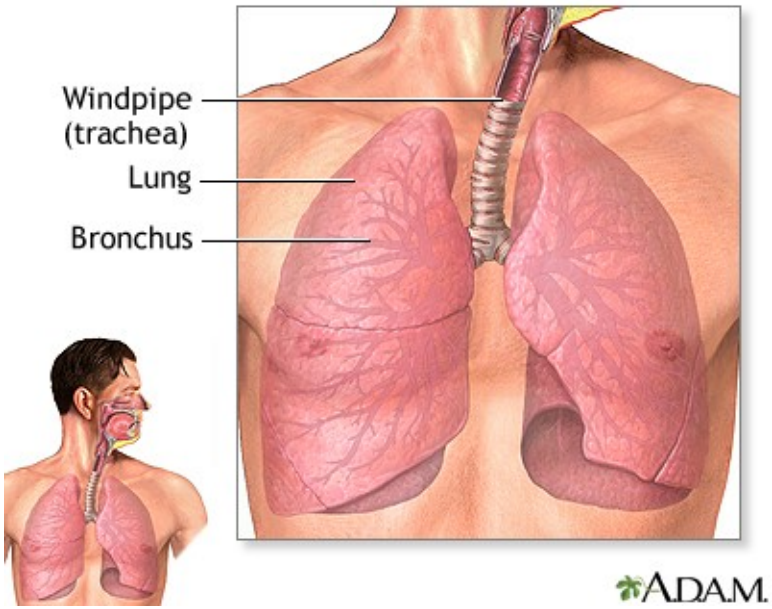
The Second the International Thematic Research group (ITRG) on Mathematical modeling and simulation of pollution in air and water

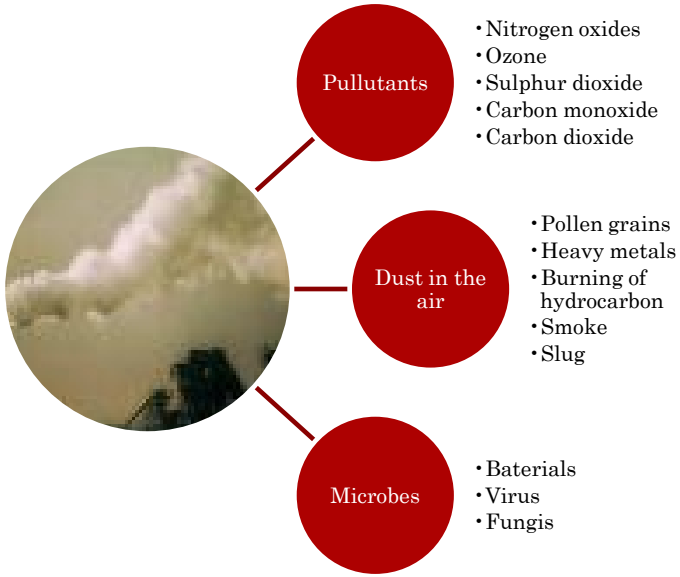
- The meeting was preceded by an International Conférence on **Mathematical modelling and Simulation of Pollution in Air and Water** which was held at the Centre on December 28-29,2016. The ITRG members presented research papers at the Conference.
- The ITRG members also presented papers at the conference in the following areas as related to the developmental plan of the Project :
- Détermination of pollution effect in the air : use of statistical models to analyse remote sensing data and satellite image. Forecasting how pollutants in air can lead to natural disasters.
- Use of models to study factors that enhances cercinogenic and allergic disease and those that lead to environmental problems. Determine how chemicals, heavy metals, slugs and petrochemicals in air or water would influence climate change and possibility of environmental mishaps.
- Determine how chemicals in the air lead to greenhouse effect and the effect of air pollution on agriculture.
- Use models to estimate the contribution of combustion of hydrocarbon fuel and greenhouse gases.
- Determine how pollution from industries leads to high prevalence of respiratory and allergic diseases.
-
- The group reviewed activities proposed in the Project in the first ITRG meeting which was held in 2nd December 2014 and updated the action plans of the project.

Air Pollution and acid rain

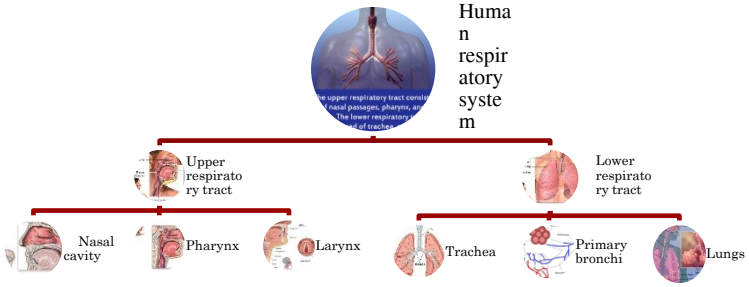


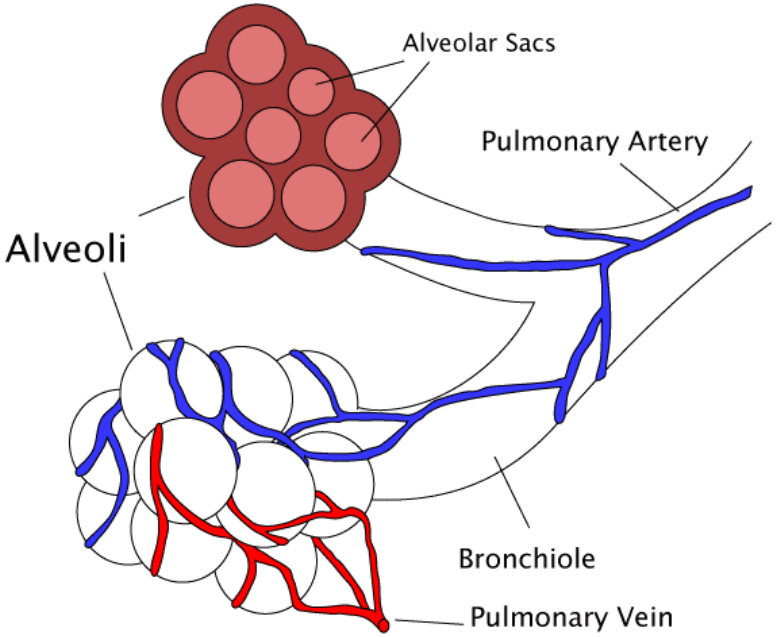
Air pollution and Medical implications





Medical effect of pollution on breathing system





Executive Summary of Research Findings

- Carbon dioxide (CO_2) and CO_2 per capita for Nigeria airspace have been projected from 2009 to 2025 using the greenhouse training equation, artificial neural network (ANN) model and polynomial interpolation method and nonlinear fitting method. The Researchers found that CO_2 is on increase and poses potential danger in future if it is not put under check. Models for studying predation of phytoplanktvore fishes on zooplankton are proposed .The condition for the existence of equilibrium points obtained via some nonlinear and Diophantine equations and investigation on the local stability for the dual population carried out and results obtained .Simulations when the noise is Gaussian was made when the ocean is polluted with oil spillage .

Executive Summary of Research Findings cont…

- The ITRG Researchers have developed a model for aerodynamic behavior of pollutants that diffuses into the airways in the lower respiratory tracks. The velocity profile of the airflow and bacteria population in mucus were computed using Nervier –Stoke equation, Lauffeger-Aris-Keller model and fractal morphologic boundaries which incorporates the fractal functions into the model. The series solution to model was obtained using the eigenvalue and eigenvector techniques. Under certain conditions population of bacteria was found to be stable and it was recommended that "for good throughput of airflow, the muscles walls must be dilated with drugs and the irreversible structures formed on the LRT be removed via surgery"
- One of the ITRG researchers considered some models for calculating biochemical oxygen demand (BOD) which is widely employed to measure the work related to the calculation of pollution extent due to organic agents as well as to evaluate the water characteristics. Some interesting results are being obtained. Research on how to design engineering equipment for reducing Air and Water pollution through process Intensification has embarked upon by an ITRG member with the view to make use process Intensification to reduce carbon footprints.
- King Talal Dam (KTD) is considered the main water source for irrigation in the Jordan Valley. Storm Water Management Model (SWMM) was used to predict the hydraulic loads of the storm water runoff entering KTD during October 25th 2012 to October 25th 2013. The preliminary simulation results obtained by a researcher showed that the SWMM model is able to predict the real surface runoff data entering the KTD.

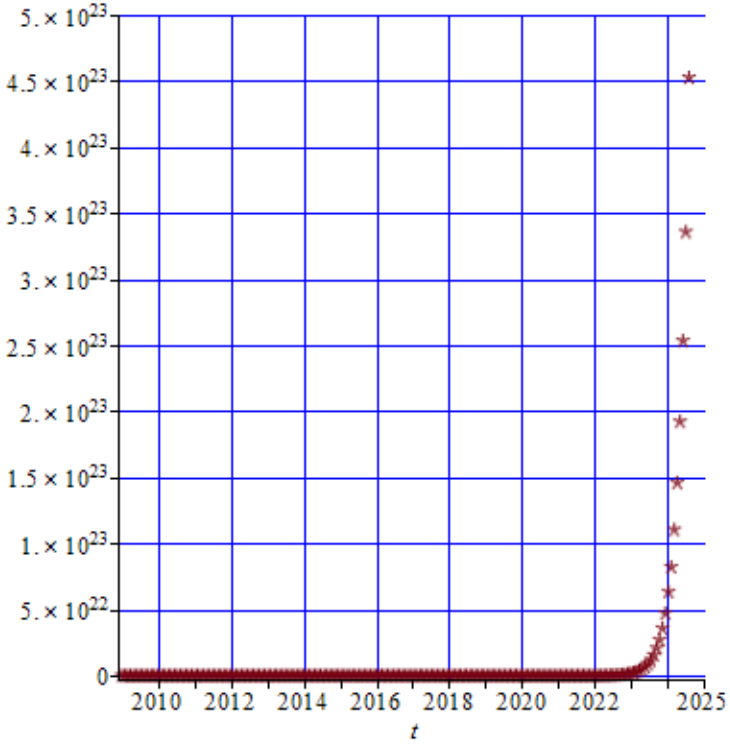
MODELS FOR COMPUTING EMISSION OF CARBON DIOXIDE FROM LIQUID FUEL IN NIGERIA

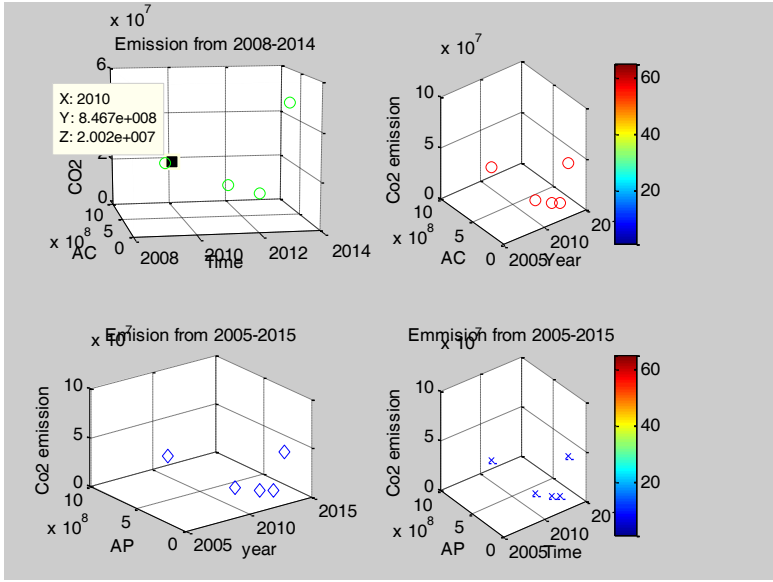
RESEARCHERS: PROF. Oyelami Benjamin Oyediran and Dr. Buba Maman Wufem

- The ITRG researchers considered Carbon dioxide emission from the liquid fuel supplied in Nigeria by the Nigerian National Petroleum Corporation (NNPC) and did analysis on the petroleum supply data from 2009 to 2013. The CO_2 emissions and CO_2 emission per capita within the given period were computed and projected emission from 2013 to 2025 made using the greenhouse training equation, artificial neural network (ANN) model and polynomial interpolation method and nonlinear fitting method. The available data from the Nigerian National Petroleum Cooperation (NNPC) was extrapolated from 2013 to 2020 using the polynomial interpolation method and the nonlinear fitting method to fit the data from 2009 to 2030.It was found that CO_2 emission and CO_2 emission per capita into the air in Nigeria decreased from 2009 to 2011 but, however, increase in 2012 and will be increasing continuously to 2025.
- The increase of carbon dioxide in the Nigerian air space will pose potential problems in future. Therefore, Policy must be put in place to reduce carbon dioxide emission by reducing flaring of natural gasses, introduce electric railways and other energy sources that are based on renewable energy. Enforcement of afforestation and greenhouse gasses emission reduction policies on the country for ecological development. There are other sources of pollution of the atmosphere with CO_2 such as flaring of gasses from refineries in Kaduna and Niger Delta areas of Nigeria and burning of bush and burning of solid fuel such as coal in the industries that their research did not cover. Those other sources were noted to also contribute substantially to CO_2 emission in Nigeria.

The 19th Meeting of COMSATS Coordinating Council, hosted by the COMSATS Institute of Information Technology (CIIT), Islamabad, Pakistan (17-18 May, 2016)

Co2 Emission Nigeria from petroleum combustion





- The researchers noted that some researchers have substantiated that CO_2 emissions from these other sources are also contributing to the increase in the pollution of Nigerian atmosphere with CO_2. The researchers intend to extend the scope of research to other greenhouse gasses so as to have balance information on the gross emission of greenhouse gasses into Nigeria airspace and attendant effect on eco-imbalance.
- Statue of paper: This paper has been accepted for publication in the American Mathematics and Statistics Review Journal USA.

Calculation of biochemical oxygen demand (BOD)
Dr. Salman Amin Malik

- The traditional dissolved oxygen model describes the fate, the "sag", of the dissolved oxygen in the river as influenced by the decay of biodegradable organic matter and the re aeration process (across the water surface). The ITRG researcher considered some models for calculating biochemical oxygen demand (BOD) which is widely employed to measure the work related to the calculation of pollution extent due to organic agents as well as to evaluate the water characteristics.
- Statue of paper: The research is completed and will be published soon.

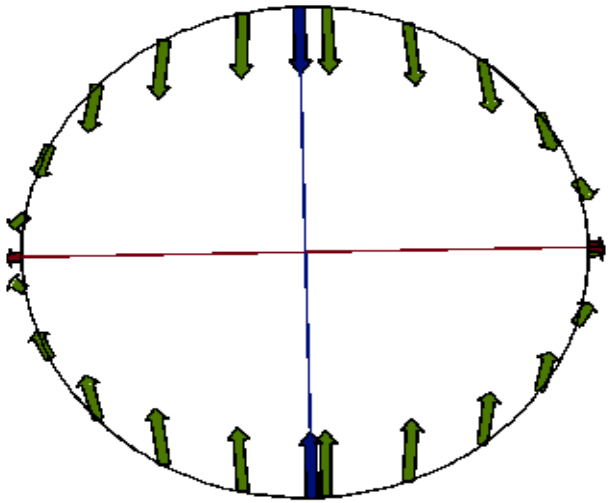
NONLINEAR ZOOPLANKTON-FISH MODEL WITH NOISE

Prof.Oyelami Benjamin Oyediran and Prof.Ogidi Jonathan Ajisafe

- Modeling integrates understanding of field observation, laboratory experiments, theory and computation within wide range of physical and biological processes. All activities in the marine ecosystem have some mathematical connections.
- In this paper, the Researchers considered nonlinear difference equations for zooplankton –fish population model with noise. The model was on predation of phytoplanktivore fishes on zooplankton, this is to understand the individual organism behaviour as well as interaction with the environment. The conditions for the existence of the equilibrium points were obtained through some nonlinear and Diophantine equations and conditions for local stability for the dual population were obtained
- Simulation made for the dual pollution when the ocean is polluted with oil spillage when the noise is assumed to be Gaussian. There is a growing need to understand the marine ecosystem in the recent times. The fish constitute great percentage of human sources of protein. The population of fishes (school) can be affected by global change in temperature, salinity, pollutants, turbulence and mixing in the ocean. The Researchers are concerned with the effect on water polluted with oil spillage will have on the school.

The 19th Meeting of COMSATS Coordinating Council, hosted by the COMSATS Institute of Information Technology (CIIT), Islamabad, Pakistan (17-18 May, 2016)

NONLINEAR ZOOPLANKTON-FISH MODEL WITH NOISE



x is an eigenvector if it is collinear with its image under left-multiplication by a square matrix A. Thus, x satisfies the equation $Ax = \lambda x$. Shown in the figure: images of unit vectors under left-multiplication by the given matrix (leaf green), eigenvectors (burgundy and navy).

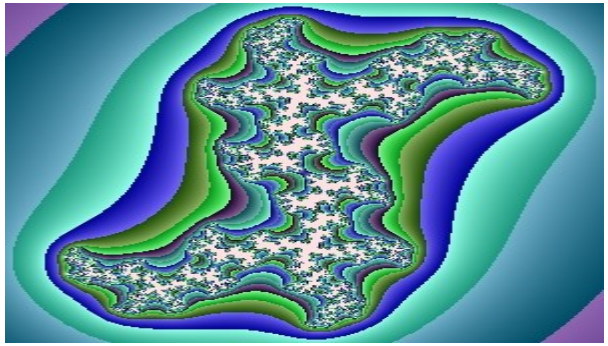
- Figure 3: Stability analysis of phytoplanktivore fishes and zooplankton using eigenspace method
- Statues of the Paper: Completed and will be forwarded for publication soon

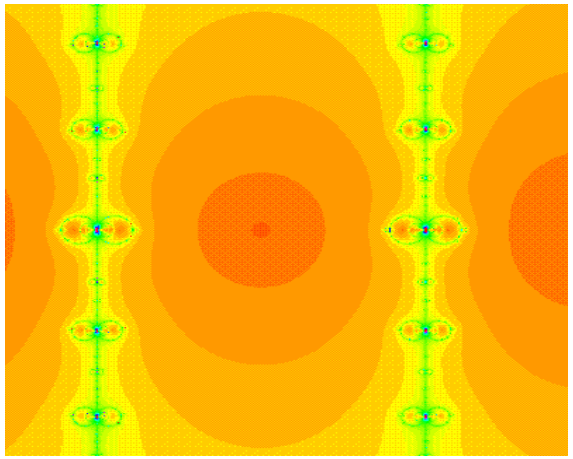
MODELS FOR COMPUTING EFFECT OF POLLUTANTS ON THE LOWER RESPIRATORY TRACT

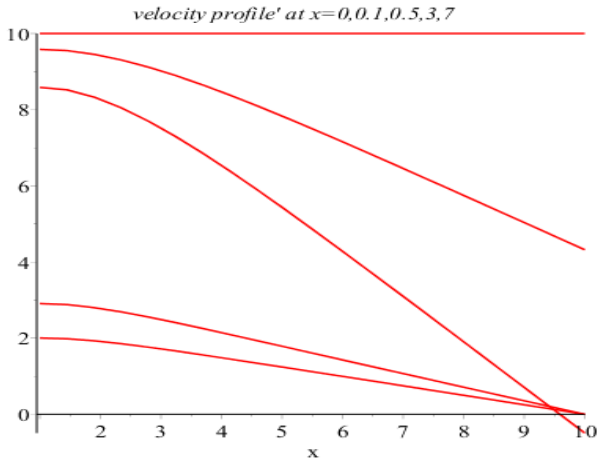
Prof. Oyelami Benjamin Oyediran

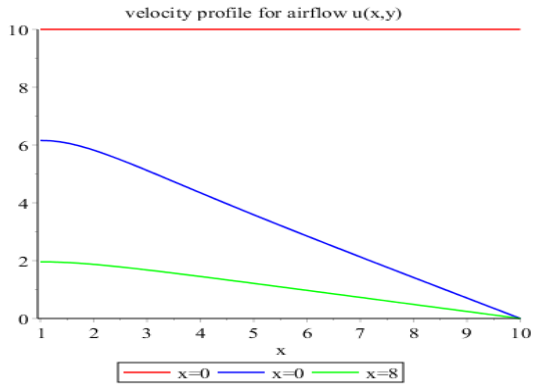
- The ITRG researcher developed a model for aerodynamic behaviour of particulates (pollutants) that diffuses into the airways in the lower respiratory track (LRT). This model is intended to help medical researchers and students to understand the physiology and pathology of the airflow when pollutants enter human lower respiratory system. The flow of air into the LRT containing pollutants, bacteria, water droplets and mucus was studied. The pollutants were assumed to react with mucus in the water droplets which led to thickening of the walls of LRT. Pollutants were assumed to be distributed uniformly in the mucus and the air reacts with the pollutants in the mucus to form irreversible structures on the walls of the trachea and bronchi. The irreversible structures formed in the breathing ducts take different shape and size and affect the volume of air in the lungs available for breathing during respiration and air expired after expiration.
- The Researcher noted that since there is no general pattern for formation of irreversible structures on the walls of breathing ducts; morphology that resembles fractals were proposed and used to model the boundary conditions of LRT. The velocity of the airflow was computed using the Nervier Stokes equation which incorporates the fractal functions into the model. The concentration of the pollutants in the mixture and the airflow velocity profile were obtained. It was found that as the thickness of the irreversible structures increase then the airflow into the airways decreases (see Fig.6 &Fig.7). The series solution to the model was obtained using eigenvalue and eigenfunction techniques.
- The population of bacteria was found to be stable if the if sustenance function is very small compared to the death rate of the bacteria. Therefore, it was recommended that “for good throughput of airflow, the muscles of the walls of breathing ducts need to be dilated with drugs”.

Air velocity profile in LRT









Recommendation

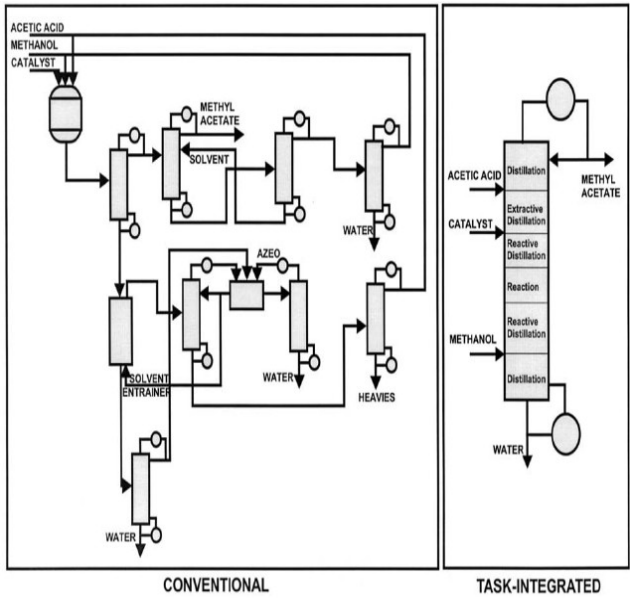
- Formation of irreversible structures on the boundaries of the human LRT makes inflow of air to be obstructed. The influx of air can be enhanced by dilating the muscles of the walls of the LRT and removing the structures by surgical means. The researcher suggested the use of aerosol therapy need to be further explored or construction of Nano pipes to allow passage of air into the air sacs by bypassing the pulmonary obstacles to enhance free flow of air into the lungs should be exploited in future.
- The use of geometric models will help us to understand the anatomy and physiology of the breathing track whenever thick structures are formed on them. The use of fractals or epitaxial growth model and imageries of technology of the structures will help us to understand the anatomy of LRT when pollutants are inhaled for long period of time and possibility of how to enhance airflow into the LRT.
- Status of the Paper: It was presented at the NMC-COMSATS-ISESCO Conference on Mathematical Modeling held in NMC Abuja on 28-29 December, 2015. The paper has been submitted for consideration in the American Journal of Modeling and Optimization.

Reducing Air and Water Pollution through Intensification

Prof. Femi Taiwo

- Process intensification consists of the development of novel apparatuses and techniques that compared to those commonly used today are expected to bring *dramatic* improvements in manufacturing and processing, substantially decreasing equipment-size/production-capacity ratio, energy consumption, or waste production, and ultimately resulting in cheaper, sustainable technologies. Or, to put this in a shorter form: any chemical engineering development that leads to a substantially smaller, cleaner, and more energy efficient technology is process intensification.

- Below (See Fig.8) is shown the methyl acetate process often used by Eastman Chemical to showcase the vast possibilities of responsible use of earth resources as well as waste minimization. It is seen how the traditional expansive layout which requires eleven pieces of equipment in the left could be carried out in just one equipment encompassing distillation and reaction, on the right. One other advantage is the vast Space left unused in the intensified option to the right which could be utilised for setting up other intensified processes as well as planting trees or accommodating other options which would reduce carbon footprints.



Professor Taiwo a ITRG is the leading research in this area in the Department of Chemical Engineering, Obafemi Awolowo University Ile-Ife,Nigeria. Typically, design and simulations of such equipment (for example reactive distillation processes) entail mathematical modeling eliciting material, energy, vapour liquid equilibrium as well as physical constraints.

One is then required to solve differential algebraic as well as partial differential equations. Programs could be written in house from scratch, or one could more expeditiously utilize standard software such as MATLAB, Hysys, as well as others. Our results so far are very encouraging.
Status: The research is ongoing

Assessment of Stormwater Runoff Entering King Talal Dam

Dr. Othman Al-Mashaqbeh and Dr. Malek Shorman

- King Talal Dam (KTD) is considered the main water source for irrigation in the Jordan Valley. Storm Water Management Model (SWMM) was used to predict the hydraulic loads of the storm water runoff entering KTD during October 25th 2012 to October 25th 2013.
- The preliminary simulation results clearly showed that the SWMM model is able to predict the real surface runoff data entering the KTD. However, more real data are required to validate the model results. The total predicted stormwater runoff entering KTD by model was 34.5 MCM.
- According to the predicted values of stormwater runoff, pollutants loads of BOD5, COD and TSS were estimated to be 1.34E+06 Kg, 7.81E+06 Kg and 5.06E+07 Kg, respectively. The results clearly showed that the pollutant loads carried by storm water runoff are very high and there is a crucial need to minimize the degree of stormwater runoff pollution by the water authorities to protect the water quality of KTD.
- Status: It was presented at the NMC-COMSATS-ISESCO Conference on Mathematical Modeling held in NMC Abuja on 28-29 December, 2015. The paper has been submitted for consideration in the special issue of the Mathematical Sciences Journal.

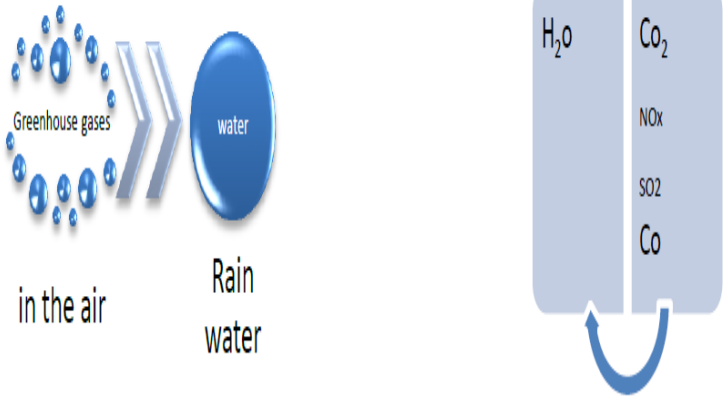
Ongoing Research

- **Pollution of Air from solid particles**
- Prof. Oyelami, Drs Nangbes and Buba have collected series of experimental data from industrial set-ups we intend to use these data to simulate models to:
- Have Insight on chemical speciation and technique for environmental clean-up;
- Analyses contribution of heavy metals and other contaminants emanated from cement and construction industries to ecosystem imbalance.
- Analyses some radioactive data and health effects on the inhabitants in the environment where the data was collected.

- **Combustion in a monolithic catalyst chamber**
- Study combustion in exhaust of automobiles and combustion of coal and pollutant effects.

Modeling Air pollution of the Environment and medical implications

- Prof. B O Oyelami, Dr. Buba Wufem & Dr. Jacob Nangbes
- **Dry Air emission**
- Problem1A: Emission of greenhouse gasses (GHG) into the atmosphere.
- .Problem 1B: Emission of greenhouse gasses (GHG) into the atmosphere in the presence of water
-



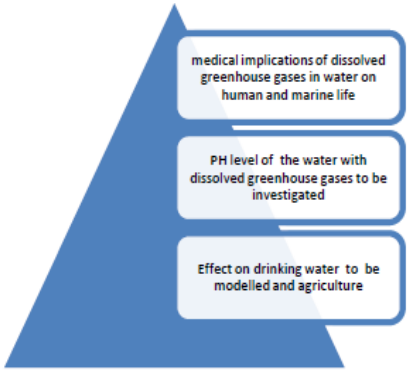


FIGURE 10: DISSOLVED GREENHOUSE GASES AND HUMAN HEALTH

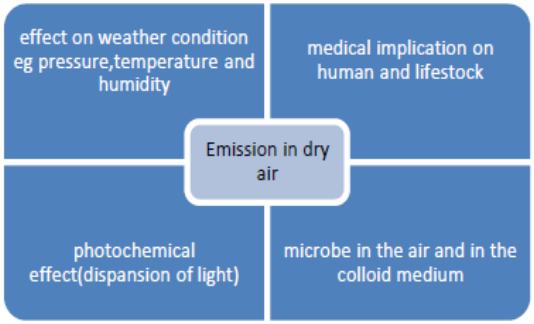


FIGURE 12: EMISSION IN DRY AIR

Leaching of gases, heavy metals and cobalt oxide in water and soil

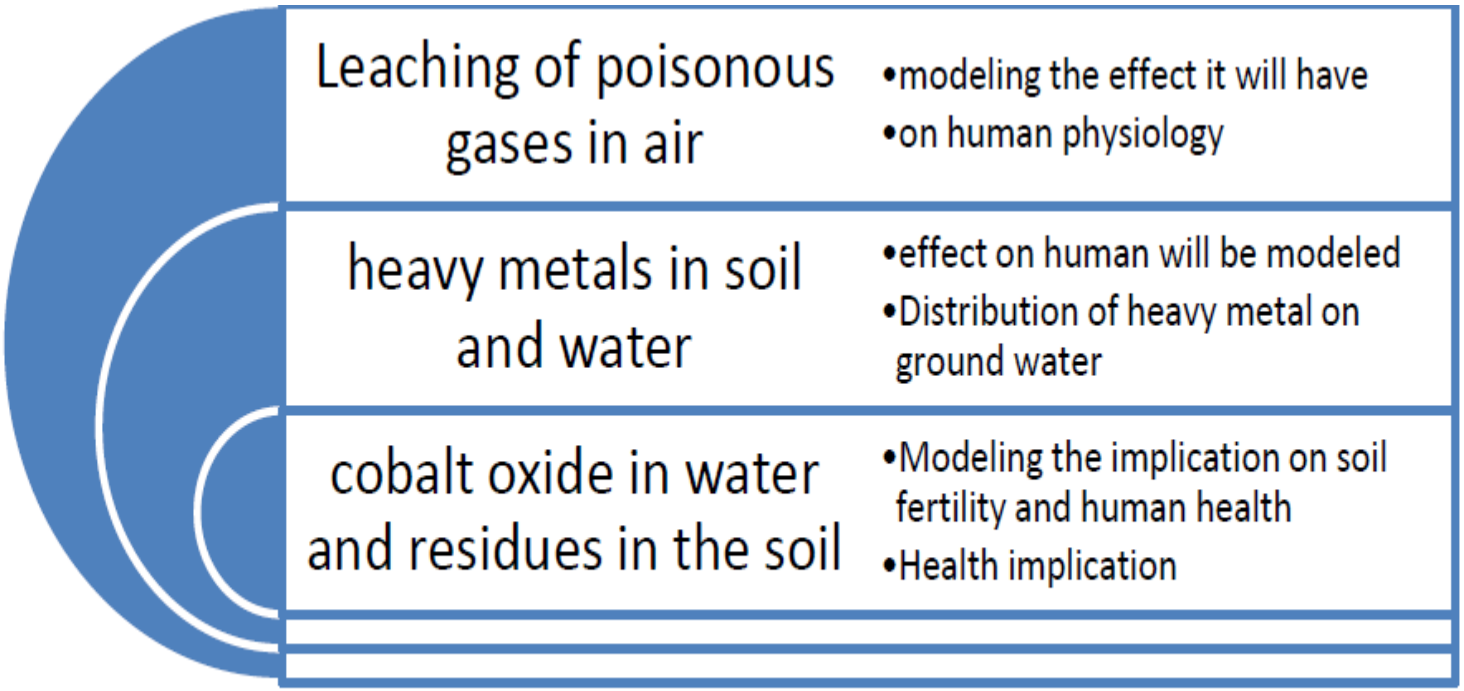


FIGURE 13: LEACHING OF GASES,HEAVY METALS AND COBALT OXIDE IN WATER AND SOIL

RESEARCH TEAM/GROUP MEMBERS

1. Prof. B O Oyelami, National mathematical Centre, Abuja, Nigeria
2. Dr. Salman Amin Malik,Department of Mathematics, CAMSATS Institute of Information Technology, Pakistan
3. Dr. Lugano Wilson Lic- Tanzania Industrial Research and Development Organisation (TIRDO) Dar-es-Salaam, Tanzania.
4. Rupesh Chandra Roy,Bangladesh Council of Scientific and Industrial Research (BCSIR), Bangladesh.
5. K.A.C.Perera,ITI, Colombo, Sri Lanka
6. Prof. M. O. Ibraheem- University of Ilorin, Ilorin Nigeria
7. Prof. Xiodong Zeng, Chinese Academy of Science Beijing ,China
8. Prof. Femi O. Taiwo-Obafemi Awolowo University, Ile-Ife
9. Othman Almashagbeh,Royal Society Jordan
10. Mountaga Lam, UCAD, Dakar, Senegal
11. Prof. K.R. Adeboye- Federal University of Technology, Minna, Nigeria
12. Prof. J.A. Ogidi-National Mathematical Centre, Abuja, Nigeria.
13. Prof. Bayo Lawal, Kwara State University, Molete Ilorin, Nigeria
14. Prof. A.A. Asere- Obafemi Awolowo University, Ile-Ife ,Nigeria
15. Dr. Wufem Buba-Plateau State University, Bokkos, Nigeria.
16. Dr. Nambes Jacob – Plateau State University, Bokkos, Nigeria
17. Dr. M. Fagbeja, National Space Centre, Abuja, Nigeria

Thank you