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"SIGNIFICANCE OF THE BASIC SCIENCES IN THE SOCIO-ECONOMIC DEVELOPMENT OF AFRICA"

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ABSTRACT

The basic sciences, e.g. physics, chemistry, biology, and mathematics are the building blocks so to speak of all the applied sciences of agriculture, food science, energy, medicine, pharmacy, engineering and telecommunications, to name a few. The pioneering discoveries by some trail blazers such as Louis Pasteur who developed the first vaccines for rabies and anthrax point to the significance of the basic sciences to the socio-economic development of any country or continent. Pasteur invented a method to stop milk and wine from causing sickness, a process that came to be called pasteurisation. As Alexander Fleming said "I certainly did not plan to revolutionise all medicine by discovering the world's first antibiotic, or bacteria killer but that was what happened. Constatin Fahlberg, a Russian Chemist, discovered saccharin, an artificial sweetener on. How did I discover saccharin?" he said. "Well, it was partly by accident and partly by study". Svante Arrhenius, a Swedish Nobel Prize winner in Chemistry gave the first indication of climate change in 1896 through his calculations of how doubling the levels of concentration of carbon dioxide (CO2) in the atmosphere would increase the mean temperature by 5-60C on earth. Some of the challenges facing teaching and learning of basic sciences in Africa include lack of interest by students in the secondary schools, inadequate teachers, facilities and equipment and lack of political will by governments to commit the required funds to the study of the basic sciences. Stakeholders, especially governments, can help create the conducive environment for basic science education in Africa by first training a critical mass of teachers to teach the basic sciences, providing state of the art laboratories with the relevant equipment, and creating schemes and the conducive environment to encourage the younger generation to study the basic sciences.

INTRODUCTION

The basic sciences, e.g. physics, chemistry, biology, and mathematics are the building blocks so to speak of all the applied sciences of agriculture, food science, energy, medicine, pharmacy, engineering and telecommunications, to name a few.

Sir Winston Churchill is quoted to have said that "the farther back you can look the farther forward you are likely to see." Consequently, let us go back briefly into history to recount some examples of people who were responsible for or improved upon previous methods of scientific breakthroughs in the study of the basic sciences to show that the socio-economic development of any country and for that matter Africa heavily depends on the study of the basic sciences.

Historical Account of the Contribution of the Study of Basic Sciences to Socio-Economic Development

Sir Isaac Newton

Newton, an English mathematician and physicist, who lived from 1642 to 1727, is believed to have had the greatest single influence on theoretical physics until Albert Einstein came on the scene. Newton's most productive period was between 1665 and 1667, when he retreated temporarily from Cambridge to his isolated home in Lincolnshire during the Great Plague. He discovered the binomial theorem, and made several other contributions to mathematics, notably differential calculus and its relationship with integration. Newton's three laws of motion was first presented in 1686. Newton gave a mathematical description of the laws of mechanics and gravitation in his major treatise, Principia Mathematica in 1687, which he applied these principles to planetary and lunar motion. Another influential work of Newton was Opticks in 1704 in which he gave an account of his optical experiments and theories including the discovery that white light is made up of a mixture of colours. His name, Newton, is the SI unit (N) of force in Physics. One newton is that force which would give a mass of one kilogramme an acceleration of one metre per second in the direction of the force (1 N = 1m. kg s-2).

Albert Einstein

Einstein, who lived from 1879 to 1955, was a German –born American who is a world renowned theoretical physicist, founder of the theory of relativity, and often regarded as the greatest scientist of the 20th century. In 1905 he published outstanding papers dealing with the photoelectric effect, Brownian motion and his special theory of relativity. In 1915, he succeeded in incorporating gravitation in his general theory of relativity, which was vindicated when one of its predictions was observed during the solar eclipse of 1919. He remained in America where spent the remainder of his life searching without success for a unified field theory embracing electromagnetism, gravitation, relativity and quantum mechanics. He wrote about the military potential of nuclear energy to President Roosevelt in 1939. This information greatly influenced the decision to build an atom bomb. It was reported that Einstein spoke out passionately against nuclear weapons after the Second World War.

Svante Arrhenius

Studies by Svante Arrhenius, a Swedish Nobel Prize winner in Chemistry gave the first indication of climate change in 1896 through his calculations of how doubling the levels of concentration of carbon dioxide (CO2) in the atmosphere would increase the mean temperature by 5-60C on earth but the scientific community described the finding as obsolete but we are all living witnesses to the global issue.

Louis Pasteur

Louis Pasteur, the French Chemist and microbiologist who was one of the most important founders of medical microbiology was born on 27 December 1822 in Dole in the Jura region of France, into the family of a poor tanner. This fact probably instilled in him the strong patriotism that later was a defining element of his character. Louis Pasteur was an average student in his early years. He earned his Bachelor of Arts degree in 1840 and Bachelor of Science degree in 1842. Louis Pasteur served briefly as professor of Physics at Dijon Lycée in 1848. He became professor of Chemistry at the University of Strasbourg, where he met and courted Marie Laurent, daughter of the University's Rector in 1849. They had five children, only two of whom survived to adulthood; the other three died of typhoid.

These personal tragedies inspired Pasteur to try to find cures for diseases such as typhoid. He is remembered for his remarkable breakthroughs in the causes and preventions of diseases. His discoveries reduced mortality from puerperal fever, and he developed the first vaccines for rabies and anthrax. His experiments supported the germ theory of disease. He was best known to the general public for inventing a method to stop milk and wine from causing sickness, a process that came to be called pasteurisation. Pasteur is regarded as one of the three main founders of microbiology, together with Ferdinand Cohn and Robert Koch. Pasteur also made many discoveries in the field of Chemistry, most notably the molecular basis for the asymmetry of certain crystals.

In Pasteur's early work as a chemist, he resolved a problem concerning the nature of tartaric acid in 1848. A solution of this compound derived from living things (specifically, wine lees) rotated the plane of polarisation of light passing through it. The mystery was that tartaric acid derived by chemical synthesis had no such effect, even though its chemical reactions were identical and its elemental composition was the same. This was the first time anyone had demonstrated chiral molecules.

Pasteur's doctoral thesis on crystallography attracted the attention of W.T. Fuillet, and he helped Pasteur garner a position of professor of Chemistry at the College of Strasbourg. In 1854, Pasteur was named Dean of the new Faculty of Sciences in Lille. It was on this occasion that Pasteur uttered his profound and often quoted remark: "… dans les champs de l'observation, le hasard ne favorise que les esprits préparés" (In the field of observation, chance favours only the prepared mind). He exposed boiled broths to air vessels that contained a filter to prevent all particles from passing through the growth medium, and even in vessels with no filter at all, with air being admitted via a long tortuous tube that would not allow dust particles to pass. Nothing grew in the broths unless the flasks were broken open; therefore, the living organisms that grew in such broths came from outside, as spores on dust, rather than spontaneously generated with the broth. This was one of the last and most important experiments disproving the theory of spontaneous generation. While Pasteur was not the first to propose germ theory (Girolamo Fracastoro, Agostino Bassi, Friedrich Henle and others had suggested it earlier) he developed it and conducted experiments that clearly indicated its correctness and managed to convince most of Europe that it was true. Today he is regarded as the father of germ theory and bacteriology, together with Robert Koch.

Germ Theory of Fermentation

Pasteur demonstrated that fermentation is caused by the growth of micro-organisms, and the emergent growth of bacteria in nutrient broths is not due to spontaneous generation, but rather to biogenesis (Omne vivum e vivo "all life is from life"). Pasteur's research also showed the growth of micro-organisms was responsible for spoiling beverages such as beer, wine and milk. With this established, he invented a process in which liquids such as milk were heated to kill most bacteria and moulds already present within them. Pasteur and Claude Bernard completed the first test on 20 April 1862. This process was soon afterwards known as pasteurisation. Beverage contamination led Pasteur to the idea that micro-organisms infecting animals and humans cause disease. He proposed preventing the entry of micro-organisms into the human body, leading Joseph Lister to develop antiseptic methods in surgery. In 1865, two parasitic diseases called pébrine and flacherie were killing great numbers of silkworms at Alais (now Alès). Pasteur worked several years proving it was a microbe attacking silkworm eggs which caused the disease, and eliminating this microbe within silkworm nurseries would eradicate the disease. Pasteur also discovered anaerobiosis, whereby some micro-organisms can develop and live without air or oxygen, called the Pasteur Effect.

Immunology and Vaccination

Pasteur's later work on diseases included work on chicken cholera. During this work, a culture of the responsible bacteria had spoiled and failed to induce the disease in some chickens he was infecting with the disease. Pasteur re-used these healthy chickens, and discovered he could not infect them, even with fresh bacteria; the weakened bacteria had caused the chickens to become immune to the disease, though they had caused only mild symptoms.

While going on holidays, Pasteur instructed his assistant, Charles Chamberland (of French origin) to inoculate the chickens and went on holiday. Chamberland failed to inoculate the chickens, but instead went on holiday himself. On his return, the month-old cultures made the chickens unwell, but instead of the infection being fatal, as it usually was, the chickens recovered completely. Chamberland assumed an error had been made, and wanted to discard the apparently faulty culture when Pasteur stopped him. Pasteur guessed the recovered animals now might be immune to the disease, as were the animals at Eure-et-Loir that had recovered from anthrax. Because of his study in germs, Pasteur encouraged doctors to sanitise their hands and equipment before surgery. Prior to this, few doctors or their assistants practiced these procedures.

Today, one of the key practices being advertised in the media is to wash our hands with soap under running water to help prevent many diseases especially cholera, thanks to the pioneering work of Louis Pasteur. It is noteworthy that 15 October each year has been declared as the Global Day for hand washing.

Alexander Fleming

Alexander Fleming was born on 6 August 1881 at Lochfield, a farm near Davel, in Ayrshire, Scotland. By 1927, Fleming was investigating the properties of Staphylococci. He was already well-known from his earlier work, and had developed a reputation as a brilliant researcher, but his laboratory was often untidy. On 3 September 1928, Fleming returned to his laboratory having spent August on holiday with his family. Before leaving, he had stacked all his cultures of Staphylococci on a bench in a corner of his laboratory. On his return Fleming noticed that one culture was contaminated with a fungus, and that the colonies of Staphylococci that had immediately surrounded it had been destroyed, whereas other colonies farther away were normal. Fleming showed the contaminated culture to his former assistant Merlin Price, who reminded him, "That's how you discovered lysozyme. Fleming grew the mould in a pure culture and found that it produced a substance that killed a number of disease-causing bacteria. He identified the mould as being from the Penicillium genus, and, after some months of calling it "mould juice", named the substance penicillin on 7 March 1929. Fleming later said that: "When I woke up on 28 September 1928, I certainly did not plan to revolutionise all medicine by discovering the world's first antibiotic, or bacteria killer," "But I suppose that was exactly what I did."

He investigated its positive anti-bacterial effect on many organisms, and noticed that it affected bacteria such as Staphylococci and many other Gram-positive pathogens that cause scarlet fever, pneumonia, meningitis, and diphtheria, but not typhoid fever or paratyphoid fever, which are caused by Gram-negative bacteria for which he was seeking a cure at the time. It also affected Neisseria gonorrhoeae, which causes gonorrhoea although this bacterium is Gram-negative. Fleming published his discovery in 1929, in the British Journal of Experimental Pathology, but little attention was paid to his article. Fleming continued his investigations, but found that cultivating Penicillium was quite difficult, and that after having grown the mould, it was even more difficult to isolate the antibiotic agent. Fleming's impression was that because of the problem of producing it in quantity, and because its action appeared to be rather slow, penicillin would not be important in treating infection. Fleming also became convinced that penicillin would not last long in the human body (in vivo) to kill bacteria effectively. Many clinical tests were inconclusive, probably because it had been used as a surface antiseptic. In the 1930s, Fleming's trials occasionally showed more promise, and he continued, until 1940, to try to interest a chemist skilled enough to further refine usable penicillin. Fleming finally abandoned penicillin, and not long after he did, Howard Florey and Ernst Boris Chain at Radcliffe Infirmary in Oxford took up researching and mass-producing it, with funds from the U.S. and British governments. They started mass production after the bombing of Pearl Harbour. When D-Day (6 June 1944) arrived, they had made enough penicillin to treat all the wounded Allied Forces. Penicillin got nick-named "the wonder drug" and in 1945, Fleming, Chain and Florey were awarded the Nobel Peace Prize for medicine. Post-1945 was the era of antibiotics. Fleming's accidental discovery and isolation of penicillin in September 1928 marks the start of modern antibiotics. Before that, several scientists had published or pointed out that mould or Penicillium spp. were able to inhibit bacterial growth, and even to cure bacterial infections in animals (Ernest Duchesne in 1897 in his thesis "Contribution to the study of vital competition in micro-organisms:

antagonism between moulds and microbes", or also Clodomiro Picado Twight whose work at Institut Pasteur in 1923 on the inhibiting action of fungi of "Penicillin spp" genre in the growth of Staphylococci drew little interest from the director of the Institut at the time). Fleming was the first to push these studies further by isolating the penicillin and by being motivated enough to promote his discovery at a larger scale. Fleming also discovered very early that bacteria developed antibiotic resistance whenever too little penicillin was used or when it was used for too short a period. Almroth Wright had predicted antibiotic resistance even before it was noticed during experiments. Fleming cautioned about the use of penicillin in his many speeches around the world. He cautioned not to use penicillin unless there was a properly diagnosed reason for it to be used, and that if it were used, never to use too little or for too short a period, since these are the circumstances under which bacterial resistance to antibiotics develops.

Constatin Fahlberg

Constatin Fahlberg, a Russian Chemist who discovered saccharin, an artificial sweetener on 27 February 1879, was born on 22 December 1850 and died on 15 August 1910.

"How did I discover saccharin?" he said. "Well, it was partly by accident and partly by study. I had worked a long time on the compound radicals and substitution products of coal tar, and had made a number of scientific discoveries, that are, as far as I know, of no commercial value. One evening, I was so interested in my laboratory that I forgot about supper till quite late, and then rushed off for a meal without stopping to wash my hands. I sat down, broke a piece of bread, and put it to my lips. It tasted unspeakably sweet. I did not ask why it was so, probably because I thought it was some cake or sweetmeat. I rinsed my mouth with water, and dried my moustache with my napkin, when, to my surprise the napkin tasted sweeter than the bread. Then I was puzzled, I again raised my goblet, and as fortune would have it, applied my mouth where my fingers had touched before. The water seemed like syrup. It flashed on me that I was the cause of the singular universal sweetness, and I accordingly tasted the end of my thumb, and found it surpassed any confectionery I had ever eaten. I saw the whole thing at once. I had discovered some coal tar substance that out-sugared sugar. I dropped my dinner, and ran back to the laboratory. There in my excitement, I tasted the contents of every beaker and evaporating dish on the table. Luckily for me, none contained any corrosive or poisonous liquid. "One of them contained an impure solution of saccharin. I worked on this then for weeks and months till I had determined its chemical composition, its characteristics and reactions, and the best modes of making it, scientifically and commercially."

When I first published my researches, some people laughed as if it were a scientific joke, others, of a more sceptical turn, doubted the discovery and the discoverer, and still others proclaimed the work as being of no practical value. But when the public first saw saccharin, everything changed. The entire press, European and American described me and my sugar in a way that may have been edifying, but was simply amusing to me. And then came letters. My mail run as high as sixty a day with people wanting samples of saccharin, my autograph or my opinion on chemical problems, desiring to become my partner, to buy my discovery, to be my agent, or to enter my laboratory, and the like. One may ask "What did Fahlberg do after all the doubting Thomas's suddenly flocked on his person and laboratory?" He started a company in Germany to manufacture saccharin with a capital of 2,000,000 marks.

Challenges Facing Teaching and Learning of the Basic Sciences in Africa

Having seen the work of the trail blazers who studied the basic sciences and how their exploits have impacted the world let us now look at some of challenges facing the teaching and learning of the basic sciences in Africa.

One of the challenges facing the teaching and learning of the basic sciences is the lack of or dwindling interest by students in the secondary schools. Data available at the West African Examinations Council on the West Africa Senior School Certificate Examinations on the numbers of candidates for 14 selected electives in the visual arts/technical compared with nine selected

Table 1. Selected subjects for the visual/technical based electives in the WASSCE, 2011, 2012 & 2013.

Subject	May/June 2011	May/June 2012	May/June 2013*
Applied Electricity	552	504	1231
Auto Mechanics	348	418	875
Basketry	248	419	637
Building Construction	2567	2940	6422
Ceramics	2617	2921	6929
Clothing and Textiles	1599	1694	4130
Crop Husbandry and Horticulture	3600	3023	5185
Electronics	45	43	116
Fisheries	250	202	324
Jewellery	738	764	1635
Leatherwork	2633	3052	6948
Metalwork	766	794	1798
Picture Making	1765	1695	3970
Sculpture	2559	3137	7760
Textiles	1583	1745	4368
Woodwork	1388	1824	4157
TOTAL	23,258	25,175	56,485

Source: West African Examinations Council, Accra; * - Double batch of candidates

Elective subjects in arts/business showed an interesting but worrying trend from 2011 to 2013 (Tables 1 & 2). The total number of candidates that opted for the nine selected the arts and business based subjects was 321,090 for 2011, 381,507 for 2012 and 905,071 for 2013. In contrast, the total number of candidates who chose the 14 technical/visual arts based elective subjects was 23,258 for 2011, 25,175 for 2012 and 56,485 for 2013.

Clearly, between 2011 and 2013 we see that the choices being made by our youths is heavily skewed in favour of the general arts and business subjects.

The choices the youths in our senior high schools make must be managed, guided and directed within the framework or context of a policy or vision otherwise the situation will implode one day as excessive individual liberty simply means chaos and anarchy.

Table 2. Selected subjects for the arts/business based electives in the WASSCE, 2011, 2012 & 2013

Subject	May/June 2011	May/June 2012	May/June 2013*
Business Management	34,801	40,013	87,990
Christian Religious Studies	23,377	28,119	70,299
Economics	92,617	111,184	260,536
Financial Accounting	33,511	38,833	86,078
Geography	31,437	37,209	89,068
Government	47,543	58,473	145,173
History	17,687	20,257	48,720
Literature-in-English	21,022	25,010	62,248
Principles of Cost Accounting	19,095	22,409	54,959
TOTAL	321,090	381,507	905,071

Source: West African Examinations Council, Accra; * - Double batch of candidates

Apart from the skewed choices that the youths are making, a good number of them are not obtaining the required grades in the core subjects of the West African Senior School Certificate Examinations, especially in English Language, Core Mathematics and Integrated Science that will gain them admission to tertiary institutions (Table 3).

The number of candidates who obtained grade C6 or better in English Language declined consistently from 2011 to 2013. The trend in Integrated Science and Core Mathematics was fluctuating but both subjects recorded less than 50% credit passes from 2011 to 2013, except for 2012 when Integrated Science recorded 56.8 % credit passes. The credit passes in Social Studies was consistently greater than 80% with the least value of 81.5 recorded in 2013.

Pragmatic steps such as incentives to attract and retain more and committed teachers must be taken to arrest this decline especially in the teaching and learning of Core Mathematics and Integrated Science so that these elements do not derail any attempts at encouraging the study of the basic and applied sciences.

Table 3. Number of candidates who obtained Grade C6 or better in the core subjects of the WASSCE, 2011-2013

Subject*		**2011**		**2012**			**2013***		
	SAT	**A1-C6**	**%**	**SAT**	**A1-C6**	**%**	**SAT**	**A1-C6**	**%**
English	148,444	112,669	75.9	173,665	118,853	68.4	406,183	266,976	65.7
Science	148,352	62,308	42.0	173,557	98,603	56.8	405,942	202,258	49.8
Maths	148,406	65,002	43.8	173,499	86,677	49.9	405,748	148,906	36.6
Social	148,409	121,993	82.2	173,417	151,864	87.5	405,508	330,533	81.5

*English =English Language; Science =Integrated Science; Maths = Core Mathematics; Social = Social Studies
Source: West African Examinations Council, Accra; * - Double batch of candidates

There is also the challenge of inadequate teachers to teach the dwindling numbers of interested students. Another challenge is the inadequate and or obsolete facilities and equipment. There is also the lack of political will by governments to commit the required funds to the study of the basic sciences. This aspect of lack of political will is well captured in the preamble of the national science and technology policy of Ghana in 2001 that " Currently, the status accorded science and technology is low; science and technology has a low priority rating in in the eyes of policy makers and managers of the nation's resources. This has resulted in the inadequate investment committed to science and technology. Presently, the country's resource allocation to science and technology fluctuates between 0.3 and 0.5% of the Gross Domestic Product. This allocation is well below the target of 1% of the country's GDP prescribed in 1980 at the summit of African Heads of State of the then OAU under the Lagos Plan of Action."

Contribution of Stakeholders to the Study of the Basic Sciences

What stakeholders can do to create the conducive environment for the continuous study and application of the basic sciences to enhance the socio-economic development of the African continent are many and varied.

Stakeholders, especially governments, can help create the conducive environment for basic science education in Africa by first training a critical mass of teachers to teach the basic sciences, providing state of the art laboratories with the relevant equipment, and creating positive schemes and the conducive environment to encourage the younger generation to study the basic sciences and continue to work in the basic sciences for the socio-economic development of Africa.

It is noteworthy that the 23rd Ordinary Session of African Union Heads of State and Government Summit in June 2014 adopted a 10-year Science, Technology, and Innovation Strategy for Africa (STISA-2024). The strategy links science, technology, and innovation to Africa's sustainable economic transformation. Developing the right capacities for institutions and individuals together with the investment needed for such capacity to be retained and utilised in Africa is, therefore, crucial. It is my hope that STISA-2024 will not follow the unenviable record of the Lagos Plan of Action of 1980, which has not been implemented in many African countries up till today.

In addition to the STISA-2024 by the AU, the African Academy of Sciences (AAS) is implementing programmes in partnership with pan African and international organisations. In 2015, the AAS launched the Alliance for Accelerating Excellence in Science in Africa, a platform created in collaboration with the New Partnership for Africa's (NEPAD) Agency. The AESA is an agenda setting and funding platform to support the development of Africa's research leadership and promote scientific excellence and innovation to overcome some of Africa's developmental challenges.

The other ways that the study of the basic sciences can be encouraged and increased among the populace in Africa include developing and operating a quota system, creating a network of mentors and operating scholarship schemes to cater for the needs of those who are encouraged to study the basic sciences.

CONCLUSION

It is an undeniable fact that we need a thorough understanding of basic sciences to enable us inspire and promote outstanding achievements in all fields of scientific enquiry as shown by the trailblazers such as Isaac Newton, Albert Einstein, Svante Arrhenius, Louis Pasteur, Alexander Fleming, and Constatin Fahlberg. The study of the basic sciences is key to the socio-economic development of Africa since the basic sciences are the building blocks of the applied sciences of agriculture, food science, biotechnology, energy, pharmacy, and engineering among others. The basic sciences are the giants on whose shoulders the Lilliputians of applied sciences of agriculture, medicine, pharmacy and engineering stand to see far and be recognised.

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Research and Innovation for Sustainable Development in Africa

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ABSTRACT
Agenda 2063 is the continental framework that projects transition of the continent from resource based economy to innovation-led knowledge driven economy portrayed an array of polices, strategies and frameworks among of which the African Union Science and Technology Strategy for Africa 2024.

This was developed by High Level Panel consist of experts both within and outside the continent, the strategy was built on the experiences accumulated during the implementation of Africa's Science and Technology Consolidated Plan of Action in addressing the international STI challenges and to respond to the mission of the AU Agenda 2063. The output of the panel comprise regional consultations and inputs of the stakeholders gave an impetus to the Science, Technology and Innovation for Africa Strategy (STIAS 2024) that was subsequently endorsed by the African Union Head of States and Governments.

Similar to any regional Strategy STISA 2024 has its challenge to be adopted; integrated and implemented at all AU levels i.e. at the level of Member States, Regional Economic Communities and the Continent. In this regards, the African Union Scientific, Technical Research Commission (AU-STRC) took the responsibility to identify the institutional and policy gaps in all AU levels to ensure STISA's successful implementation.

Using finite element analysis and problem tree methodology and taking into cognizance STASA output/objectives as the boundary conditions for the analysis leads to the identification of policies and institutional gaps that may exist in our Member States.

This article is to highlight these gaps and to encourage the leading STI African Countries to champion the transition of the Africa's economy by utilizing Science Technology and Innovation.

INTRODUCTION

Since the down of time and over many years, Africa has gone through different stages of development and glories era that were founded on strong system of research and innovation. The undisputedly fact is that most technologies today employed across the world emanated from Africa. This remarkable long scientific history/contributionportrays Africa as the ***"Nerve of the World",*** the centre point; the incubator of global enlightenment, civilization, scientific research and innovation.

The early African people astounded the world, when their findings on science, research, technology and innovation were revealed by the recent past discoveries. The contribution of our glorious grand Fathers was expanding on all the Science domains covering Maths, Astronomy, Architecture, Navigation, Medicine and more:

In Maths: Studies reveal that many modern high school level concepts in mathematics were first developed in Africa as well as the first method of counting. It is recorded that more than 35,000 years ago, Egyptians scripted textbooks about math that included division andmultiplication of fractions and geometric formulas to calculate the area and volume of shapes(Woods, G; 1988). Distance and angles were calculated, algebraic equations were solved and mathematically based predictions were made of the size of floods of the Nile. The ancient Egyptians considered a circle to have 360 degrees and estimated π at 3.16 (Woods, G.; 1988).

In Astronomy: This was birthed by several ancient African nations which today are foundations which many Africans still rely on, and some were so advanced that their mode of discovery still cannot be understood. Egyptians charted the movement of the sun and constellations and the cycles of the moon. They divided the year into 12 parts and developed a yearlong calendar system containing 365¼ days (Woods, G.;1988). Clocks were made with moving water and sundial-like clocks were used (Woods, G.; 1988).

In Architecture and engineering: Various past African societies created sophisticated built environments, a typical example are the engineering feats of the Egyptians: the bafflingly raised obelisks and the more than 80 pyramids. The largest of the pyramids covers 13 acres and is made of 2.25 million blocks of stone (Woods, G.; 1988). Later, in the 12th century and much farther south, there were hundreds of great cities in Zimbabwe and Mozambique. There, massive stone complexes were the hubs of cities. One included a 250-meter-long, 15,000-ton curved granite wall (Asante, M. et al.; 1983).

In Navigation: There are several lines of evidence suggest that ancient Africans sailed to South America and Asia hundreds of years before Europeans. In addition to thousands of miles of waterways across Africa were trade routes. Many ancient societies in Africa built a variety of boats, including small reed-based vessels, sailboats and grander structures with many cabins and even cooking facilities. The Mali and Songhai built boats 100 feet long and 13 feet wide that could carry up to 80 tons (Van Sertima, I.; 1983).

This also demonstrated by genetic evidence from plants, and descriptions and art from societies inhabiting South America at the time suggest that small numbers of West Africans sailed to the east coast of South America and remained there (Van Sertima, I.;1983). Contemporary scientists have reconstructed these ancient vessels and their fishing gear and have completed the transatlantic voyage successfully. Around the same time as they were sailing to South America, the 13th century, these ancient peoples also sailed to China and back, carrying elephants as cargo (Van Sertima, I.; 1983).

In Medicine: It is undeniably true that most treatments used today were employed by several ancient African people and tribes. Before the European invasion of Africa, medicine in what is now Egypt, Nigeria and South Africa, to name just a few places, was more advanced than medicine in Europe. Some of these practices were the use of plants with salicylic acid for pain (as in aspirin), kaolin for diarrhoea (as in Kaopectate), and extracts that were confirmed in the 20th century to kill Gram positive bacteria (Van Sertima, I.; 1983). Other plants used had anticancer properties, caused abortion and treated malaria — and these have been shown to be as effective as many modern-day Western treatments. Furthermore, Africans discovered ouabain, capsicum, physostigmine and reserpine. Medical procedures performed in ancient Africa before they were performed in Europe include vaccination, autopsy, limb traction and broken bone setting, bullet removal, brain surgery, skin grafting, filling of dental cavities, installation of false teeth, what is now known as Caesarean section, anesthesia and tissue cauterization (Woods, G.;1988). In addition, African cultures preformed surgeries under antiseptic conditions universally when this concept was only emerging in Europe (Van Sertima, I.; 1983).

It is true that People of African descent come from ancient, rich and elaborate cultures that created a wealth of technologies in many areas around the world. Inspite of all these remarkable achievements of the African people of the early era, a contradictory fact to these achievements is that Africa is a continent currently faced with socio-economic instability, political anarchy, technological setback, weak economic systems among others.

Most successful economies in the world are innovation driven, because creation of new ideas and technologies leads to invention of products, services, machinery, infrastructure, which improve human standard of living and quality of life.

It was against the backdrop of the technological setback in Africa that triggered the First speech by President Kwame Nkrumah, at the foundation summit of the Organization of Africa Unity in Addis-Ababa, 24 May 1963; where he stated that "We shall accumulate machinery and establish steel works, iron foundries and factories; we shall link the various states of our continent with communications; we shall astound the world with our hydroelectric power; we shall drain marshes and swamps, clear infested areas, feed the undernourished, and rid our people of parasites and diseases. It is within the possibilities of science and technology to make even the Sahara bloom into a vast field with verdant vegetation for agricultural and industrial developments". Such statement is a testimony on the placement of Science and technology on the top of our political agenda sine the establishment of the OAU in 1963.

So far, there have some strategic events targeted towards the moving the continent forward through science and technology. These include:

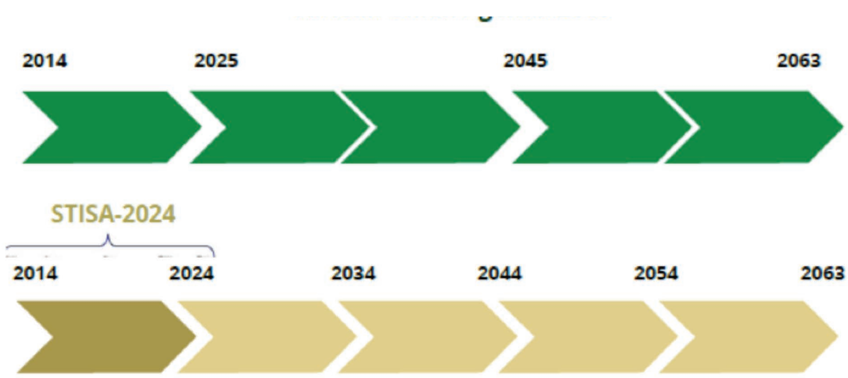
- The Lagos Plan of action in 1980 that brought the expression and awareness of the key role of the science and technology.
- The first (1st) Congress of Scientists in Africa in 1987 saw the creation of the Pan African University of Science and Technology (PUST) with its headquarter in Brazzaville; the meeting declared 30th June each year as the science and technology Renaissance Day in Africa.
- In 2005, there was the Consolidated Plan of Action which brought about the joining of the science and technology vision, plans and actions that of the African Union Commission and NEPAD.
- In 2007, there was the Addis Ababa declaration on Science and Technology where the heads of States and Governments commit themselves to invest 1% GDP in Science and Technology advancement in the continent
- In 2014, Science, Technology, and Innovation Strategy for Africa (STISA-2024) brought about the expression of the Agenda 2063 a new dimension and determination of science, technology and innovation in Africa.

STISA-2024

The STISA-2024 recognizes Science, technology and Innovation as a tool/mechanism for Africa's transformation to an innovation lead economy. In this regard, Africa needs to work at all levels of Member States, Regional Economic Communities and the African Union to identify its Science Technology and Innovation comparative advantage and priority areas to build its success stories. Science, Technology and innovation socio-economic impact is to be in the fore front in Africa's battle for existence.

On the development of STISA, four prerequisite pillars were defined to ensure the achievement of its mission **"Accelerate Africa's transition to an innovation-led, Knowledge-based Economy"** and the realization of its goals and objectives. These pillars are **Upgrading/Building Research Infrastructure;Enhancing Technical and Professional Competencies;Innovation and Entrepreneurship; and Providing an Enabling Environment for STI Development in the African Continent.**

STISA-2024 is the first decade incremental strategy that is designed to address Africa's challenges with the ultimate goal of contributing significantly to the AU Agenda 2063.



Timeline for STISA- 2024

Science and Technology development in Africa is critical to the promotion of overall growth and prosperity on the continent. To enhance such development, there is need for sound strategies that will reduce the uncertainties or risks faced by entrepreneurs and industrialists and further generate and disseminate information about investment opportunities in the Science and Technology industry. The AU Agenda 2063 is critical in this regards. It recognizes Science, Technology and Innovation (STI) as multi-functional tool and the enabler for achieving continental development goals. The Agenda further emphasizes that Africa's sustained growth, competitiveness and economic Transformation require sustained investment in new technologies and innovation in areas such as Agriculture, Clean Energy, Education and Health etc.

Recent political statements and policy instruments underscore the need for increased investment in STI to achieve sustainable socio-economic growth, reduce poverty; achieve food security and nutrition; fight key communicable and non-communicable diseases; and stem environmental degradation among others.

The impact of Science and Technology on Africa's Growth performance can be much more elaborated using the STISA- 2024, and its Policy Analysis document which champions the course of its implementation through:

- Improving STI readiness in Africa in terms of infrastructure, professional and technical competence and entrepreneurial capacity;
- Implementing specific policies and programs in science, technology and innovation that address societal needs in a holistic and sustainable way.

The New Era for Africa in Science Technology and Innovation can only be achieved through the domestication and implementation of the endorsed continental frame work designed to accelerate Africa's Transition to an innovation led, knowledge based Economy (STISA-2024). The realisation of the role of community based, inclusive innovation and building of a robust network of African Scientists, inventors with the aim of developing and implementing fact based policies will serve as a catalyst that will make Africa soar high socio- economically within the possibilities of Science and Technology. Also maximizing on available allocated funds by Member States will boost the impact of science and technology in Africa's Economic Prosperity.

The organizational capacity by entities responsible for STI policy making reveals that most of the entities responsible for STI policy making have operated in isolation from other policy agencies, with weak links not just to the private sector; education and research sectors; but also to Africa's and international Policy Research think tanks. Not having easy access to empirical material and recent knowledge in STI policy making and ignoring inter-sectoral linkages and policy mixes make their institutional outputs much less reliable. The STISA 2024 Policy Analysis is to be used as a tool for better STI dialogue on the intra-Africa level and also with other concerned stakeholders and partners. On the other hand for STISA 2024 to achieve its mandate, strategic policies for improved Science and Technology should be properly implemented through effective legislation and structured implementation tools at all Government levels.

The Success Stories of economically transformed countries in Science and Technology have undeniably proven the enormous possibilities achievable within the realms of Science Technology and Innovation. Examples of such countries are: United States of America, Korea, Malaysia, Turkey and the United Kingdom. The Power of Science, Technology and Innovation has taken the lead as a driving force for Economic advancement and prosperity soaring on the prioritization of Science, Technology and Innovation to the nation's Economy. That systematically, has set target for other developing countries to meet up with.

STISA-2024 Policy analysis

The STISA-2024 was subjected to critical analysis considering present, past and future based on the needs and gaps that yielded all the pre-requisite and required systems and mechanisms including policies and institutions needed were identified. The analysis was made to ensure that Member States and RECs are informed on the systems needed for the domestication and implementation of the strategy. This analysis is to help Member States to build robust systems and mechanisms that will respond to STI challenges and attend to the STISA-2024 mission.

The policy analysis exercise was designed considering the following factors:

- The implementation of strategy (STISA-2024) requires minimum set of requisite infrastructure, human resource with necessary skills and an enabling environment.
- AU Member States and RECs are at different stage of readiness in terms of infrastructure, human and organizational capacity to properly undertake activities/ actions that addresses the STISA priority areas.

1. **<u>STISA Pillars Analysis</u>**

Using problem Tree methodology each of the STISA pillars were analysed and the needed sub-pillars were identified, the following represents the need sub pillars that came out from the analyses.

Under Research and development the following sub-pillars were identified: Strengthen existing National R&D Institutions; Establish new National R&D Institutions in the Priority Sectors; Encourage Private Sector to establish new R&D Institutions/Facilities; Encourage Private Sector to establish Universities/ Higher Education Institutions; and Promote Science Parks. While Build critical mass of MScs & PhDs with emphasis to industry; Promote Technology transfer & Acquisition; Promote Professional membership of regulatory bodies; Build lifelong learning; Promote Knowledge exchange and brain circulation; Develop advocacy programs and outreach at all AU levels; and Promote Community Innovation Hubs were the sub-pillars to the technical/Professional Competence pillar. For the innovation and entrepreneurship pillar,Technology Acquisition, transfer and commercialization; Commercialization of research outputs; Entrepreneurship capacity building' Local market protection; Financial instruments for entrepreneurship establishment; Inclusive Innovation (Community Innovation); Green Innovation; Innovation capacity building. Finally the analysis recognizes Development of Integrated market across all AU levels; financial mechanisms to support STISA implementation; Enabling Infrastructure (ICT, Railways, roads etc.); Advocacy & Communication; and STI policies as the sub-pillars for STI Enabling Environment pillar.

2. **<u>Analysis of the STISA sub-pillars</u>**

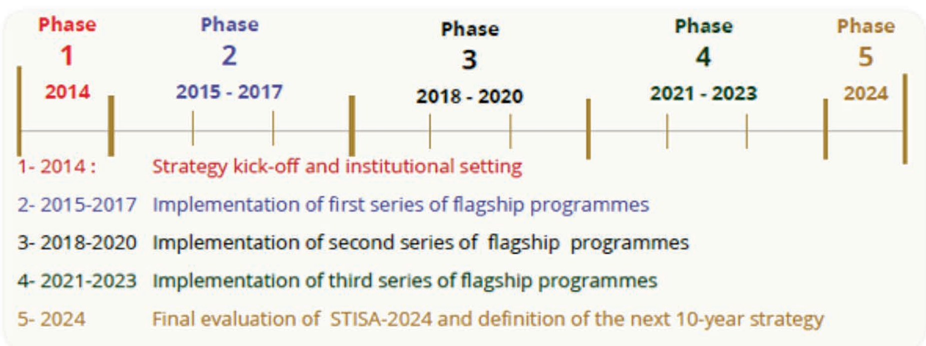
Each sub-pillar was analysed considering the needed physical infrastructure, systems, mechanisms, stakeholders and Partners. The policy analysis exercise was done taking in consideration:

- The Implementation of such strategy (STISA 2024) requires minimum set of requisite infrastructures, human resources with necessary skills and an enabling environment for the achievement of a knowledge-based economy;
- AU Member States and RECs are at different stage of readiness in terms of infrastructural, human and organizational capacity to properly undertake activities/ actions that addresses the STISA priority areas;
- That the 1st phase STISA implementation is focusing on putting in place required institutions at national, regional and continental levels to facilitate the integration of the strategy in national and regional STI processes;
- The pillars under the STISA were put in place to ensure that necessary or essential actions to be implemented are in place to improve the level of STI readiness of Member States and RECs;
- The six priority areas identified under the strategy were recognized as the boundary for the finite element analysis excurses.

STISA Priority Areas

3. Output of the Analysis

The output of the analysis identified the policy gaps and institutional arrangements that may not exist in the majority of our Member States and/or its Regional Economic Communities, these gaps and arrangements are a must for STISA integration in national and regional STI processes. On the other hand the output of this analysis is designed to enhance stakeholder consultations, and communication campaigns that to be conducted by the African Union Commission as per phase one of the STISA implementation.



STISA implementation Phases

The policy analyses excurses identified 13 policies and 7 institutions; some of these policies and institutions are interlinked and addressing commonalities.

3.1 Policy Clusters

The following table illustrates the policy gaps and highlight the objectives and the aims for each policy.

Policy	Aim	Objectives
Investment Policy on R&D Infrastructures	• To build and Strengthen existing R&D infrastructures in MS Higher Education institutions and research facilities • Encourage and facilitate the establishment of private R&D institutions and facilities	• Improve national budgetary allocation for R&D infrastructure • Maximize the use of existing infrastructure • Promote R&D agreements between private companies/SMEs and national research centres to attend to private sector R&D needs • Create an enabling/encouraging environment for private sector investment on Universities and Higher Education institutions • Facilitate Regulation on the establishment of privet Universities and Higher Education institutions • Promote standardization and quality control systems for private Universities and Higher Education institutions
Science Parks Promotion Policy	Encourage the establishment of science parks at the national level	• Leverage the entrepreneurship at National and Regional levels • Building the National and Regional entrepreneurship capacity • Attract more foreign direct investments • Extending the local/regional market size • Promote introduction of African made products to the African market • Incubate innovations and inventors • Create wealth
National Policy on Community Innovation Hub	Encourage Existing Universities, Higher Education and Research Institutions at Member States to participate in addressing local community challenges	• Increase the impact of Universities, Higher Education and Research Institutions in community livelihood improvement • Link research centers and researchers with their community challenges • Promote more public recognition for STI as a magic way to address their dally problems and ultimately the national development agenda • Promote inclusive innovation concept among the research communities.
Reviews on National Higher Education Policies	Linking national higher education policies to the national priority areas including national Industry needs	• Build critical mass of MSc's & PhDs with special emphasis to industry • Establish national councils of Industry, Higher Education and Research in Member States • Promote HR mobility between industry and academia
Policy on Technology Transfer, Adoption and Acquisition	Promotion of technology transfer, adoption and acquisition for wealth creation and market competitiveness	• Enhance productivity and value added processes • Increasing market share for African products • Increase national (public, privet) investment in technology transfer, adoption and acquisition • Promote human capacity building in technology related issues • Advocate for the role of technology in Africa's economic transformation • Establish legal framework (environment) on which African union Member States would exchange their technological findings • Build Africa's Technology Market Place • Capitalize on the Africa market size to achieve better context/framework on technology licensing and production agreements • Enhance Africa human capacity competitiveness in the field of technology transfer and acquisition
AU Policy Guideline on	Encourage Member	• Enhance knowhow exchange and practitioners capacity

Professional and Practitioners Regulatory Bodies	States to establish professional and practitioner's regulatory bodies in one hand while Recs and AU to establish regional and continental bodies.	building in all the AU levels • Extend the size of the job market • Encourage professional mobility and mobilizations • Harmonize of codes of conduct and work ethics
Policy on Lifelong Learning	Improve the competitiveness of African professionals and practitioners	• Improve the scales of African professionals and practitioners to address the priority areas/sectors of STISA • Extend the national/ Africa benefit from existing work force • Promote career development, direction, and change/adaptation • Extending Job market size and wealth creation
Policy on Knowledge Exchange and Brain Circulation	Introducing new and up-to-date knowledge to the African Knowledge society and ultimately to boost the African knowledge process	• Introduce a new dimension of cooperation and mutual benefit of the African Diaspora Scientists and their bears in Africa • Network the African Diaspora with their mother land for the benefit of the African Knowledge society • Advocate and promote intra Africa cooperation in STI • Advocate and promote the role of Africa's friends (non-African Scientists) in addressing Africa's problems and to create conducive environment for their active contribution • Advocate for Diaspora integration with their motherland • Africa bilateral and multilateral partnership in STI
Policy on Research Commercialization	To change Africa's entrepreneurship and enterprise land scape by addressing the demands and ambition of its entrepreneurs	• Develop a smart partnership between Private sectors and R&D institutions • Network the African research centres and the African entrepreneurs • Identify Financial systems and lows needed to promote entrepreneurship and enterprise • Address the gabs in existing Education policies to introduce a new dimension of entrepreneurship development/Capacity Building • Introduce the concept of local market protection and advocate for made in Africa (Nationalism & Pan Africanism)
Policy on Inclusive Innovation	Africa to utilize Inclusive innovation as the driving force for its competitiveness and market access and to recognize its vital role in addressing the Africa's community challenges and problems	• To link innovation cycle to the community needs • To let recognize the inclusive innovation as a wealth creation tool • Advocate inclusive innovation among the scientific and entrepreneurs communities
Policy on Green Innovation	To introduce the extended dimension of Green innovation to the AU and its Member States and to highlight the need for Africa to participate actively in the green economy as it	• Introduce green innovation as new opportunity and challenge to the African Scientific community • Highlight the International trends on green innovation and identify African priority sectors • Identify financial mechanisms to integrate green innovation into national financial systems

	is the new industrial era where large opportunities could be defined for wealth creation.	
National Strategy on Creative Thinking and Innovation Capacity Building	To introduce creative thinking and Innovation capacity building to the African Education System in all levels	• To develop innovative thinkers and inventors • To develop competitive work force in African market
Policy on Popularization of STI	Build public understanding and raising awareness on Science, Technology and Innovation as a driving agent for social and economic progress for Africa and regional integration.	• Popularization and promotion of Science, technology and Innovation in AU Member States; • Promoting public understanding, participation and recognition of the Science, technology and Innovation role; • Establishment of supporting (pressurized) groups for more allocation to STI on the national budget.

Table 1: Illustrates the policy gaps identified from the policy analysis

3.2 Insttutional Clusters

The following table illustrates the institutional arrangements and highlight the objectives and the aims for each.

Institutional arrangement	Aim	Objectives
Science Parks at Member States level	See the Science Parks Promotion Policy	
Community Innovation Hub	See National Policy on Community Innovation Hub	
Joint Council of Industry and Higher Education/ Research	To provide a solid platform for researchers, research institutions, Higher Educational Institutes and Industries for cross-fertilization of ideas and eventually to link Higher Education priority areas to those of the industry	• Introduce Joint research areas on the priorities' of Industry • Empower/Improve of research facility in Universities/Research Institutions • Maximize the number of Ph.D. and MSc. research work that response to the national industry challenges. • Generate an innovative way/alternative resources to fund R&D in universities to maximize national R&D expenditure promote HR mobility between industry and academia

Office of Technology Transfer and Acquisition	Narrow the technology gap between Africa and the glob and to introduce African solution to African problems	• Facilitate technology transfer and acquisition between Member states • Develop action plans/policies aiming to integrate technology to national priority development sectors • Accelerate economic growth from commodity base economy to value addition economy • Lead the transition of Africa's economy to Innovation led economy • Promote made in Africa products and Harmonize Standardization at all AU levels • Develop market gap analysis a technology commercialization plans
African Union Network of Sciences	To utilize the talent of the African Scientific Community to address each other problems and challenges and allow them to recognize the diversity of Africa and to benefit most. It is also a braking through to introduce the virtual lab, virtual library and open source to the African Scientists.	• Facilitate access to accurate and up-to-date information • Foster knowledge production and sharing • Update the scientific knowledge in Africa • Create forums for discussion and interaction • Enhance intra-Africa research • Bridge the African Scientists in Diaspora and at home by introducing a new dimension of brain circulation • Enable the environment/tool for the friends of Africa to contribute to Africa's socio-economic development and • Promote publication sharing and open access.
National Centre for Development& Promotion of Entrepreneurship and Enterprise	To build the Entrepreneurship capacity of African researchers and university students.	• To promote Entrepreneurship in the national level • Network the enterprises and entrepreneurs in national level • Identify financial mechanisms to commercialize research outputs
(CDPEE)		
African Union Trade Office (AUTO)	To strengthen Intra Africa Trade	• To establish smart connection between production and demand at the AU level • To enhance intra-Africa trade in domain other than commodities • Increasing the market size and opportunities for Africa's SMEs and Enterprises

CONCLUSION

The New Era for Africa in Science Technology and Innovation can only be achieved through the domestication and implementation of the endorsed continental frame work designed to accelerate Africa's Transition to an innovation led, knowledge based Economy (STISA-2024). The realisation of the role of community based, inclusive innovation and building of a robust network of African Scientists, inventors with the aim of developing and implementing fact based policies will serve as a catalyst that will make Africa soar high socio- economically within the possibilities of Science and Technology. Also maximizing on available allocated funds by Member States will boost the impact of science and technology in Africa's Economic Prosperity.

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MODELLING TRANSITION FROM NORMAL TO EPILEPTIC EEG SIGNALS: A NEURON - ASTROCYTE MASS ACTION APPROACH

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ABSTRACT

Epileptic seizures occur intermittently as a result of complex dynamical interactions among many regions of the brain. The sudden and apparently unpredictable nature of refractory seizures is one of the most disabling aspects of the disease. Therefore, there is need for interdisciplinary research efforts directed at better understanding of the mechanisms involved in the emergence of epileptic seizures. Our research objective in this field is the use of applied methods from deterministic and nondeterministic dynamical systems modeling to study epilepsy. Dynamical systems refer to systems whose state variables evolve in time. By the assumption of deterministic system,the physiological system (the brain) can be treated as low dimensional without any random components. Nondeterministic assumption on the other hand allows randomness in some input components. We developed at the macroscopic level physiologically based mathematical models of parts of the brain believed to be eliciting the abnormal signals observed during Generalized Absence Epilepsy (GAE) and Temporal Lobe Epilepsy (TLE). In developing our models, we considered the activities of nerve cells, the surrounding astrocyte cells and the dynamics of extracellular neurotransmitters and conducted parameter sensitivity studies on our models. The models were then validated using Electroencephalogram (EEG) data of epileptic patients.

The important conclusion from our findings is that the transition from normal to epileptic brain activity is critically dependent on small variations in few system parameters and/or the balance between a small number of system parameters, be it neural or astrocytes activity dependent.

Key words: Dynamical Systems, Temporal Lobe Epilepsy, Neuron-Astrocyte Mass Action Model

LIST OF ABBREVIATIONS

AED:	Anti-epileptic-drug
AMPA:	α-amino-3-hydroxy-5-methyl-4-isoxazolepropionic acid
EEG:	Electroencephalography
GABAa:	γ-aminobutyric acid A
GABAb	γ-aminobutyric acid B
GAE:	Generalized Absence Epilepsy
IN:	Interneurons
ODE:	Ordinary differential equations
PSP:	Post synaptic potential
SWD:	Spike-wave discharges
TCR:	Thalamo-cortical relay cells
TLE:	Temporal lobe epilepsy

INTRODUCTION

Two observations about epilepsy are intriguing and challenging at the same time. First, despite many new "antiepileptic" drugs, the percentage of epilepsy patients who are rendered seizure free by current pharmacological treatment has not significantly increased over recent years. Second, despite most intensive interdisciplinary efforts, it is still not possible to predict epileptic seizures with a specificity that would allow for relevant improvements of clinical management (Schindler, 2013). These unpleasant facts may at least be due to our incomplete understanding of epileptic seizures. Therefore, it is reasonable to assume that we may be able to better control epilepsy if we first deepen our knowledge of seizure dynamics.

Traditionally, mathematical models of epileptic seizures take into account only the observed activities of nerve cells (neurons) whose dynamics have been described both at the microscopic and macroscopic scales. However, in recent years researches have indicted glia cells (mainly astrocytes) as an important factor in the regulation of neural activities. Consequently, astrocytes dysfunctions are involved in several brain pathologies(Losi et al., 2012,Pittenger et al., 2011, Seifert et al., 2006). Studying the interactions between the neurons and astrocytes cells has therefore become essential in order to deepen our knowledge about seizure dynamics.

In this regard, computational models have proven to be a key tool for interpreting observed electrophysiological data. They can also reveal the different patho-physiological mechanisms which may underlie the observational data. A very important class of such models is the neural mass models (NMM) which have been extensively used in epilepsy research. We present in Table 1 a summary of prominent neural mass models found in the literature.These models have the advantage that they describe the activities of a large population of nerve cells and as such their output can be directly compared with the brain's membrane potential recorded from the scalp (EEG). Several models incorporating the metabolic regulation mechanisms of glia cells have been proposed. These models however have been limited to the cellular (microscopic) scale. Some researchers built models of tripartite synapse (Postnov et al., 2009, Volman et al., 2012)which considers an astrocyte cell that is coupled with both presynaptic and postsynaptic neurons and the dynamics of neurotransmitters, ions and molecules.Others considered a single nerve cell coupled with an astrocyte cell (De Pittà et al., 2011)and sometimes with a hemodynamic compartment and the dynamics of neurotransmitters, ions and molecules(Aubert and Costalat, 2002).

In the present work, we introduce new models of mass action (Neural Mass Models) of two most commonly encountered epileptic seizures (generalized absence and temporal lobe epilepsy) incorporating already documented roles of glia cells (astrocytes) in the dynamics of the extracellular neurotransmitters (glutamate and GABA). We therefore refer to the models as Neuron-Astrocyte Mass Action Models. The neural compartment of the generalized absence model is based on the neural mass model of Suffczynski et al., 2004. However, we have reduced the biophysical complexity in the original model by considering only cortical cells interactions (pyramidal and interneuron cells). We however include a self- excitatory feedback connection to the pyramidal cell populations in addition to an external or distant excitatory feedback connections as existence of both types of excitatory feedback connections are physiologically relevant in cortical population of pyramidal cells. In the same vein the neural compartment of our temporal lobe epilepsy model is based on the neural mass model of (Wendling et al., 2002)but with slight biophysical modifications. To build the glia cells compartment of our epilepsy models, we considered a simplified version of a variety of processes called neurotransmitter cycles involving the dynamics (releases and uptakes) of neurotransmitters (GABA and glutamate) in the extracellular space.

Thereafter, we performed bifurcation analysis and simulation of the models to identify regions in the parameter space producing epileptic activities.

Table 2.1 Prominent Neural Mass Models in Literature

Reference	Epilepsy Type	Research Question	Neural populations Considered	Conclusions
Lopes da Silva et al (1974)	Generalized Absence Epilepsy	Can the thalamus generate alpha rhythm which is observed during epilepsy?	Thalamo -cortical relay cells (TCR) and interneurons (IN)	Model can generate alpha rhythm which is linked to seizures
Jansen et al (1993)	Temporal Lobe Epilepsy	Can the cortical columns generate epileptiforms	Pyramidal neurons, Local excitatory and Local inhibitory neurons	The model can produce epileptic activities
Jansen et al (1995)	Temporal Lobe Epilepsy	Can the cortical columns generate epileptiforms	Pyramidal neurons, Local excitatory and Local inhibitory neurons	The model can produce epileptic activities
Wendling et al. (2002)	Temporal Lobe Epilepsy	Can the fast EEG activity observed during focal epilepsy be modelled	Pyramidal neurons, Local excitatory neurons, Fast and Slow local inhibitory neurons	The fast activity can be modelled. Transition to the fast activity is caused by slow inhibitory processes.
Suffczynski et al. (2004)	Generalized Absence Epilepsy	What mechanisms are responsible for transitions from normal EEG activity to paroxysmal (pathological) Spike wave discharges in Generalized Absence Epilepsy (GAE)	Pyramidal neurons, interneurons, Thalamo-cortical neurons and Reticular thalamic neurons	Transitions to seizure caused by random fluctuations in external input
Grimbert and Faugeras (2006)	Temporal Lobe Epilepsy	What is the influence of the stationary input I on the Jansen & Rit (1995) model	Pyramidal neurons, Local excitatory and Local inhibitory neurons	Varying parameter I can cause transitions into and out of seizures
Goodfellow et al. (2011)	Generalized Absence Epilepsy	Can spike wave discharges (SWD) activity be generated in broad regions of the brain?	Pyramidal neurons, Local excitatory and Local inhibitory neurons	spike wave discharges (SWD) activity can be generated in broad regions of the brain

METHODOLOGY

2.1 Generalized Absence Epilepsy: Model of Cortical Columns

The original neural mass model of Suffczynski et al. (2004) consists of four cell populations: pyramidal, interneuron, thalamocortical and reticular thalamic cells. This model was based on the experimental findings that favour interactions between cell populations in the cortical and the thalamic areas of the brain (Vergnes and Marescaux, 1992) over interactions only between cell populations in the cortical area (Lytton et al., 1997, Pinault et al., 1998) as the source of GAE. Although the model produced outputs that resemble those seen in the EEG as well as spontaneous transitions to epileptic activities (quasi sinusoidal waveform), the model fails to produce the characteristic spike wave discharges which are the electrographic correlate of GAE (Taylor and Baier, 2011).

We therefore for simplicity give preference to experimental findings supporting the cortical genesis of GAE and reduced the biophysical complexity of the model by ignoring the thalamic cell populations in our model. In addition, we introduced into our model a self-excitatory feedback connection to the pyramidal cell population in addition to an external or distant excitatory connection. Lastly we built an astrocyte compartment from the activities of the neural compartment and modeled the interaction (feed forward and feedback mechanisms) between them through the dynamics of the extracellular neurotransmitters.

In what follows we give detailed explanation on the development of our new neuron – astrocyte mass action model for the GAE. We first give explanation on the development of the neural compartment of the model followed by that of the astrocyte compartment. Thereafter, we present the equations governing the dynamics of our coupled neuron – astrocyte mass action model for the GAE.

3.0 The Neural Compartment

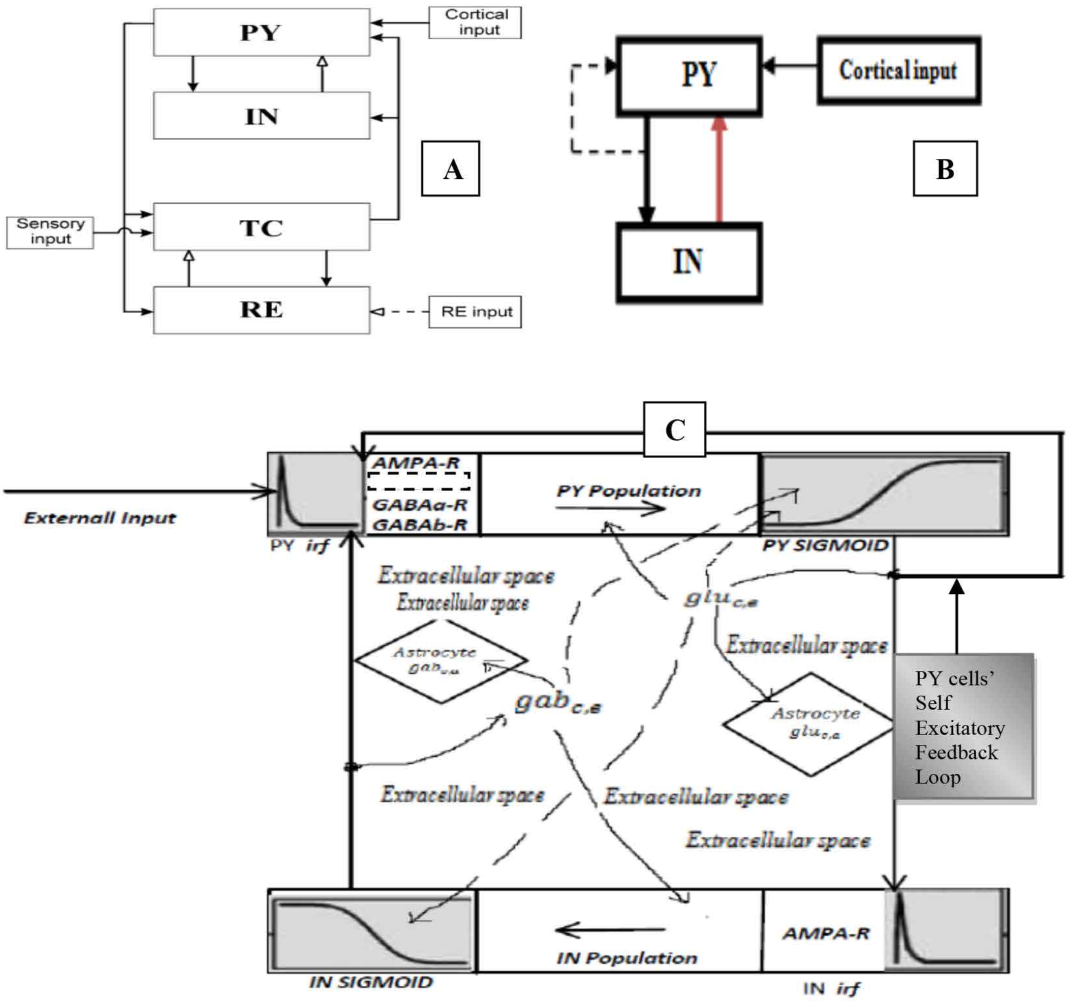


Figure 3.0 Schematic representations of (A) model of Suffczynski et al.(2004) (B) neural compartment of our neuron – astrocyte model for GAE showing the self-excitatory feedback loop (broken arrow) (C) detailed mechanism of interactions in our neuron – astrocytes mass action models.

The general framework of the neural compartment of our model is described as follows: Incoming impulses (action potentials or firing densities)generate post-synaptic currents in each population. The pyramidal cell (PY) population sends excitatory connection to the interneuron (IN) population while the interneuron population feeds back with an inhibitory connection. The pyramidal cells population receives **self-excitatory feedback connection** as well as distant excitatory connections from other cortical areas meaning that the average membrane potential of the PY cell population does not only depend on inputs from other cell populations but also the inputs coming from within itself. This is not the case in previous models.

In every population, the conversion from average presynaptic firing density (input to the population) into average postsynaptic firing density (output of the population) followed these steps. First we converted the presynaptic firing densities into postsynaptic currents through a second order linear transfer function and set up a material (current) balance equation. We then integrated the current balance equation to obtain the mean membrane potential profile of the population. Finally we transform this membrane potential to the average postsynaptic firing density of the population.

3.1 Postsynaptic currents and Material (current) balance

Postsynaptic currents

The mediating neurotransmitters receptors we considered are AMPA (excitatory in nature), GABAa (inhibitory) and GABAb (inhibitory) receptors. Experiments show that most ligand-gated ion channels mediating synaptic transmission (AMPA, GABAa, e.t.c) display an approximately linear current-voltage relationship when they open (Roth and van Rossum, 2009). We therefore modeled them as an Ohmic conductance g_{syn} which when multiplied by the driving force, the difference between the membrane potential, v and the reversal potential E_{syn} (i.e. equilibrium potential) for the synapses gives the post synaptic current. Consequently we modeled the postsynaptic currents as:

$$I_{syn}(t) = g_{syn}(t)\big(v(t) - E_{syn}\big) \quad syn = \{AMPA, GABAa, GABAb\} \qquad 3.0$$

In line with earlier works(Wilson and Cowan, 1972, Destexhe, 2007)we modeled the synaptic conductance $g_{syn}$by convolvingincoming action potential sequence, i.e. firing density($fd_{syn}(t)$) with a synaptic impulse response function,$irf_{syn}(t)$

$$g_{syn}(t) = \int_{-\infty}^{t} irf_{syn}(t-\tau) fd_{syn}(\tau) d\tau \qquad 3.1$$

for the synaptic impulse response functionwe adopted a dual exponential function:

$$irf_{syn}(t) = G_{syn}\left[e^{-\frac{1}{t_{r,syn}}t} - e^{-\frac{1}{t_{d,syn}}t}\right] \qquad 3.2$$

where G_{syn}, t_r and t_d are maximum synaptic conductances, rise time and decay time respectively. Mathematically, it is verified here that this dual exponential function is a solution of the second order differential equation:

$$\frac{d^2 g_{syn}(t)}{dt^2} = -\left(\frac{1}{t_{r,syn}} + \frac{1}{t_{d,syn}}\right)\frac{dg_{syn}(t)}{dt} - \left(\frac{1}{t_{r,syn} \cdot t_{d,syn}}\right) g_{syn}(t) + G_{syn}\left(\frac{1}{t_{r,syn}} - \frac{1}{t_{d,syn}}\right) fd^p(t).\ syn = \{AMPA, GABAa, GABAb\} \quad 3.3$$

that is the response of the differential equation 3.3 to an impulse takes the shape of the dual exponential function (equ. 3.2). Further, GABAb conductance relies on high stimulus intensities for its activation (Kim et al., 1997)we therefore assumed in consonance with earlier researchers (Lopez da Silva, 1974, Wendling et al, 2002) that the amplitude of the GABAb postsynaptic current increases nonlinearly with the firing density of the IN populations. We then approximate this nonlinear behaviour with the activation function f_{act} that takes the form of a sigmoid:

$$f_{act} = \left[1 + e^{\sigma_a (fd(t) - \theta_a)}\right]^{-1} \qquad 3.4$$

where σ_a and θ_a set the stiffness and threshold of the activation function.

Material (current) Balance Equation

By considering all sources of current (synaptic and leaks) contributing to change in the mean membrane potential of each population we can set up a current balance equation for both IN and PY populations in the neural compartment of our model. These equations are just the time derivatives of average charge accumulated around the membrane of each cell population (Q = CV). These equations are derived as:

$$C_m^{py} \frac{dv^{py}(t)}{dt} = -(I_{leak}^{py} + I_{Syn}^{py}) \qquad 3.5$$

$$C_m^{IN} \frac{dv^{IN}(t)}{dt} = -(I_{leak}^{IN} + I_{Syn}^{IN}) \qquad 3.6$$

where$I_{leak}^{py}(t) = g_{leak}\left(v^{py}(t) - E_{leak}^{py}\right)$; $I_{leak}^{IN}(t) = g_{leak}\left(v^{IN}(t) - E_{leak}^{IN}\right)$ and $I_{Syn}^{py}(t) = g_{Syn}^{py}(t)\left[v^{py}(t) - E_{Syn}^{py}\right], Syn = AMPA, GABAa, GABAb$;$I_{Syn}^{IN}(t) = g_{Syn}^{IN}(t)\left[v^{IN}(t) - E_{Syn}^{IN}\right], Syn = AMPA$

$g_{syn}(t)$, synaptic conductance is given by equation 3.3. C_m,I_{leak} represent membrane capacitance and leak current respectively. Note that in equations 3.5 and 3.6 we have assumed a constant nerve cell membrane capacitance, C_m. Next we explain how we converted mean membrane potential to mean firing density for each population.

In cortical cells experiments it was shown (Pollen, 1964) that firing density increases with increasing membrane potential of the cells and also that there is a refractory period for nerve cells (time during which they seize to produce an action potential even with increasing membrane potential). These properties provide that a function describing the cells' firing density with respect to membrane potential should be increasing as well as bounded. A sigmoidal function of the form in equation 3.7 was proposed (Freeman, 1975):

$$fd^p(t) = \frac{fd^p_{max}}{\left[1 + e^{s^p(v^p - v^p_{th})}\right]}, p = \{IN, PY\} \qquad 3.7$$

where $fd^p_{max}, s^p, v^p_{th}$ and v^p are the maximum firing density, slope of the sigmoidal function at inflection point, threshold potential and mean membrane potential of an arbitrary nerve cells population, p have these properties. We therefore used the function to model the conversion from mean membrane potential to mean firing density of each population which then serves as the output of the population.

3.2 The Astrocyte Compartment (feed forward and feedback mechanisms)

Following (Blanchard et al., 2016) the astrocyte compartment of our neuron-astrocyte mass action models are built on the firing densities of the pyramidal neurons and interneurons population (feed forward). The mechanism is as follows (figures 3.0C and 3.1): excited pyramidal neurons and interneurons release glutamate and GABA respectively in the extracellular space (synaptic cleft). Astrocytes and presynaptic neurons take up the neurotransmitters. Astrocytes recycle or consume the neurotransmitters, while

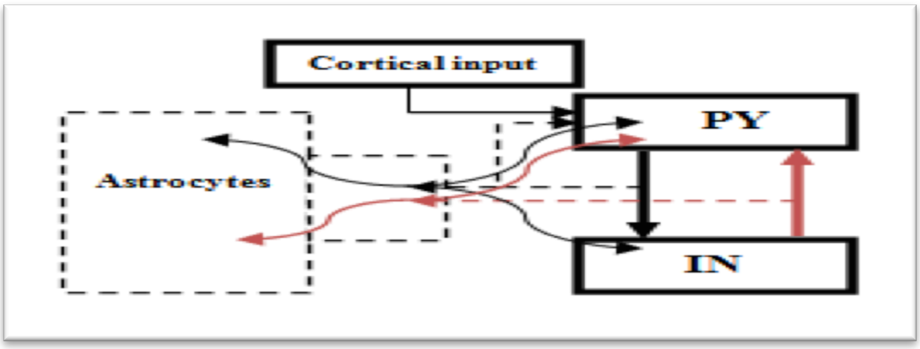


Fig. 3.1

Schematic representation of our neuron – astrocyte mass action model for GAE

while the presynaptic neurons capture them to complete their stock. We observed from Figure 4 in the article presented in (Hires et al., 2008)Hires et al(2008) the extracellular concentration of glutamate in response to a single action potential (impulse response).

The shape of this response (Fig 3.2), with very different rise time and decay time informed our decision to model the impulse response by dual exponential function similar to that given in equation 3.2 and consequently led us to describing the flux of the neurotransmitters (glutamate & GABA) from neurons to the extracellular space by second order differential equations which are similar to the one already given in equation 3.3:

$$\frac{d^2J_{glu}(t)}{dt^2} = -(a_1 + a_2)\frac{dJ_{glu}(t)}{dt} - a_1a_2J_{glu}(t) + Aa_1fd^{py}(t) \quad 3.8$$

$$\frac{d^2J_{gab}(t)}{dt^2} = -(b_1 + b_2)\frac{dJ_{gab}(t)}{dt} - b_1b_2J_{gab}(t) + Bb_1fd^{IN}(t) \quad 3.9$$

where A, B are the gain coefficients of glutamate and GABA releases transfer functions respectively, a_1, a_2 ,$b_1 and\ b_2$ represent the reciprocal of rise and decay times of the impulse response,J_{glu} and J_{gab} are the flux of glutamate and GABA respectively, $fd^{py}$and fd^{IN} are the firing densities (outputs of the PY and IN populations) contributing to the release of the neurotransmitters.

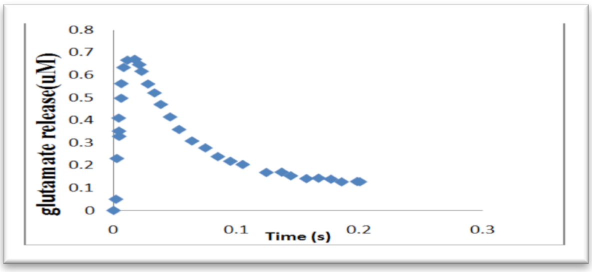


Fig. 3.2, Time course of glutamate release in response to an action potential (Hires et al., 2008)

Uptake of glutamate by astrocyte begins when glutamate concentration in the extracellular space reaches certain concentration (i.e. threshold effect). Furthermore glutamate uptake by astrocyte displays a saturation effect (Tan et al., 1999) so, a sigmoid function can adequately account for these behaviours. Conversely, glutamate reuptake by neurons is typically said to be 10% to 20% (Tan et al., 1999) of the total glutamate concentration taken from extracellular space. Consequently we modeled glutamate uptakes by astrocyte and neuron $glu_{e,a}\ and\ glu_{e,n}$by: $glu_{e,a}(t) = glu^{ua}_{max}/\left[1 + e^{\sigma(glu_{c,e}(t)-\theta)}\right]$, $glu_{e,n}(t) = x \cdot glu_{e,a}(t)$ where glu^{ua}_{max} is the maximum glutamate uptake rate, $glu_{c,e}(t)$ is the extracellular concentration of glutamate and x is a value in the range 0.1-0.2. The dynamics of glutamate in the intracellular regions of the astrocyte that exist in literatures have very complex mechanisms most of which do not fit into the simplification principle of modeling at the macroscopic level. For simplicity, we assume that the consumption rate cr^{a}_{glu} of glutamate within astrocyte is constant. Now we can write mass balance equations for the extracellular glutamate concentration and astrocyte intracellular glutamate concentration assuming first order dynamics respectively as follows:

$$\frac{glu_{c,e}(t)}{dt} = J_{glu}(t) - glu_{e,a}(t) - glu_{e,n}(t) \qquad 3.10a$$

$$\frac{glu_{c,a}(t)}{dt} = glu_{e,a}(t) - cr_{glu}^{a} glu_{c,a}(t) \qquad 3.10b$$

In the experimental literature GABA uptakes by astrocytes and neurons follow the Michaelis-Menten kinetics (Tan et al., 1999). Therefore we represent neuronal and astrocytic GABA uptakes respectively using the Michaelis Menten formality:

$$gab_{e,n}(t) = \frac{V_{mn}}{K_{mn}+gab_{c,e}(t)} gab_{c,e}(t) 3.11a$$

$$gab_{e,a}(t) = \frac{V_{ma}}{K_{ma}+gab_{c,e}(t)} gab_{c,e}(t) \quad 3.11b$$

where $gab_{c,e}(t)$ is the GABA concentration in the extracellular space and V_{ma}, V_{mn}, K_{ma} and K_{mn} are the Michaelis-Menten parameters.

Similarly, we can account for the GABA released into the extracellular space and astrocyte intracellular GABA concentration by writing material balance equations. On the assumption of first order kinetics we arrive at equations 3.12 and 3.13 for extracellular GABA concentration and astrocyte intracellular GABA concentration respectively as follows:

$$\frac{gab_{c,e}(t)}{dt} = J_{gab}(t) - gab_{e,a}(t) - gab_{e,n}(t) \qquad 3.12$$

$$\frac{gab_{c,a}(t)}{dt} = gab_{e,a}(t) - cr_{gab}^{a} gab_{c,a}(t) \qquad 3.13$$

3.3 Development of Astrocyte feedback mechanism on the neural Compartment

Although it has been observed that extracellular concentration of neurotransmitters have a threshold impact on neural activity(Araque et al., 1998) quantitative experimental data of the impact of neurotransmitter concentrations on neural excitability do not exist up to date. It is however logical to reason as follows: if there is an excess of neurotransmitter in asynapse connecting an interneuron (presynaptic) to a pyramidal neuron (postsynaptic) and vice versa, the extracellular concentration of neurotransmitter acts on the postsynaptic neuron by changing its excitability threshold (i.e. results in an increase or decrease in magnitude of the mean membrane potential the neuron must attain before it can fire an action potential). In the neural compartment of our model this will directly have a modulation effect on the population threshold parameter at normal physiological conditions$v_{th}^{p}$and in turn on the excitability of the neural populations.

To model this modulation effect (i.e. increase/decrease in v_{th}^{p}as a result of excess neurotransmitter in the extracellular space) we considered sigmoidal functions that relate extracellular neurotransmitter concentration to magnitude of change in excitability threshold. This seems natural since most biochemical interactions in the nerve cells exhibit saturation property. We note that glutamate binding mechanisms are the same for both pyramidal neurons and interneurons since both cell types express the same type of transporters (Huang, 2004)**.** This led us to using the same set of parameters for the sigmoidal functions involving glutamate extracellular concentration. The only difference is in the maximum coupling gainsglu_{m}^{py} ,glu_{m}^{IN} due to the fact that the number of transporters is cell-specific and so is the ensuing uptake rate (Huang, 2004)**.** The sigmoidal functions modeling the glutamate-dependent component of excitability modulations for pyramidal and interneuron populations are then given respectively as:

$$glu_{m}^{py}/\left[1+e^{s_g\left(glu_{c,e}-v_g\right)}\right] \qquad 3.14a$$

$$glu_{m}^{IN}/\left[1+e^{s_g\left(glu_{c,e}-v_g\right)}\right]. \qquad 3.14b$$

For the GABA-dependent component of excitability modulations, we take into consideration only pyramidal cell populations as existing literatures lack definite information as to how excess extracellular GABA concentration impact the physiological activities of interneurons. The sigmoidal function in this regard is given by

$$gab_{m}^{py}/\left[1+e^{s_{gab}\left(gab_{c,e}-v_{gab}\right)}\right] \quad 3.15$$

similar to those of glutamate but with entirely different set of parameter values.

The magnitude of change in v_{th}^{p} with respect to excess extracellular neurotransmitter concentration has been taken care of we now focus on the direction of this change. An excess concentration of glutamate in the vicinity of postsynaptic pyramidal population should result in enhanced excitability which translates to a reduction in the excitability threshold parameter and hence a negative change$\left(-\frac{glu_{m}^{py}}{\left[1+e^{s_g\left(glu_{c,e}-v_g\right)}\right]}=\Delta_{\mathrm{glu}}^{\mathrm{py}}\right)$. On the other hand an excess GABA concentration in the vicinity of postsynaptic pyramidal population results in enhanced inhibition which translates to an increase in the excitability threshold parameter and hence a positive change $\left(\frac{+gab_{m}^{py}}{\left[1+e^{s_{gab}\left(gab_{c,e}-v_{gab}\right)}\right]}=\Delta_{\mathrm{gab}}^{\mathrm{py}}\right)$. Finally, an excess concentration of glutamate in the vicinity of postsynaptic interneuron population results in stronger excitability which translates to an increase in the excitability threshold parameter and hence a negative change $\left(\frac{-glu_{m}^{IN}}{\left[1+e^{s_g\left(glu_{c,e}-v_g\right)}\right]}=\Delta_{\mathrm{glu}}^{\mathrm{IN}}\right)$. These terms can now be introduced in equation 3.5/3.6 for both pyramidal and interneuron populations as follows:

$fd^{py}(t) = \frac{fd^{py}_{max}}{\left[1+e^{s^{py}\left(v^{py}-(v^{py}_{th}+\Delta^{\mathrm{py}}_{\mathrm{gab}}+\Delta^{\mathrm{py}}_{\mathrm{glu}})\right)}\right]}$ and $fd^{IN}(t) = \frac{fd^{IN}_{max}}{\left[1+e^{s^{IN}\left(v^{IN}-(v^{IN}_{th}+\Delta^{\mathrm{IN}}_{\mathrm{glu}})\right)}\right]}$ thus building the astrocyte compartment's feedback mechanism on the neural compartment. The overall equations describing the dynamics of the coupled neuron-astrocyte mass action model is then obtained as follows: we introduced the appropriate firing density terms, $fd^{p}(t)$(equ. 3.7) contributing to the change in the mean membrane potential of each population in equation 3.3 and adapted the equation for each of the mediating synapses, we inserted the population to population synaptic connection strength parameters C, C2, C3, C4, C5, C6 and brought these equations together with equations 3.5 and 3.6 to obtain equations for the neural compartment. Likewise we bring equations 3.8 -3.13 together to obtain equations for the astrocyte compartment. The complete set of equations is presented in equations 3.16. Equation3.16can be integrated numerically to obtain the average membrane potential profile of the pyramidal cell population which is the output of the model and also represents the scalp EEG signal.

3.4 Temporal Lobe Epilepsy: Model of the Hippocampus

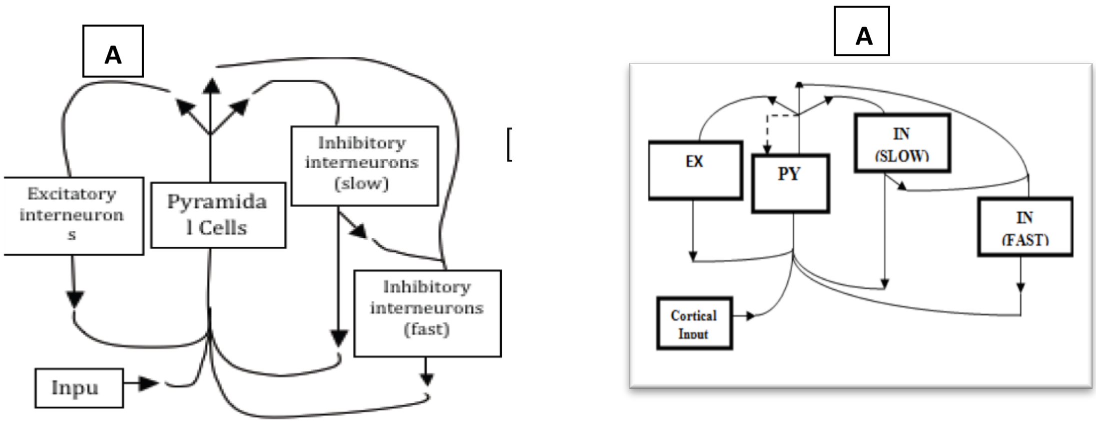


Fig. 3.3.Schematic representation of (A) model of Wendling et al (2002) (B) neural compartment of our neuron – astrocyte mass action model for TLE showing the self-excitatory feedback loop (broken arrow)

The original neural mass model of the hippocampus by Wendling et al. (2002) was built on four interconnected neuronal populations (Fig.3.3 A). The main cells (excitatory pyramidal neurons) excite the three other populations. The distant excitatory pyramidal neurons excite these main cells. Next to these two excitatory populations, there are also two inhibitory populations included in the model. One of these represents inhibitory interneurons that project to the soma of the main cells. The other one represents inhibitory interneurons that project to the dendrites of the main cells. This means that both inhibitory

$$C_m^{py}\frac{dv^{py}(t)}{dt} = -\{Cg_{leak}(v^{py}(t) - E_{leak}) + g_{AMPA}^{py}(t)[v^{py}(t) - E_{AMPA}] + C2\, g_{GABAa}(t)[v^{py}(t) - E_{GABAa}] + C3g_{GABAb}(t)[v^{py}(t) - E_{GABAb}]\} \quad 3.16a$$

$$C_m^{IN}\frac{dv^{IN}(t)}{dt} = -\{Cg_{leak}(v^{IN}(t) - E_{leak}) + g_{AMPA}^{IN}(t)[v^{IN}(t) - E_{AMPA}]\} \quad 3.16b$$

$$\frac{d^2 g_{AMPA}^{py}(t)}{dt^2} = -\left(\frac{1}{t_{r,AMPA}} + \frac{1}{t_{d,AMPA}}\right)\frac{dg_{AMPA}^{py}(t)}{dt} - \left(\frac{1}{t_{r,AMPA}\cdot t_{d,AMPA}}\right)g_{AMPA}^{py} + G_{AMPA}\left(\frac{1}{t_{r,AMPA}} - \frac{1}{t_{d,AMPA}}\right)(C5fd^{py}(t) + C4p) \quad 3.16c$$

$$\frac{d^2 g_{AMPA}^{IN}(t)}{dt^2} = -\left(\frac{1}{t_{r,AMPA}} + \frac{1}{t_{d,AMPA}}\right)\frac{dg_{AMPA}^{IN}(t)}{dt} - \left(\frac{1}{t_{r,AMPA}\cdot t_{d,AMPA}}\right)g_{AMPA}^{IN} + G_{AMPA}\left(\frac{1}{t_{r,AMPA}} - \frac{1}{t_{d,AMPA}}\right)C6fd^{py}(t) \quad 3.16d$$

$$\frac{d^2 g_{GABAa}(t)}{dt^2} = -\left(\frac{1}{t_{r,GABAa}} + \frac{1}{t_{d,GABAa}}\right)\frac{dg_{GABAa}(t)}{dt} - \left(\frac{1}{t_{r,GABAa}\cdot t_{d,GABAa}}\right)G_{GABAa} + G_{GABAa}\left(\frac{1}{t_{r,GABAa}} - \frac{1}{t_{d,GABAa}}\right)fd^{IN}(t) \quad 3.16e$$

$$\frac{d^2 g_{GABAb}(t)}{dt^2} = -\left(\frac{1}{t_{r,GABAb}} + \frac{1}{t_{d,GABAb}}\right)\frac{dg_{GABAb}(t)}{dt} - \left(\frac{1}{t_{r,GABAb}\cdot t_{d,GABAb}}\right)g_{GABAb} + G_{GABAb}\left(\frac{1}{t_{r,GABAb}} - \frac{1}{t_{d,GABAb}}\right)fd^{IN}(t)f_{act} \quad 3.16f$$

$$\frac{d^2 J_{glu}(t)}{dt^2} = -(a_1 + a_2)\frac{dJ_{glu}(t)}{dt} - a_1 a_2 J_{glu}(t) + Aa_1 fd^{py}(t) \quad 3.16g$$

$$\frac{d^2 J_{gab}(t)}{dt^2} = -(b_1 + b_2)\frac{dJ_{gab}(t)}{dt} - b_1 b_2 J_{gab}(t) + Bb_1 fd^{IN}(t) \quad 3.16h$$

$$\frac{glu_{c,e}(t)}{dt} = J_{glu}(t) - glu_{e,a}(t) - glu_{e,n}(t) \quad 3.16i$$

$$\frac{glu_{c,a}(t)}{dt} = glu_{e,a}(t) - cr_{glu}^{a} glu_{c,a}(t) \quad 3.16j$$

$$\frac{gab_{c,e}(t)}{dt} = J_{gab}(t) - gab_{e,a}(t) - gab_{e,n}(t) \quad 3.16k$$

$$\frac{gab_{c,a}(t)}{dt} = gab_{e,a}(t) - cr_{gab}^{a} gab_{c,a}(t) \quad 3.16l$$

populations inhibit the main cells. The dendritic projecting interneurons further inhibit the somatic projecting interneurons.

The model did not account for various synaptic currents contributing to the mean membrane voltage of each population but lumped them into inhibitory and excitatory post synaptic membrane potentials arising from presynaptic firing densities (inputs) that each population receive. The model is known to produce various outputs that resemble normal and pathological EEG signals but to the best of our knowledge spontaneous transitions among these activities has never been reported for the model.

Our novel modification of the model therefore include (1) addition of self-excitatory feedback loop on the main pyramidal cell population (Figure 3.3B) (to obtain the neural compartment of our neuron-astrocyte mass action model for TLE) and (2) introduction of a bidirectional coupling with the activities of the astrocyte cell population through the dynamics of the extracellular neurotransmitters (Figure 3.4) details of which has been given in the foregoing (in the neuron-astrocyte mass action model for GAE). The astrocyte activity however only couples with the pyramidal and fast inhibitory cell populations. Next we present the process of development of the neuron – astrocyte mass action model for TLE.

3.5 Development of Neuron – Astrocyte Mass Action Model for TLE

For every population in the neural compartment, the conversion from average presynaptic firing density (input to the population) into average postsynaptic firing density (output of the population) followed two distinct steps. First we converted average presynaptic firing rate (density) of a population into its mean membrane potential directly through a second order linear transfer function whose differential equation is given by equation 3.17. In this equation $v_p(t), r,$ $G$and $fd^p$are respectively the mean membrane potential, reciprocal of impulse response time constant, maximum mean membrane potential and the firing density contributing to the change in the mean membrane potential of an arbitrary population p. The impulse response function corresponding to equation 3.17 is the alpha function (Rall, 1969)which has the form given in equation 3.18.

$$\frac{d^2 v_p(t)}{dt^2} + 2 * r \frac{dv_p(t)}{dt} + r^2 * v_p(t) = G * r * fd^p(t) \qquad 3.17$$

$$irf(t) = G \frac{t}{\tau} e^{-\left(\frac{t}{\tau}\right)} \qquad 3.18$$

where$G$is the maximum mean membrane potential and τ represents the time constant. Obviously by our choice of impulse response we have assumed equal rise and decay times for our mean membrane potential in response to an action potential. Since inhibitory and excitatory cells population show different characteristics (Jansen and Rit, 1995) alpha impulse response vary across populations in the value of the time constant and maximum mean membrane potential.

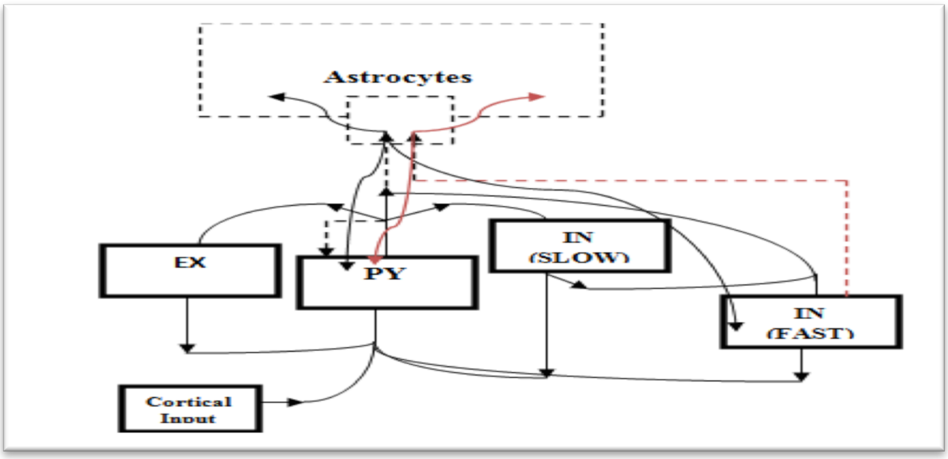


Fig.3.4. Schematic representation of our neuron – astrocyte mass action model for TLE

In the second step we transformed the mean membrane potential of each population to postsynaptic firing rate of this population using a sigmoid function similar to equation 3.7. The astrocytes compartment (Figure 3.4) and the feedback mechanism to the neural compartment are built in a similar manner as described for GAE model above. The equations describing the dynamics our neuron - astrocytes mass action model for TLE are now derived as follows.

$$\frac{d^2 v_{py}(t)}{dt^2} = Ge * re * fd^1(t) - 2 * re \frac{dv_{py}(t)}{dt} - re^2 * v_{py}(t) \qquad 3.19a$$

$$\frac{d^2 v_{ex}(t)}{dt^2} = Ge * re \left(J * fd^1(t) + p + c2 * fd^2(t)\right) - 2 * re \frac{dv_{ex}(t)}{dt} - re^2 * v_{ex}(t) \qquad 3.19b$$

$$\frac{d^2 v_{is}(t)}{dt^2} = Gis * ris * c4 * fd^3(t) - 2 * ris \frac{dv_{is}(t)}{dt} - ris^2 * v_{is}(t) \qquad 3.19c$$

$$\frac{d^2 v_{if}(t)}{dt^2} = Gif * rif * c7 * fd^4(t) - 2 * rif \frac{dv_{if}(t)}{dt} - rif^2 * v_{if}(t) \qquad 3.19d$$

$$\frac{d^2 v_{is}(t)}{dt^2} = Gis * ris * fd^3(t) - 2 * ris \frac{dv_{is}(t)}{dt} - ris^2 * v_{is}(t) \qquad 3.19e$$

$$\frac{d^2 J_{glu}(t)}{dt^2} = -(a_1 + a_2)\frac{dJ_{glu}(t)}{dt} - a_1 a_2 J_{glu}(t) + A a_1 fd^{py}(t) 3.19f$$

$$\frac{d^2 J_{gab}(t)}{dt^2} = -(b_1 + b_2)\frac{dJ_{gab}(t)}{dt} - b_1 b_2 J_{gab}(t) + B b_1 fd^{IF}(t) 3.19g$$

$$\frac{glu_{c,e}(t)}{dt} = J_{glu}(t) - glu_{e,a}(t) - glu_{e,n}(t) 3.19h$$

$$\frac{glu_{c,a}(t)}{dt} = glu_{e,a}(t) - cr_{glu}^{a} glu_{c,a}(t) 3.19i$$

$$\frac{gab_{c,e}(t)}{dt} = J_{gab}(t) - gab_{e,a}(t) - gab_{e,n}(t) \quad 3.19j$$

$$\frac{gab_{c,a}(t)}{dt} = gab_{e,a}(t) - cr_{gab}^{a} gab_{c,a}(t) \quad 3.19k$$

where v_{py},v_{ex},v_{is} and $v_{if}$are mean membrane potentials of the four cell populations (fig. 3.4).Parameters Ge, re: Gis, ris and Gif, rif represent the maximum mean membrane potential and reciprocal of time constant for the excitatory, slow inhibitory and fast inhibitory populations in that order. Furthermore,$fd^1(t)$, $fd^2(t)$,$fd^3(t)$,$fd^4(t)$ are the firing densities contributing to changes in the mean membrane potential of populations.$C2, C4, C7$ and $J$are population to population connection strength parameters.

3.6 Bifurcation Analysis

Essential parameters in our models are the input firing rate P(t), the connection strength C5 (or J) and the ratio of the maximum coupling gain of astrocytic GABA feedback to the neural compartment to the maximum coupling gain of astrocytic glutamate feedback to the neural compartment, $\Upsilon = \frac{gab_m^{py}}{glu_m^{py}}$. P(t) is a density of action potentials which represents the external input to the neural mass while C5 (or J) is the pyramidal cell population's self excitatory feedback connection strength. In co-dimension one bifurcation analysis we consider these parameters (P and C5 (or J)) in turn and studied the behavior of the model when one varies. We therefore studied the dynamical systems (neural compartments) all parameters, but P or C5 (or J) being kept constant. However in codimension two bifurcations we studied the effect of varying two parameters on the dynamical behaviour of our models (neural compartments). To make the analysis easy we considered P(t) as a constant input P although in reality this input is random. All bifurcation analyses were carried out using MATCONT (matlab continuation software) while time series and phase plane diagrams were generated using the XPPAuto dynamical systems software. Understanding the bifurcation diagram according to these parameters will enable us to know qualitatively the time series pattern that our model generates by varying system's parameters.

3.7 Systems' Simulink Models

In order to incorporate salient experimental observations found in literature in the coupled neuron-astrocyte mass models we introduced six nonlinearites (precisely four sigmoidal functions and two Michaelis Menten functions) in our models. The price we had to pay is to look for alternative means of analyzing the model behaviour as bifurcation study through MATCONT and XPPAuto would takea lot of computational time due to convergence issues. We therefore resorted to brute force analysis by building a simulink model of our systems using MATLAB and exploring the model behaviour carefully in the parameter space. Figures 3.5a & b show the simulink models of our systems. To make our model outputs look like real EEG signals we modeled the input firing rate P(t) as random signal having a constant component and Gaussian noise component. We fix C5 (or J) and varyΥ.

3.8 Parameter Space

In this work, we explored the dynamics of the models as a function of three system parameters which are most relevant for the richness of the dynamics: the extrinsic input, P. the self-excitatory feedback connection strengths, C5 (or J) and the ratio of the maximum coupling gain of astrocytic GABA feedback to the neural compartment to the maximum coupling gain of astrocytic glutamate feedback to the neural compartment, $\Upsilon = \frac{gab_m^{py}}{glu_m^{py}}$. We justify this choice in what follows: Parameters C5 (or J) and Υwere newly introduced by us and thus we would like to know their impacts. Furthermore in the forms described in equations 3.16(a-l) and 3.19(a-k) for our models of GAE and TLE respectively we have 50 system parameters for GAE (29 for the neural compartment and 21 for the astrocyte compartment) and 39 system parameters for TLE (18 for the neural compartment and 21 for the astrocyte compartment). This large dimensionality has rendered any exhaustive analysis prohibitive.

3.9 Dimension Reduction

3.9.1 Neural Compartments Parameters

To reduce the dimensionality of the parameter space we fixed all but three parameters (P, C5 and J) of the neural compartments of our models based on the range of values that were reported in experimental literatures (see appendix).

3.9.2 Astrocyte Compartment

Glutamate and GABA release Parameters: We manually tuned the glutamate and GABA flux parameters into the extracellular space as close as possible to experimental response of an action potential. To scale up from synaptic action potential to population firing rate we only needed to modify the gain coefficient of the glutamate and GABA releases transfer functions.

Glutamate uptake by astrocyte sigmoid parameters: In experimental literatures this is usually represented by Michaelis-Menten curves. To adapt our sigmoid function to the Michaelis-Menten representation we had to manually tune the parameters of the sigmoid to obtain a function whose maximum and slope are as close as possible to those of the Michaelis-Menten curves.

GABA uptake by astrocyte and neuron Michaelis-Menten parameters: We chose the Michaelis-Menten parameter values found in experimental literatures. These values correspond to GAT1 for rats/human in neural case and GAT3 for rats/human in the astrocyte case.

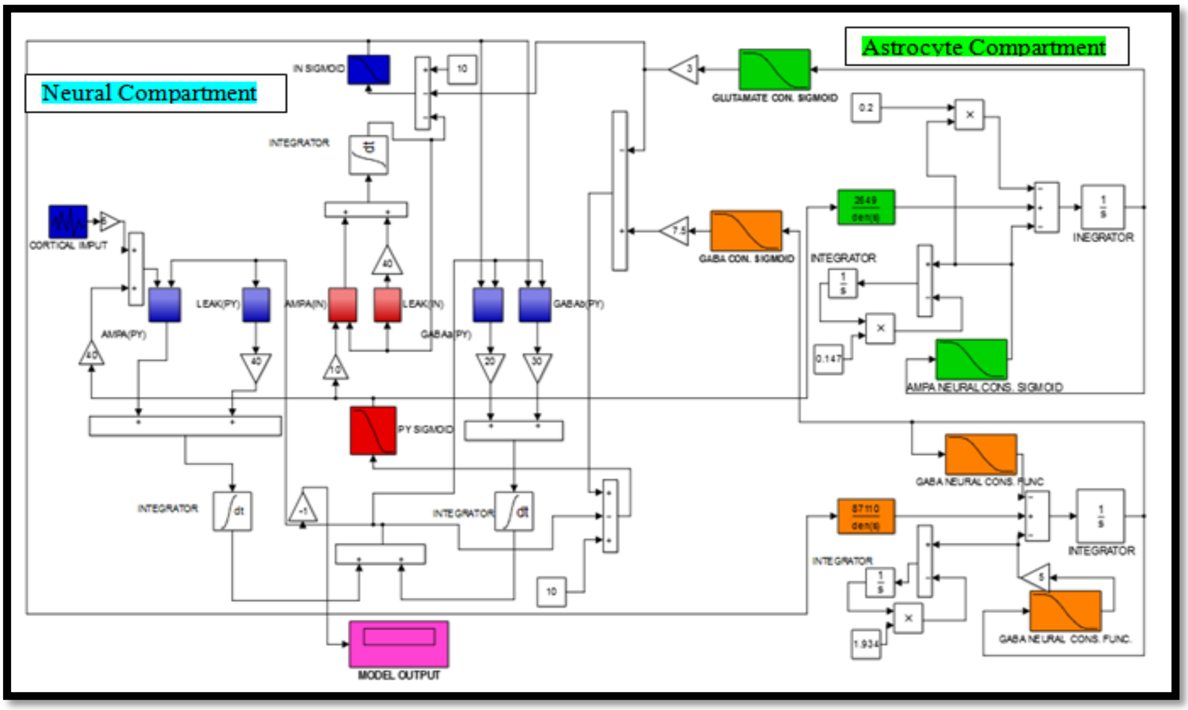


Figure 3.5aSimulink Diagram of our Neuron-Astrocyte Mass Action Model for GAE

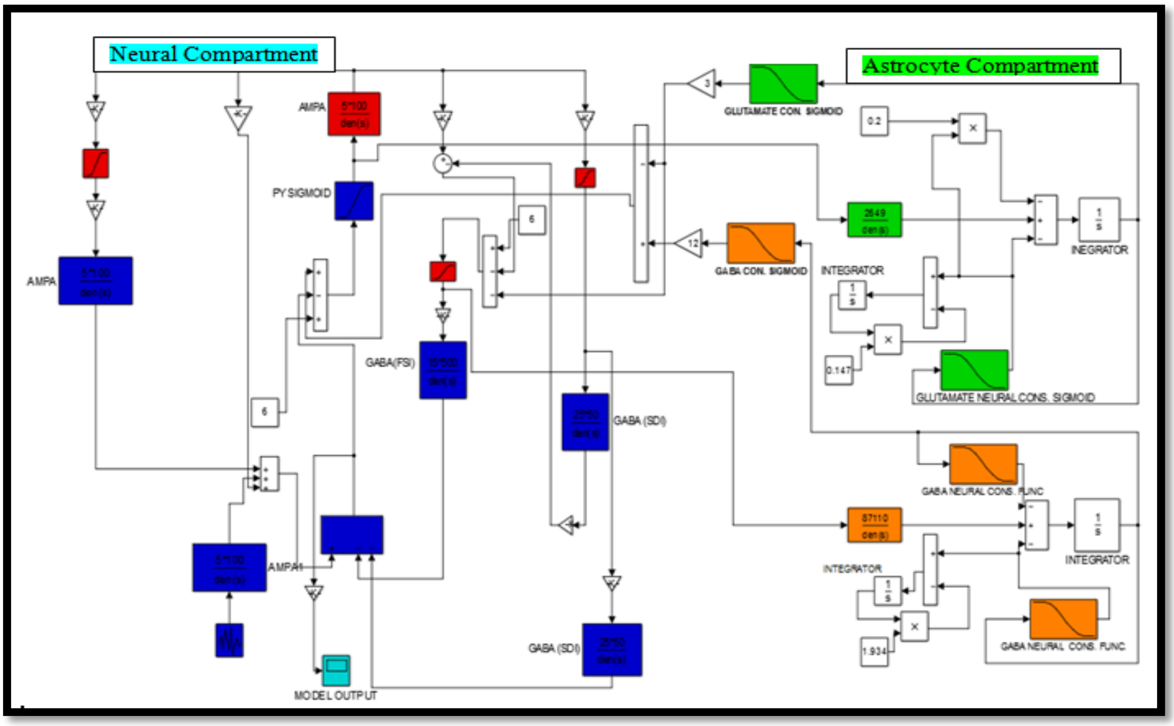


Figure 3.5b Simulink Diagram of our Neuron-Astrocyte Mass Action Model for TLE

DATA RESOURCES AND ANALYSES

4.1 DATA RESOURCES

In this study, database collected at Neuropsychiatric Hospital, Aro, Abeokuta was used for model validation. There are a total of 109 EEG recordings from nineteen epilepsy patients. Seven of these patients suffer from refractory seizures. In the whole database there are just five recordings containing seizure data. This is due to the fact that no recording was done for more than 30 minutes in the hospital and the chance that a patient would have seizure within this short duration is very low. More seizure events can only be obtained with longer duration of recording (days or weeks) which can be achieved through long term admission of patients for continuous EEG recording in the clinic or through wearing of ambulatory EEG devises by the patients. These two options are not yet available in the country.

The EEG recording of patients with refractory seizures was extracted from the database through the help of a neurologist who marked the interictal, pre-seizure, seizure and post seizure activities in the data and also differentiated between the seizure types. Only two of the seizure recordings are useful to us because they are the types studied in this work, GAE and TLE. The other three seizures fall under different types of seizures which are not considered in our work. Data was sampled at 256Hz, referenced using a Laplacian montage and band pass filtered between 0.5Hz and 75Hz. The recordings used the standard 10-20 international 19 channel electrode placement system. Table 3.1 below gives information about patients whose data were used.

Table 3.1 Patients information

S/N	Patient Id	Sex	Age	Seizure Type
1	A00027	Male	41	Focal seizure (Left Temporal lobe)
2	A0002_1	Male	13	Generalized seizure

4.2 STATISTICAL VALIDATION

We validated our models using a signal classification scheme based on evolutionary artificial neural networks. This is an artificial network whose parameters are obtained through Evolutionary algorithms (EA), a stochastic search technique inspired on the theories of evolution and natural selection which can be employed to find an optimal configuration for a given system within specific constraints (Holland, 1975). The classification system was trained to learn the difference between interictal and preictal EEG data of epileptic patients. A comparison of the level of discriminations between preictal and interictal signals from previously unseen real and simulated EEG by the system is a measure of validity of EEG models (Marchena et al., 2012).

A database of simulated EEG signals which are 5 seconds long (TLE)/3 seconds long (GAE) was created. The database contained 90 interictal and 90 preictal signals for each of GAE and TLE models. Segments of equal lengths were also created from the real EEG data from epileptic patients. A total of 204 5-sec long interictal segments and 60 5-sec long preictal segments were obtained for TLE while a total of 300 3-sec long interictal segments and 60 3-sec long preictal segments for GAE. Three characterizing features: mean absolute value (MAV), average value (AV) and curve length (CL) (Fernandez et al., 1996) were extracted from each 5-sec/3-sec long signals. Afterwards we randomly selected training and testing sets from the feature vectors .In the case of the TLE feature vectors from 136 interictal and 40 preictal segments were used to train the EANN while feature vectors from 68 interictal and 20 preictal segments were used for testing the performance of the EANN. For the GAE feature vectors from 100 interictal and 40 preictal segments were used for training while feature vectors from 50 interictal and 20 preictal segments were used for testing. In summary we have 176 x 3 and 88 x 3 training and testing arrays respectively for TLE and 140 x 3 and 70 x 3 training and testing arrays respectively for GAE. We selected the best three individuals with the training set for the discrimination task between previously unseen preictal and interictal signals of real and simulated EEG data.

RESULTS

5.1 Generalized Absence Epilepsy Model (Neural Compartment)

5.1.1 Bifurcation study in $P(t) = P$

The result of bifurcation analysis with $p$as the bifurcation parameter is shown in Figure 5.1. The diagram shows two bifurcation points $p = p_{Hopf1} and\ p_{Hopf2}$. These two bifurcations are called the Andronov Hopf. Since the fist Lypanuv exponent of the normal form in each case is negative the two bifurcation points are of the supercritical Andronov Hopf bifurcation.

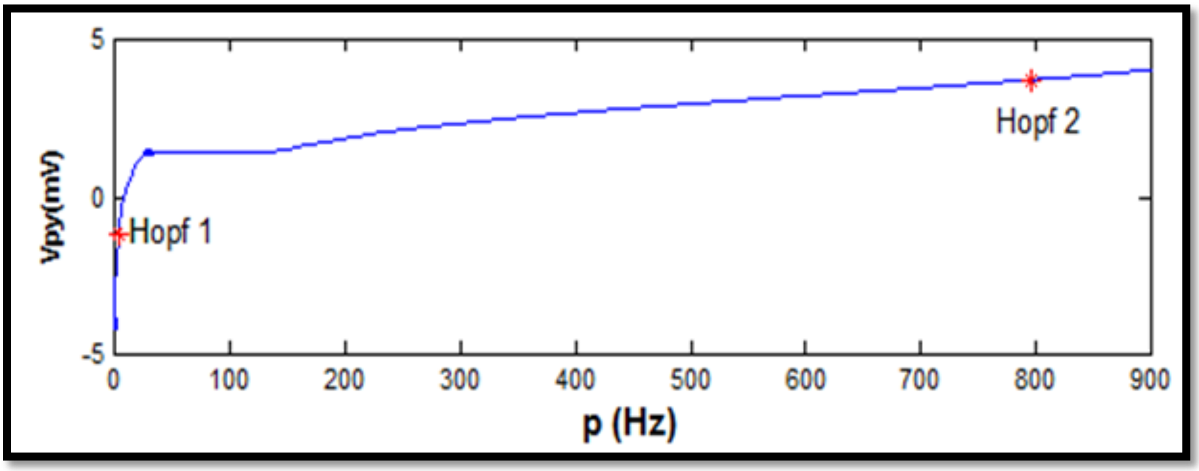
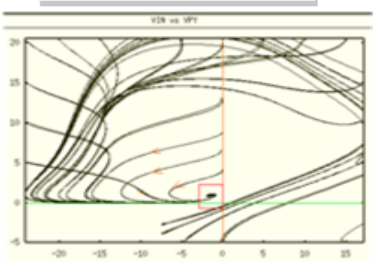


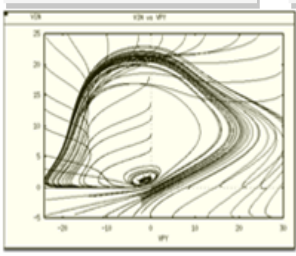
Figure 5.1 Solution (bifurcation) diagram of the GAE model (Neural compartment)

For values of $p < p_{Hopf1}$, the model admits unique singular points (i.e. equilibrium solutions). Local linear analyses of these points show that eigenvalues of the Jacobian matrixes are complex conjugates meaning that the singular points are of the foci type. In the phase plane of the system we refer to these singular points as stable point attractors (i.e. eigenvalues of the Jacobian matrix at these points have negative real parts). At $p = p_{Hopf1}$bifurcation occurs (one or more negative real parts of the eigenvalues have become zero) and the system is on the verge of changing behaviour. For values of $p > p_{Hopf1}$the foci lose their stability (one or more negative real parts of the eigenvalues have become positive values).

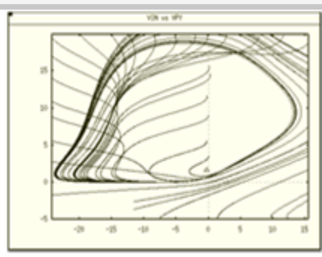
A.P < PHopf1



B. P = PHopf1



C. PHopf1<P <PHopf2



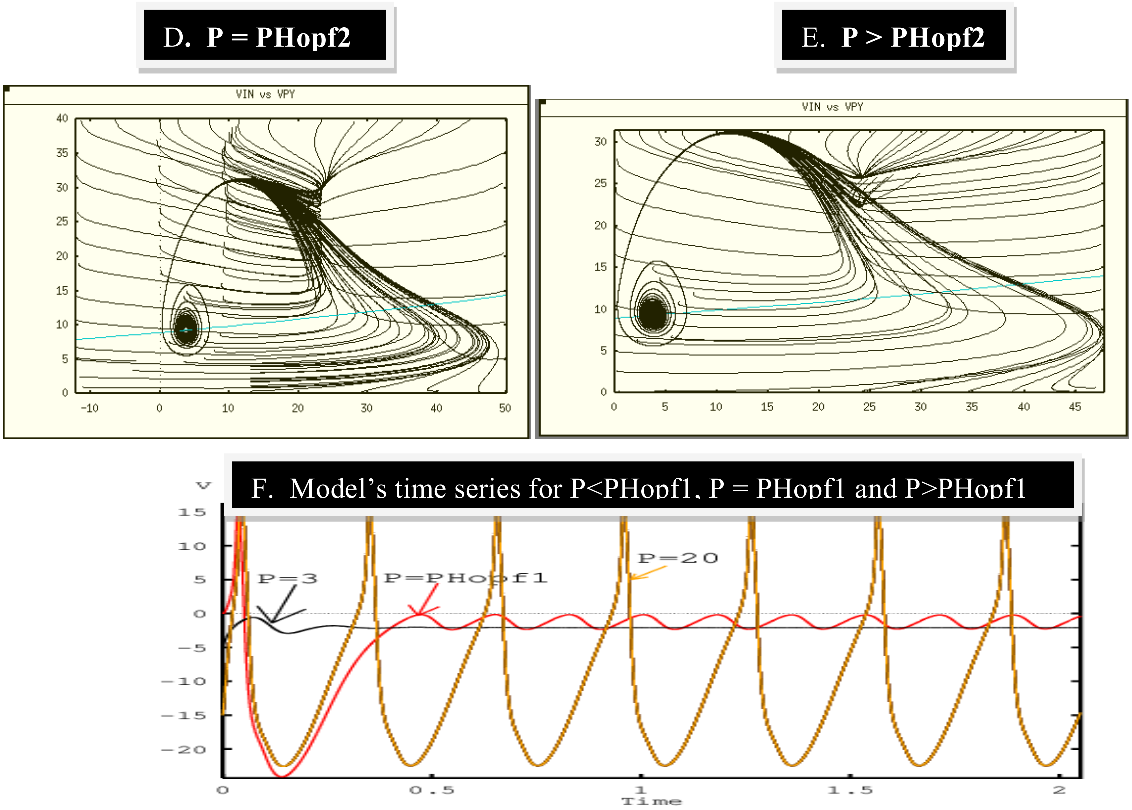


Figure 5.2. Phase space structures (A-E) and time series pattern comparison (F) for different parameter, p values

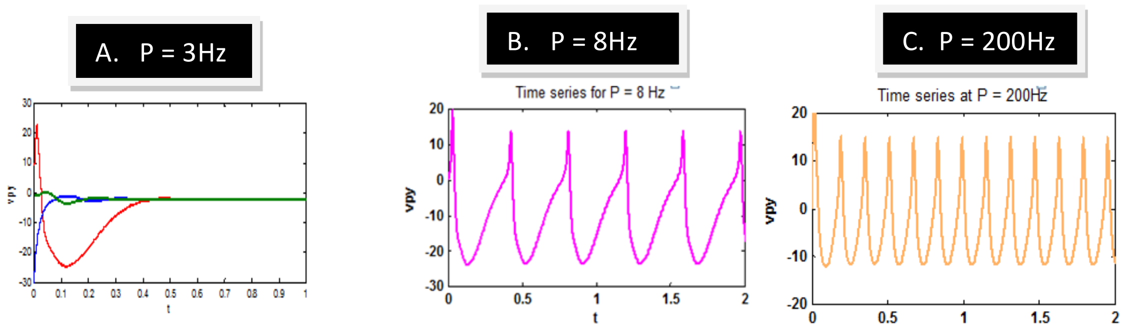


Figure 5.3 (A-C). Time series showing different model behaviours at different parameter values

through the supercritical Andronov Hopf bifurcation and the system admits periodic solutions (stable limit cycles in the phase space). This continues until $p = p_{Hopf2}$ where the system undergoes another supercritical Andronov Hopf bifurcation giving rise to stable singular points again. In summary, for $p < p_{Hopf1}$ *and* $p > p_{Hopf2}$ the system produces unique stable solutions so that starting from any initial conditions the trajectory of the system will always approach a particular point in the phase plane. The time series corresponding to this type of behaviour is shown in Figure 5.3A and are called equilibrium solutions. It can be seen that starting from different initial values of the pyramidal cells population average membrane potential (bifurcation variable) the system always approach a unique value after the transients have died out. For $p_{Hopf1} < p < p_{Hopf2}$ the system produces limit cycles in the phase plane so that starting from any initial condition on the phase plane the trajectory always form circles about a point but do not converge to the point. The time series corresponding to this type of behaviour is shown in Figure 5.3 B & C and are called periodic solutions. The amplitude and frequency are modulated by the magnitude of the input p.

5.1.2 Bifurcations study in $C5$

Theresult of bifurcation study in $C5$ is shown in Figure 5.4. The diagram shows three types of bifurcations, Andronov Hopf (Hopf), Neutral Saddle (NS) and saddle-node (SN) bifurcations. For $0 < C5 < C5_{Hoph}$, we have unique stable singular points (monostability) in the phase plane. For the very narrow parameter range $C5_{Hopf} < C5 < C5_{NS*}$ the system exhibits periodic solutions. At $C5_{NS*} < C5 < SN$we have series of neutral saddle bifurcations where the system limit cycles give rise to saddles. At $C5 = C5_{SN*}$,$C5_{SN}$ there are saddle-node bifurcations.The upper branch of these points represents the node while the lower represents the saddle. In the parameter range $C5_{SN*} < C5 < C5_{SN}$the system exhibit a phenomenon known ashysteresis or bistability where twostable singular points (the nodes) and unstable singular points (saddle) appear on the phase plane, depending on initial condition the system trajectories can approach any of these stable singular points. Finally for the parameter values $C5 > C5_{SN}$ the system returns to monostability. Figure 4.5 shows system's time series corresponding to each parameter range.

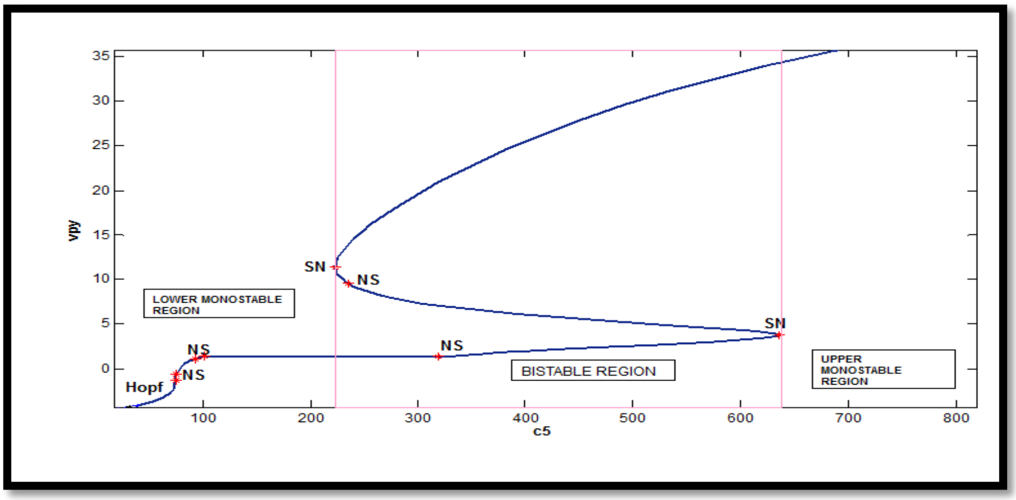


Figure 5.4. Solution (bifurcation) diagram of the GAE model (Neural compartment) with C5 as the Bifurcation parameter and mean membrane potential of pyramidal cells as the bifurcation variable

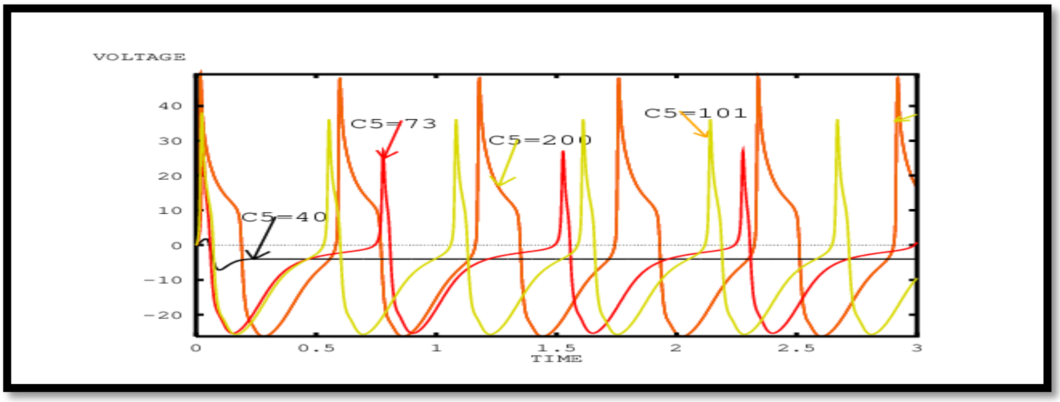


Figure 5.5

Time series depicting different behaviours found in the neural compartment of the GAE model.

5.1.3 Codimension Two Bifurcations Study in C5, P Space

The result of codimension two bifurcations study in P and C5 is shown in Figure 5.6. The blue curve is codimension 1 bifurcation diagram while the red points are codimension two bifurcation points. At (C5, P) = (179.254809, 767.431354) and (174.414926, 777.838118) spurious zero Hopf (ZH) bifurcations are detected and there is a cusp bifurcation at (C5, P) = (68.937527, 1049.305581). In the C5, P parameter space the bistability detected in codimension 1 bifurcation of the system is delimited by a wedge of limit point bifurcations which occurs at the cusp point. At (C5, P) = (78.974981, 1049.305581) the Bogdanov takens bifurcation occurs where a stable equilibrium point undergoes saddle node and Andronov Hopf bifurcations simultaneously.

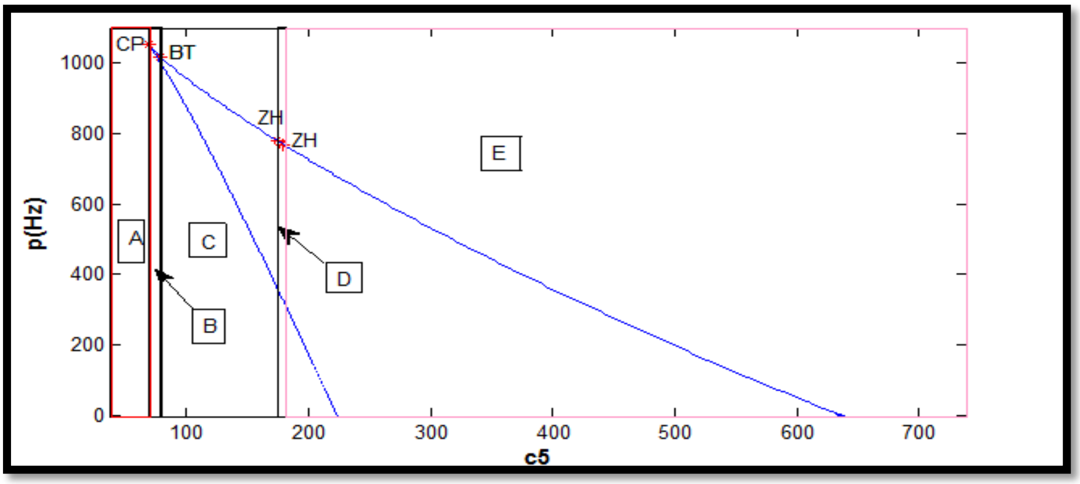


Figure 5.6 Solution (bifurcation) diagram of the neural compartment of the GAE model in the two parameter (P and C5) space

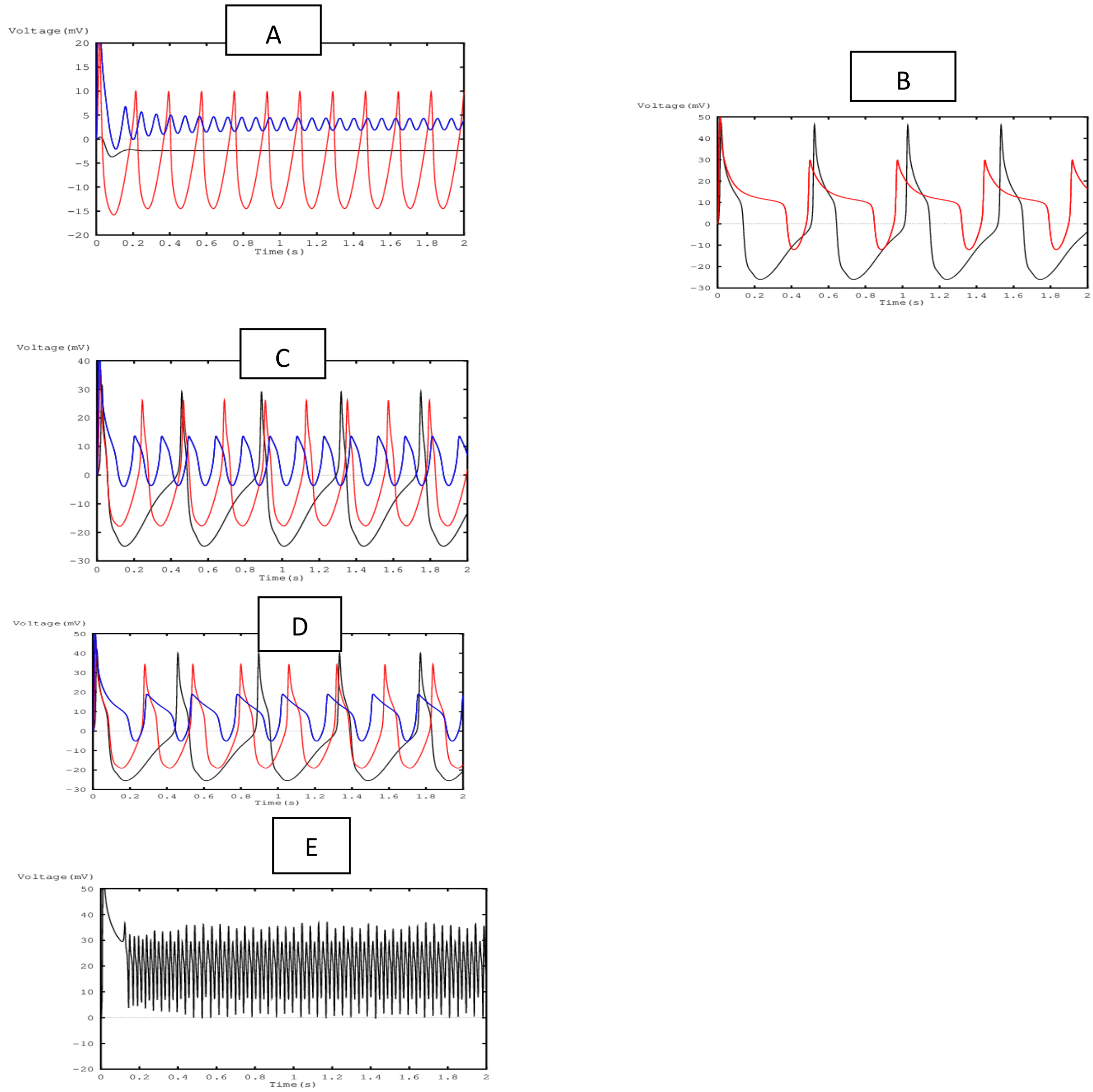


Fig. 5.7 A-C. Time series resulting from partitioning of the C5, P space through codimension 2 Bifurcation analysis

The codimension two bifurcation analyses allow us to recognize and partition the relevant regions of the P, C5 parameter space. In Figure 5.3 we partition the P, C5 space into five (5) regions A - E along C5 real line and study the model behaviour in each column. Figure 5.7 gives the predominant activities found in each of the regions.

5.2 Temporal Lobe Epilepsy Model (Neural Compartment)

5.2.1 Bifurcations

The bifurcation diagrams of the neural compartment of our TLE model are shown in Figures 5.8 (A and B). Saddle-node and Hopf bifurcations are the main types found. The SN2 found in both diagrams occur at negative values of the parameters. This is spurious as by nature these parameters can only take positive values. We show in Figure 4.8C time series pattern obtainable from our model.

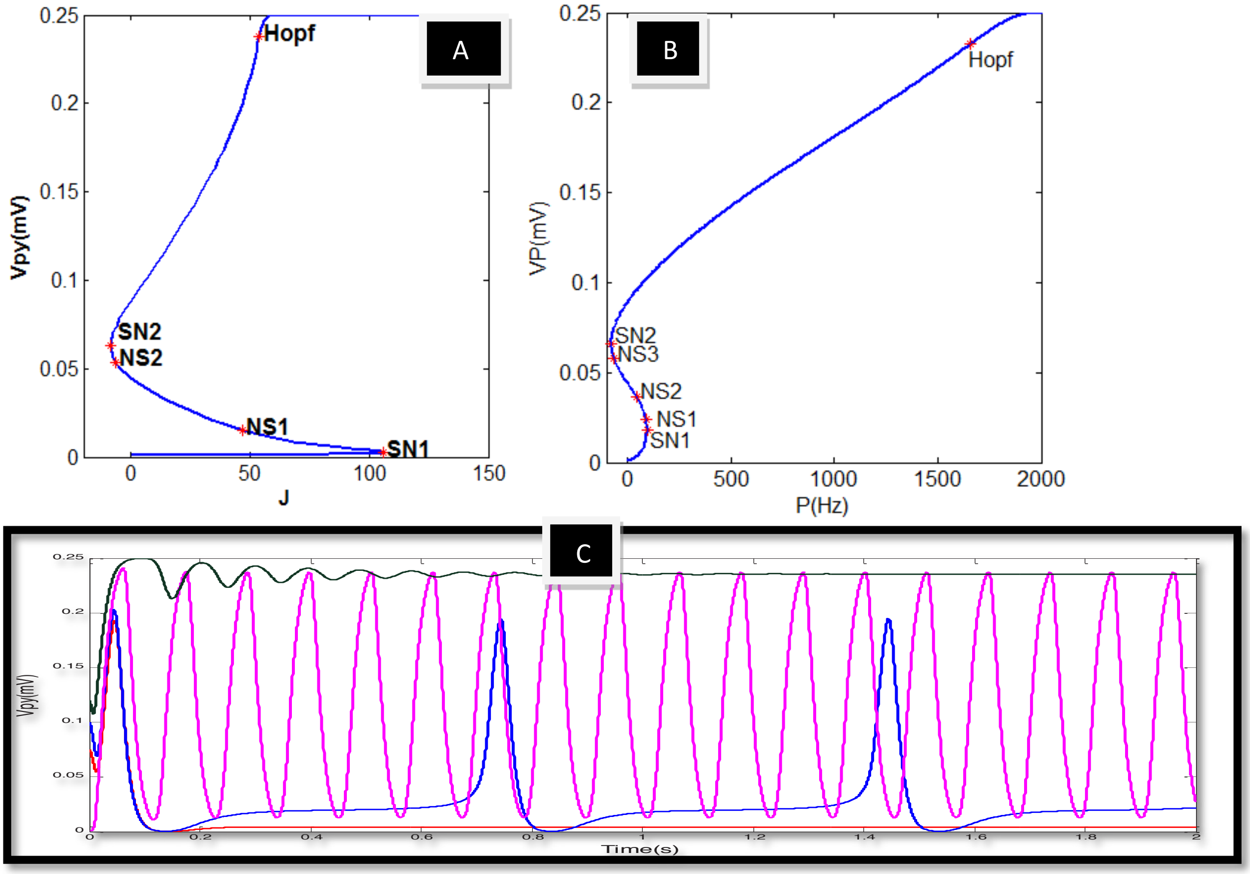


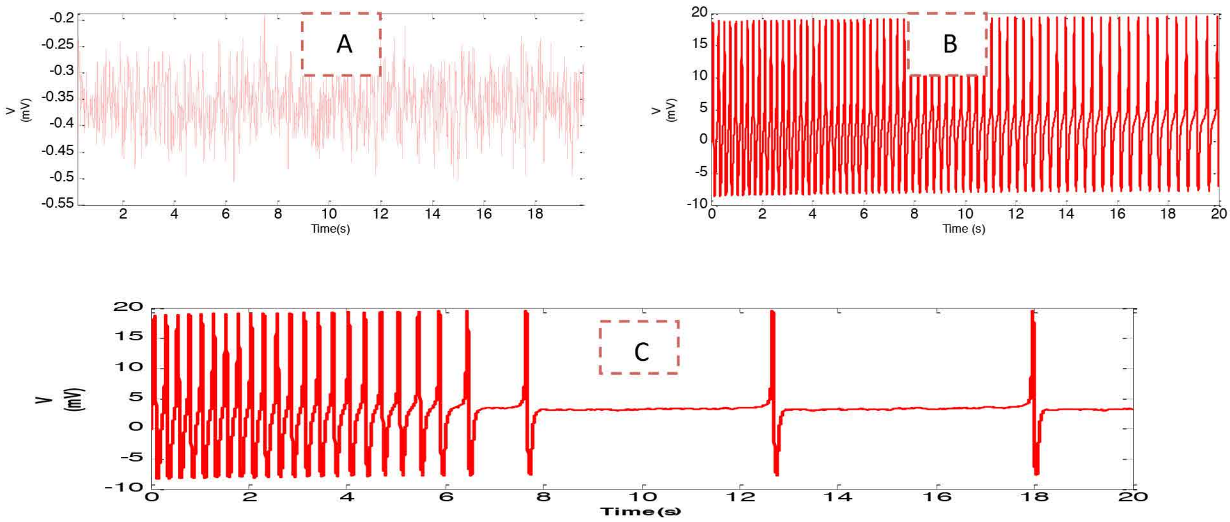
Fig. 5.8: Solution (bifurcation) diagram of TLE model with (A) P as bifurcation parameter (B) J as bifurcation parameter (C) Comparison of time series corresponding to different parameter P values.

5.3 Neuron – Astrocyte Mass Action Models:

5.3.1 Simulation of TLE EEG signals

Figure 5.9 shows different time series patterns that can be generated by the coupled neuron-astrocyte mass model for hippocampus activity. For the simulations we set the mean value of the firing density P(t) = P = 90Hz and the variance equal 30 making the input vary between 60Hz and 120Hz. To obtain each result we fix parameters Ge, Gis and Gif and vary the ratio of the maximum coupling gains of astrocytic GABA feedback to the neural compartment to astrocytic glutamate feedback to the neural compartment, $\Upsilon = \frac{gab_m^{py}}{glu_m^{py}}$. The time series in Panel A can be described as a noisy perturbation around equilibriumbecause in the absence of noise the system goes to equilibrium. The values of

(Ge, Gis, Gif) used are (5, 50, 15). This activity persists for all values of Υ considered. The time series in panel B can be described as sustained spike wave discharges (SWD) an activity which represents an irregular oscillatory behaviour around an unstable fixed point. This activity was obtained using (Ge,Gis,Gif,Υ)=(5,40,15,1.7).The time series in panel C shows spontaneous transition from sustained spiking activity to an isolated spiking behavior. The activity was obtained by setting (Ge,Gis,Gif,Υ)=(5,25,15,4).The nature of the spike wave discharge and isolated spikes are shown boldly in panel D and E respectively. In panel F we observe two consecutive transitions, first from a long duration, slow quasi sinusoidal activity to short duration SWDs activity. Second, is from SWDs activity to isolated spiking behaviour. This transitory behaviour persists for the range $1.3 \leq \Upsilon \leq 3$. For $\Upsilon < 1.3$, the only activity seen is slow quasi sinusoidal while values of $\Upsilon > 3$ evoked transition from SWDs to a noisy equilibrium activity and not isolated spiking. We set (Ge, Gis, Ges) = (5, 15, 0) to obtain the result. Panel G shows clearly these transitions. An activity called poly spike wave discharges was observed in panel H. We set (Ge, Gis, Ges, Υ) = (7, 25, 150, 2.3) to obtain the result. $\Upsilon < 2.3$ gives increased frequency of this behaviour while $\Upsilon > 2.3$ causes poly spike wave discharges and noisy equilibrium activity to coexist at moderate values. For larger ratio values the poly spike wave activity disappears and only equilibrium activity remains.



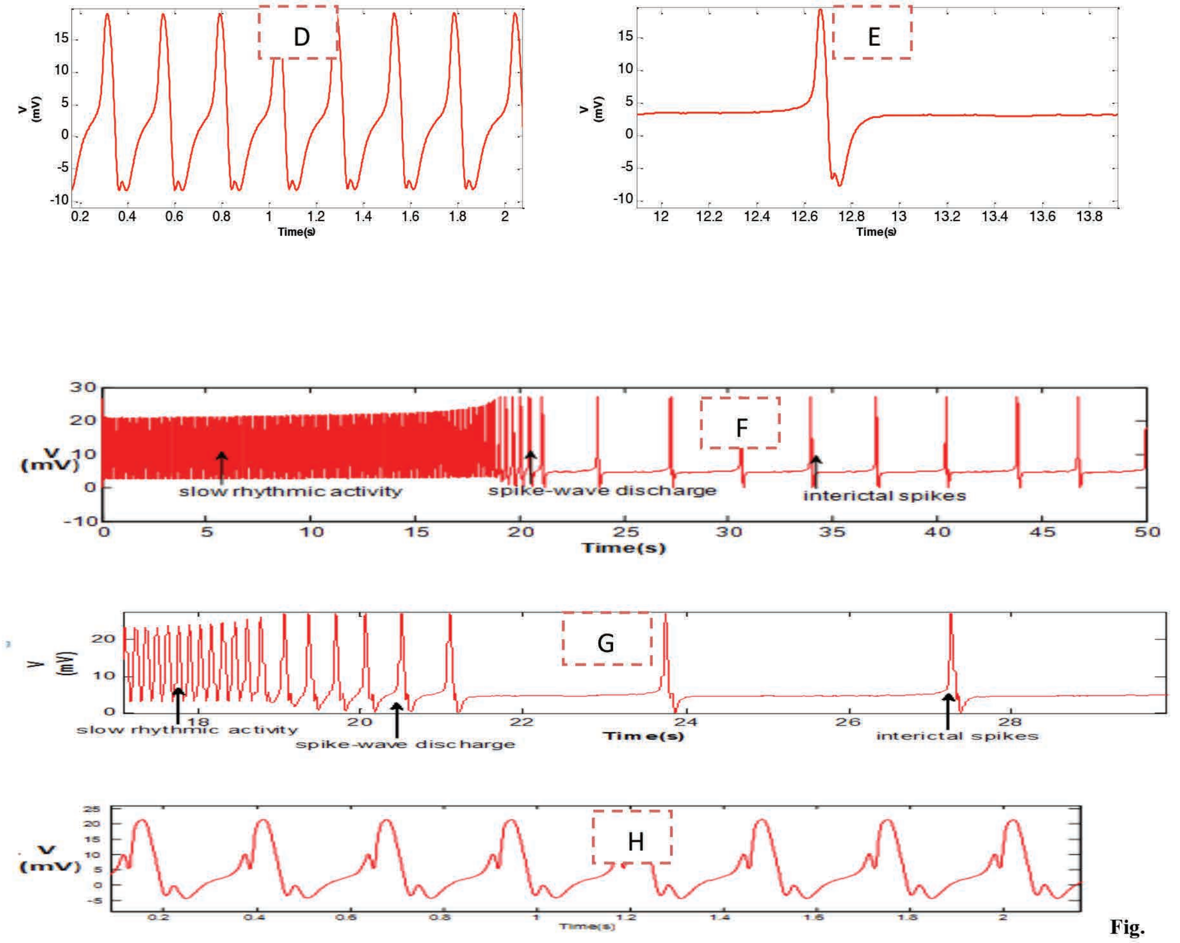


Fig. 5.9 Different time series patterns that can be generated by coupled neuron-astrocyte mass model for hippocampus activitie

5.3.2 Simulation of GAE EEG signals

Figure 5.10 shows different time series patterns that can be generated by the coupled neuron-astrocyte mass model for the activities in the cortical columns. For the simulations we set the mean value of the firing density P(t) = P = 13Hz and the variance equal 3 making the input vary between 10Hz and 16Hz. We vary Υ and obtain the various activities shown. Time series in panel I was obtain for $\Upsilon > 2.4$. It is an equilibrium activity masked in background noise. The activity displayed in panel J shows a waxing and waning pattern. This activity exists in the parameter range$2.3 < \Upsilon \leq 2.4$. In the parameter range $2.3 < \Upsilon \leq 2.35$ there is a waxing and waning pattern with sporadic spikes occurring at intervals. This activity is shown in panel K. The last activity shown in panel L is a form of spike wave discharges (SWDs). The pattern was obtained for $\Upsilon < 2.3$

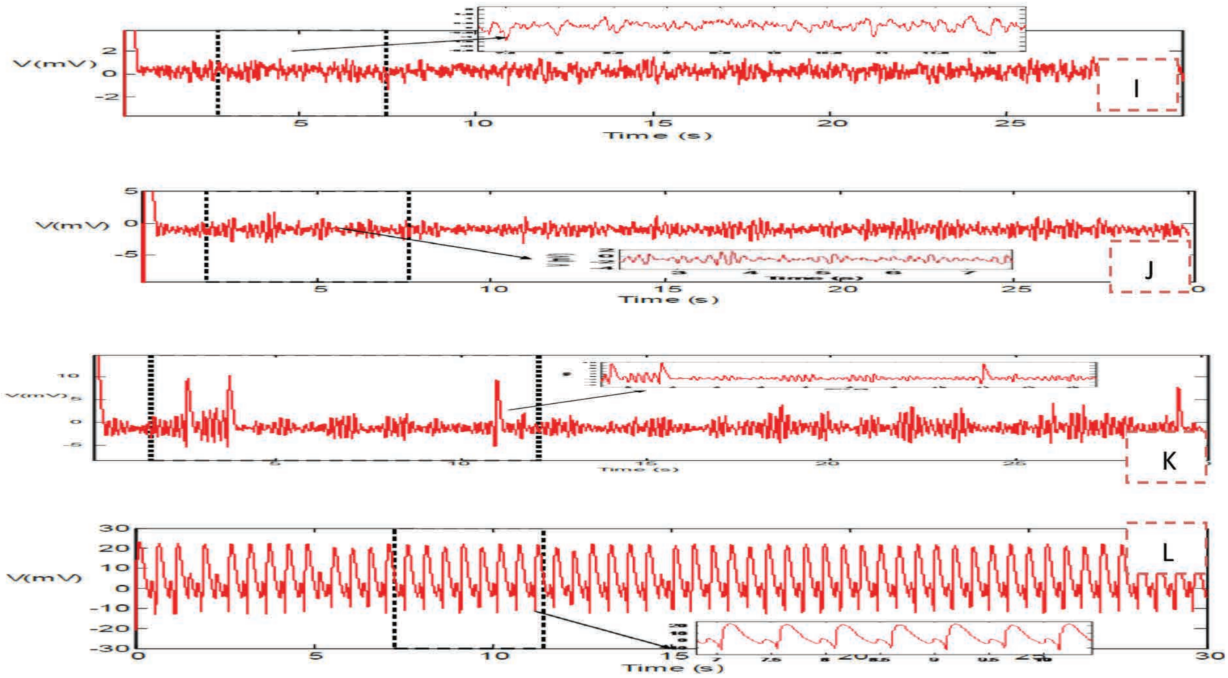


Fig5.10 Different time series patterns that can be generated by coupled neuron-astrocyte mass model for cortical column activities

5.4 Model of electrographic transition from normal to epileptic activity

From clinical observations it has been confirmed that spike wave discharges and low frequency high amplitude discharges are the electrographic correlates of the GAE and TLE respectively. While it has been widely observed that the TLE low frequency high amplitude oscillations are always preceded by preictal spikes and low voltage rapid activity the GAE spike wave discharges are only preceded by normal ongoing EEG activity hence showing no electrographic seizure precursors.

We simulate this possible seizure dynamics based on the above widely observed phenomenon in clinical observations. With guidance from our earlier results we varied parameters P and ϒ while parameter J was left constant for simplicity. Indeed we are able to simulate EEG signals for GAE and TLE making transitions from normal (interictal) activity through epileptic (ictal) activity and back to normal activity. Our simulated seizure onset dynamics for GAE and TLE are shown respectively in Figures 5.11C & D respectively with their observed counterparts in Figures 4.11A & B. The corresponding activity type – parameter maps are displayed in Figures 5.11E & F respectively.

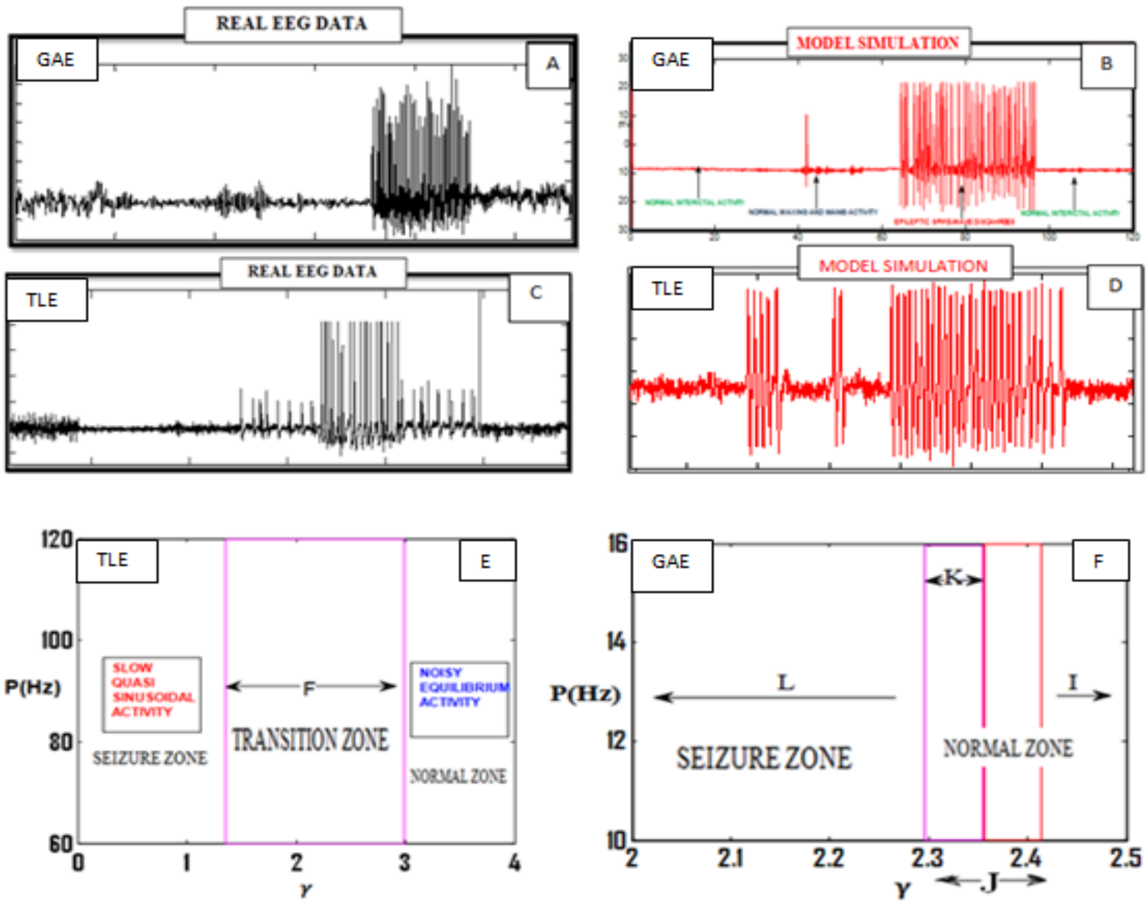


Fig. 5.11 (A&B) Real transitions (C&D) Simulated transitions (E&F) Activity type – parameter maps

5.5 Statistical Validation

Evolutional Algorithm is stochastic in nature therefore several trainingswith different numbers of neurons in the hidden layer (N) of the EANN were performed. A total of 40 trainings were conducted using the three features. The best individuals of the 40 trainings were stored (interconnection weights of the EANN) to be evaluated with the testing sets of real and simulated signals. Trainings were divided as follows: 20 with 1 neuron in the hidden layer and 10 trainings with 2, and 3 neurons in the hidden layer to complete the 40 trainings.

Specificity (S_P), Sensitivity (S_e) and Accuracy (AC) are three commonly used statistical parameters for the evaluation of a classification system. These statistics measure the classification accuracy and relationship between positive and negative classes. Out of the 40trainings (individuals) the best three individuals based on the statistics described above were selected to perform the classification of the testing sets. Table 5.1 shows the results obtained for the best three individuals in the trainings. The classification results for the simulated and real signals are shown in Figures 5.2 for TLE and 5.3 for GAE respectively. We assess the validity of our models through classification accuracy of the three best individuals with the previously unseen observed (real) EEG and the simulated EEG. We notice from Table 5.2 for TLE model that the accuracies of the three individuals on the observed and simulated EEG are very close. Individual 1 particularly has the minimum absolute difference of 0.0084 while individual 3 has the maximum absolute difference of 0.0555. This close accuracy values can be explained by the level of similarity between the observed interictal and preictal EEG patterns and their simulated counterparts. The same trend is noticed from Table 5.3 for the GAE model where the minimum absolute difference in accuracy value of 0.0031 occurred in individual 2 while the maximum absolute difference occurred in individual 1 with a value of 0.023.

For further conviction about the validity of our models we subjected to statistical test the seemingly very close accuracy results obtained for the classification result shown in Tables 5.2 and 5.3. We desired to test at 95% confidence level the null hypothesis: there is no difference in the mean accuracy results obtained for the classification of interictal and preictal epochs of observed and simulated EEG data. This resulted in a two tailed test and if we fail to reject this null hypothesis we conclude that our models are valid.

	Individuals	N	t_p	f_p	t_n	f_n	S_P	S_e	AC
GAE	1	1	39	2	98	1	0.9800	0.9750	0.9785
	2	1	36	5	95	4	0.9500	0.9000	0.9357
	3	2	34	6	94	6	0.9400	0.8500	0.9143
TLE	1	1	38	5	131	2	0.9630	0.9500	0.9602
	2	2	36	7	129	4	0.9485	0.9000	0.9375
	3	1	35	11	125	5	0.9191	0.8750	0.9090

Table 5.1 Result of three best individuals with the training set. N(number of neurons in the hidden layer), t_p(true positives), f_p(false positives), t_n(true negatives), f_n(false negatives), S_P(Specificity), S_e(Sensitivity),

TLE	Individuals	N	t_p	f_p	t_n	f_n	S_P	S_e	AC
REAL EEG (TESTING SET)	1	1	18	0	60	2	1.0000	0.9000	0.9750
	2	2	18	4	56	2	0.9333	0.9000	0.9250
	3	1	15	7	53	5	0.8833	0.7500	0.8500
SIMULATED EEG	1	1	85	1	89	5	0.9888	0.9444	0.9666
	2	2	87	4	86	3	0.9555	0.9666	0.9611
	3	1	83	10	80	7	0.8888	0.9222	0.9055

Table 4.2Result of three best individuals with the real and simulated EEG data for TLE

GAE	Individuals	N	t_p	f_p	t_n	f_n	S_P	S_e	AC
REAL EEG (TESTING SET)	1	1	17	6	44	3	0.8800	0.8500	0.8714
	2	1	17	3	47	3	0.9400	0.8500	0.9142
	3	2	15	2	48	5	0.9600	0.7500	0.9000
SIMULATED EEG	1	1	80	9	81	10	0.9000	0.8888	0.8944
	2	1	81	7	83	9	0.0922	0.9000	0.9111
	3	2	80	11	79	10	0.8777	0.8888	0.8944

Table 5.3 Result of three best individuals with the real and simulated EEG data for GAE

The same procedure was adopted for GAE and TLE models. To proceed we assumed normal distribution for our random variables that is classification accuracy values of both real and simulated EEG data by the best performing individuals (1 for TLE and 2 for GAE). We then drew samples of size $n = 35$from the two populations by classifying an ensemble of randomly selected interictal and preictal feature vectors of real (testing) and simulated EEG signals. We calculated the means and standard deviations of the two samples. The test statistic $z\ scores$ obtained for TLE and GAE resulted in $p - values 0.072$ and 0.106 respectively. Since these values are larger than the test significance level $(\alpha = 0.05)$ we fail to reject the null hypothesis and conclude that our models are valid.

DISCUSSION

In this study we present two novel physiologically based mass action models mimicking EEG activities of cortical columns and hippocampus which are believed to be the sites eliciting GAE and TLE respectively in the human brain. We incorporated the activities of the astrocyte compartment into those of the nerve cells and studied the effect of astrocyte cells feedback on the activities of the neural compartment.

Initial study of the neural compartments of our models through bifurcation analysis showed interesting dynamical properties which can be correlated to existing clinical observations of human EEG signals. Although bifurcation analysis of our combined Neuron-Atrocyte models proved difficult we were able to build block models of our systems using simulink/Matlab software. We discovered that the astrocyte compartment has a strong effect on the dynamics of the neural compartment through its feedback. Varying the value (even slightly) of the parameter Υ which represents the ratio of the maximum coupling gains of astrocytic GABA feedback to the neural compartment to astrocytic glutamate feedback to the neural compartment produces drastic changes in the dynamics of the neural compartment in both models. This result has gone a long way in confirming various experimental observations indicting astrocyte cells as key players in the perceived neural activities through EEG signals.

To obtain results similar to real EEG signals we allowed random component in the extrinsic input into the models. Indeed we are able to simulate through the models normal and abnormal (epileptic) EEG signals

6.1 Bifurcations and Electroencephalogram (EEG) Signals

Electroencephalogram (EEG) signals are characterized by different phenomena which can be related to mathematical objects such as found in bifurcation analysis of the GAE and TLE mass action models. The existence of stable fixed points can be linked to a normal EEG signals exhibited by both non-epileptic individuals and epileptic patients while the existence of limit cycles regardless of the frequency band may be correlated with oscillatory EEG activity whether normal (waxing and waning) or abnormal (epileptic spike wave discharges in GAE and low frequency, high amplitude oscillations in TLE). Fast EEG activity can be either related to the existence of a family of limit cycles having a high frequency, or to the destabilization through noise of a stable equilibrium whose Jacobian matrix has complex eigenvalues. We may say epileptic low frequency oscillations can be related to the existence of homoclinic orbits which are for instance caused by the presence of a Bogdanov-Takensbi furcation.

The existence of multistability in the models makes transitions from one EEG pattern to another possible. But these transitions seem not to happen under a noise free condition. Indeed we observe in our simulations that constant bifurcation parameters' values produced only one qualitative EEG signal pattern such as seen in Figures 4.7(A-C) and 4.8C. Transitions from one EEG pattern to another are however observed after the introduction of noise components in the bifurcation parameters' value e.g. Figures 4.9C, 4.9F and 4.10K.

These transitions can then be explained as random perturbation of some stable equilibrium points which may cause interictal and/or preictal spikes. These perturbations may also lead to the destabilization of the stable equilibrium points which may, depending on how close the initial condition is to the epileptic basin of attraction on the phase plane lead to epileptic activities.

6.2 Comparison of our neuron-astrocyte mass models with earlier neural mass models of transition from normal to epileptic EEG activities for GAE and TLE

Hitherto computational modeling of transition from normal to epileptic activities has been carried out with all attention given to neural masses. No attention was paid to the astrocytes cells. In this work we have successfully shown through computational modeling that activities of the astrocyte mass play significant role in regulating the dynamics of neural mass. More specifically imbalance in the concentration of major neurotransmitters within the astrocytes domain can lead to transition from normal to epileptic neural activity. In the earlier transition models parameters directly related to neural masses were varied specifically, extrinsic input , connection strength parameter c or j , maximum excitatory/inhibitory neural mass gain and time constants have been varied in contrast to the astrocyte cells activity related parameter γ that we varied. This of course has far reaching significances for the epilepsy research community for instance pharmacist can begin to focus on both neurons and astrocyte cells but not only neurons as target sites for new antiepileptic drugs.

In Figure 6.1,we present outputs of transition models obtained from earlier studies through neural mass models and those obtained from our neuron-astrocyte mass models. Comparison of the outputs of the two modeling approaches reveals striking similarities in the transition caused through varying parameters relating to neural masses and that of astrocyte cells.

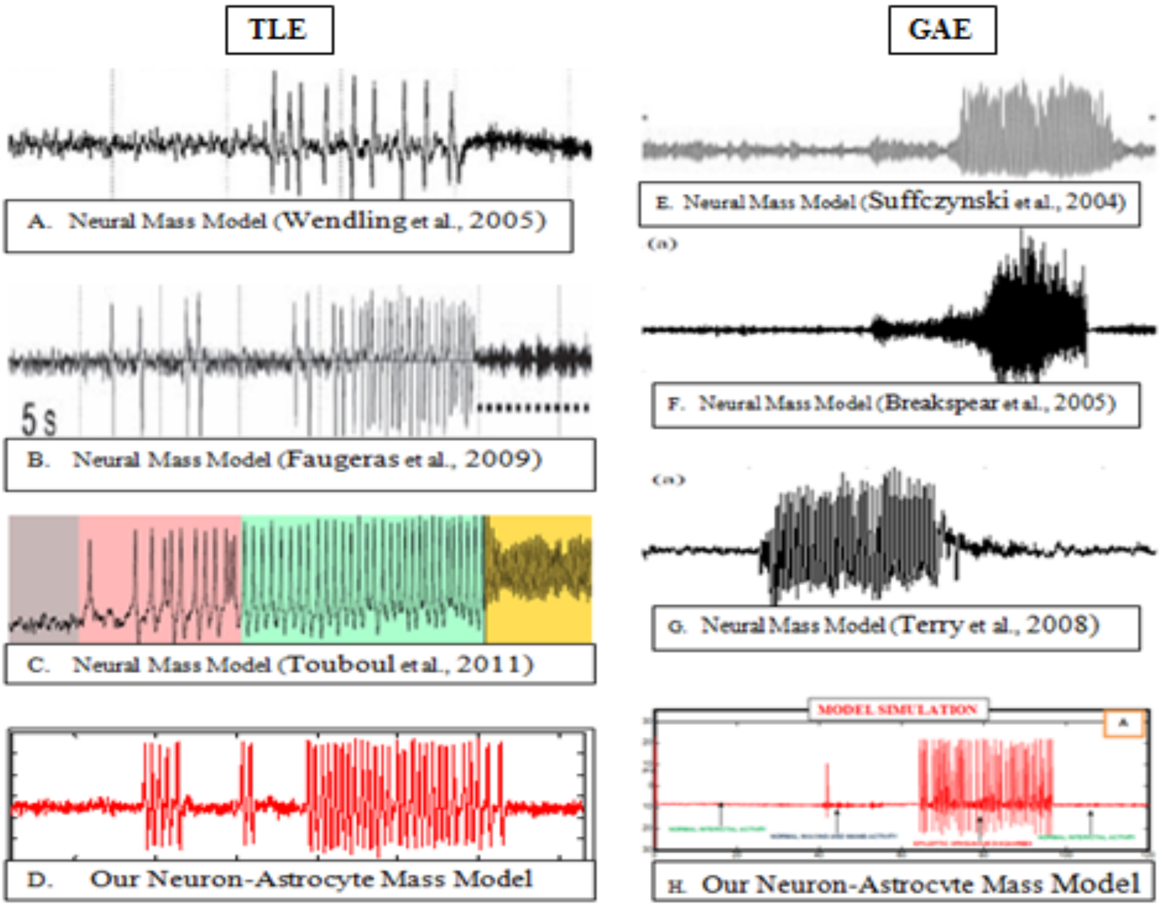


Fig. 6.1 Comparison between outputs of earlier neural mass models (A, B, C: E, F, G) and our neuron-astrocyte mass models (D & H)

5.3 Activity Maps

We present in Figures 5.11(E & F) activity maps obtained from parameter sensitivity study of our neuron – astrocyte mass models (TLE & GAE respectively). The regions associated with normal and epileptic activities are clearly labeled in the **P**, $\boldsymbol{\gamma}$ plane for given constant parameter (**j** or **c5)**. There is a transitory region associated with the TLE model a phenomenon obviously missing in the GAE. This vital observation might be pointing to the fact that TLE events are easily detectable or predictable while GAE might not be.

Activity maps showing regions in parameter plane associated with normal and epileptic activities have earlier been obtained for some neural mass models earlier proposed. Modelers however exploited parameters directly related to activities of neural masses. For instance Wendling and Chauvel, 2005 obtained from parameter sensitivity study of their neural mass model of transition from normal to abnormal EEG activity for TLE an activity map in the SDI (maximum slow dendritic inhibition), FSI (maximum fast somatic inhibition) plane for a constant parameter EXC (maximum excitation). The activity map is shown in Figure 5.13 below. Regions having blue colour represent normal EEG activities while regions where epileptic activities reside are marked with white colour. Transition zones are marked with the other colours.

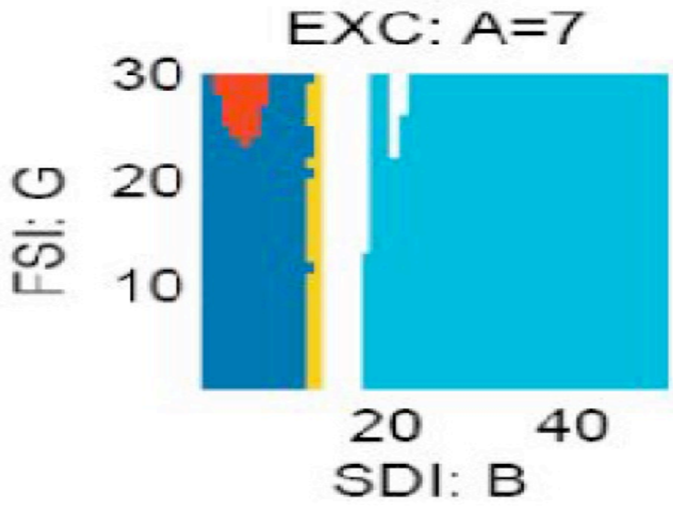


Fig 5.13 Activity map in the FSI, SDI plane for TLE (Wemdling et al., 2005)

CONCLUSION

In this work we have applied methods from dynamical systems modeling to study epilepsy – a dynamical disease of the brain whose hallmark is recurrent seizures. We developed physiologically based mathematical models of sections of the brain believed to be eliciting the abnormal signals observed during these seizures. Tools from dynamical systems theory were deployed to characterize different types of activities in the models.

We were able to produce normal and epileptic activities by slowly varying certain model parameters. We were also able to obtain activity-type parameter maps for the GAE and TLE models in the P, Υ parameter space. The basic conclusion from our findings is that the dynamics of epilepsy can be critically dependent on small variations in few system parameters or on the balance between a small numbers of system parameters.

Finally, we wish to stress that in this paper we are more interested in obtaining qualitative rather than quantitative information about our models' behaviour. That is, we are more interested in finding out how varying a parameter value affects the modes of behavior of a model, rather than finding the exact parameter values at which these changes occur. We note that qualitative insights are at a much greater depth than quantitative results because of the uncertainty associated with parameter values in nature and because models are necessarily simplifications of reality, the exact quantitative predictions of a model have little significance. It is the type or mode of behavior that is most important. Qualitative analyses are concerned mainly with long–term rather than transient behavior. Transient dynamics vary with the initial values of variables and the time period over which solutions are calculated, whereas qualitative studies deal with the eventual behavior of the system once the initial transients have died away.

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APPENDIX

Parameter values used for GAE & TLE models

Neural Compartments

GAE model

Parameter	Description	Reference value	Source
C_m^{py}, C_m^{IN}	Membrane capacitance of PY and IN cells	$1\ \mu F/cm^2$	Wang et al 1991
g_{leak}	Leak current conductance	$0.04\ mS/cm^2$	Wang et al 1991, Golomb et al. 1996
$E_{leak}^{py} E_{leak}^{IN}$	Reversal potential of leak current	Py = 0mV, IN = 0mV	Bal et at 1995a and b
G_{AMPA},$t_{r,AMPA}$ $t_{d,AMPA}$. E_{AMPA}	Amplitude, rise and decay times of AMPA Conductance. Reversal potential of AMPA postsynaptic current	$0.1 mS/cm^2$, 0.0004s ,$0.01s$, , $0mV$	Wang et al 1991
G_{GABAa},$t_{r,GABAa}$ $t_{d,GABAa}$. E_{GABAa}	Amplitude, rise and decay times of GABAa Conductance. Reversal potential of GABAa postsynaptic current	$0.1 mS/cm^2$, 0.0004s, $0.012s$, -$15mV$	Wang et al 1991
G_{GABAb},$t_{r,GABAb}$ $t_{d,GABAb}$. E_{GABAb}	Amplitude, rise and decay times of GABAb Conductance. Reversal potential of GABAb postsynaptic current	$0.0125 mS/cm^2$,$0.025s$, 0.05s, -$30mV$	Wang et al 1991
σ_a, θ_a	Slope and threshold for GABAb activation function	0.01pps, 8pps	Suffczynski et al 2004
$fd_{max}^p, s^p, v_{th}^p$	Amplitude, slope and threshold of PY and IN sigmoid function	50pps, 2/mV, 10mV	Jasen and Rit (1995)
$C2, C3, C4, C5, C6$	Average number of synaptic connections in cortical lump	20, 30, 6, free parameter, 10	Sherman and Koch, 1986
P, q (Hz)	Mean and standard deviation of cortical input	13, 3	Free parameters

TLE model

Parameter	Description	Reference value	Source
ge, gis, gif (mV)	Average excitatory, slow inhibitory and fast inhibitory populations' synaptic gains	3.25, 22, 10	Free parameters
re, ris, rif (Hz)	Reciprocals of excitatory, slow inhibitory and fast inhibitory populations' time constants	100, 50, 500	Jasen and Rit (1995)
$C2, C3, C4, C5, C6, C7, J$	Average number of synaptic connections in the hippocampus lump	135, 108, 33.75, 33.75, 40.5, 13.5, free parameter	Sherman and Koch, 1986
$fd^{p}_{max}, s^{p}, v^{p}_{th}$	Amplitude, slope and threshold of inhibitory and excitatory populations' sigmoid function	5Hz, 0.56/mV, 6mV	Jasen and Rit (1995)
P, q (pps)	Mean and standard deviation of cortical input	90, 30	Free parameters

Astrocyte Compartment

Parameter	**Description**	**Reference value**	**Source**
A, B ($\frac{\mu M}{s}$)	Gain coefficients of glutamate & GABA release transfer functions	18.46, 20.3	Jasen and Rit (1995)
a_1, a_2, b_1, b_2 (S^{-1})	Reciprocals of glutamate (a) and GABA (b) releases impulse responses' time constants	90, 33, 90, 33	Hires et al., 2008
$glu^{ua}_{max}, \sigma, \theta$	Magnitude, stiffness and threshold of glutamate uptake sigmoid function	$5\frac{\mu M}{s}$, $0.5\mu M^{-1}$, $9\mu M$	Garlin et al, 1995
$V_{ma}, V_{mn}, (\frac{\mu M}{s}), K_{ma}, K_{mn}(\mu M)$	Michaelis-Menten maximum velocities and concentrations of GABA uptake functions	5, 24, 2, 8	Tan et al, 1999
$cr^{a}_{glu}, cr^{a}_{gab}(\frac{\mu M}{s})$	Rate of glutamate and GABA degradation in astrocyte	0.147, 1.984	Sibson et al (1997), Patel et al (2005)
$\Upsilon = gab^{py}_{m}/glu^{py}_{m}$, $glu^{IN}_{m}(\frac{\mu M}{s})$	Ratio of the maximum coupling gain of astrocytic GABA feedback to the neural compartment to the maximum coupling gain of astrocytic glutamate feedback to the neural(PY cells)compartment, Maximum coupling gain of astrocytic glutamate feedback to the neural compartment (IN cells).	2.3, 3	Free parameter, free parameter
s_g, s_{gab} $(\mu M^{-1}) v_g, v_{gab}(\mu M)$	Slope and threshold of glutamate and GABA feedback sigmoid functions.	0.15, 0.12 30, 25	Garlin et al, 1995

Features Definition

The Mean Absolute Value (MAV)

$$MAV = \frac{1}{N}\sum_{k=1}^{N}|x_k|$$

The Average Value (AV)

$$AV = \frac{1}{N}\sum_{k=1}^{N}x_k$$

The Curve Length

$$CV = \frac{1}{N}\sum_{k=1}^{N}|x_{k+1} - x_k|$$

where:

$x =$ value of the current sample,

$k =$ sample number and

$N =$ number of samples in epoch (i.e. $signal\ sampling\ freq \times epoch\ length$)

SOURCES OF INFORMATION ON FAMILY LIFE HEALTH EDUCATION (FLHE) AMONG THE YOUTH AND PREPAREDNESS OF TEACHERS FOR FLHE CURRICULUM DELIVERY IN NASARAWA STATE, NIGERIA

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ABSTRACT

The youth constitute a significant demographic group with peculiar developmental and reproductive health needs. They encounter challenges such as limited access to proper health information needed for informed life choices and this makes them vulnerable to risky behaviour that threatens their proper development and well-being. This survey sought to find out the current and the preferred sources of information for the youth about family life health education (FLHE). It also sought to ascertain the preparedness of teachers to provide such education to in-school youth. The survey was a cross sectional study among in-school youth, out-of-school youth and science teachers in 6 selected schools in Nasarawa State, Nigeria. The findings showed that school teachers (44.1%), and mothers (28.4%) are the most common sources of FLHE information for the youth. Only 4% of the youth consider this to be satisfactory. About 36% would prefer impersonal sources such as television, films or magazines. This findings suggest that there is an urgent need for government and youth development stakeholders to redirect efforts to upscale the teaching of family life health education in schools as that is where pupils are currently obtaining the information they need. It is therefore suggested that more training should be conducted for teachers while the FLHE curriculum should be adapted to meet local needs. It is also important to prepare educational materials for media such as films, videos and magazines, as the youth have a preference for these sources.

Key Words: Health, Family Life, HIV Education, Youth, Information,

List of Abbreviations:

FLHE:	Family Life Health Education
HIV/AIDS:	Human Immunodeficiency Virus/ Acquired Immune Deficiency Syndrome
JSS:	Junior Secondary School
LGA:	Local Government Area
LSACA:	Lagos State Aids Control Agency
SSS:	Senior Secondary School

INTRODUCTION

Family Life Health Education (FLHE) is a comprehensive life skills-based form of education, intended to foster the development of knowledge, skills and attitudes in young persons to enable them become productive adults, make for a healthy family life, as well as increase their ability to make responsible decisions about social and sexual behavior (King-Cameron, 2018). The goal of family life education is to teach and foster life skills including effective communication, interpersonal relationship skills, self awareness, empathy, assertiveness, and negotiation skills, to enable individuals and families to function optimally. Family life education provides information through an educational approach, often in a classroom-type setting or through educational materials that can be used for those not in a formal school setting (Adeniyi, 1993; AHI, 2009). FLHE emphasizes processes that help people develop into healthy adults, work together in close relationships, and bring out the best in others (Kolbe, 1986). Although many refer to the 'H' in the FLHE acronym as representing HIV - Human Immunodeficency Virus (AHI, 2009), it is used to represent 'health' in this article.

Young people aged between 10 and 24 years make up about one quarter (more than 1.8 billion) of the total world population, estimated at 7.3 billion in 2015 (UNFPA, 2014), and belong to a socio demographic group referred to as the youth. This group includes students (in school), in secondary and tertiary institutions, as well as employable and employed young adults who have either dropped out of school, or have never been to a formal school. Taken together, the youth comprise people in the most impressionable stages of their development process and, potentially, are the exuberant work force of the country. Their singular shared reality however, is that of inadequate capacity and underdevelopment, poor access to information that will build their capacities for better life outcomes (UNFPA, 2010).

The youth currently account for 80 million of Nigeria's 177 million population (Edouard & Edouard, 2012). This teeming youth population lacks access to the requisite information and capacity to make informed life and health decisions which may result in danger of self – destruction and manifest as a negative value to the nation. This therefore strengthens the call to action for increased investment to enable the youth have access to information on social development and reproductive health (AHI, 2009). Information on reproductive health is mostly taught in schools, and religious groups through FLHE (Abah, 2013).

Young people are the future leaders of any community or nation. Their lives today are, however, laden with anxieties, identity crises, relationship break-down, conflict and stress. The youth have many questions, yet few sources of answers. They are being influenced by the media, societal and family pressures, yet the platforms or fora where they could come together and talk freely about their issues are generally not available. Despite the information explosion in contemporary times, the youth seldom get access to relevant and reliable information. Where young people do not have access to information, they are most susceptible to becoming victims of risky behaviour and casualties of the consequences (Kolbe et al, 1993; Dlamini et al, 2012). Information is critical to decision making, which can lead to a modification or change in attitude and behaviour. Consequently the success and sustainability of any project or development initiative depends not only on providing timely information, but also on how the information is disseminated, received and used by intended beneficiaries (Stone, 1990; Gribble, 2010).

In Nigeria, the likelihood of young persons being denied or deprived of information that will improve their knowledge and ability to negotiate is higher than that of other socio-demographic groups. Youth access to information, proper communication, as well as provision and utilisation of information through FLHE will lead to better decision making (Onokerhoraye et al, 2012). The objectives of this study were to ascertain how young people, aged 10 to 24 years, in Nasarawa State obtained information about family life, sexuality and reproductive health and how prepared the science teachers in the schools were to provide FLHE to the pupils, using the curriculum that had been developed for the purpose.

METHODS

A multi-stage sampling procedure was used for the survey. This enabled an initial selection of LGAs from the three senatorial districts of the State, and the subsequent stratification of selected schools into rural and urban. The study population consisted of in-school youth aged 10-24 years in 6 selected private and public rural and urban secondary schools in Lafia LGA (Nasarawa South Senatorial District), Akwanga LGA (Nasarawa North Senatorial District), and Keffi LGA (Nasarawa West Senatorial District); out-of-school youth aged 10-24 years in 7 rural and urban communities in the three selected LGAs; and science teachers in the 6 selected schools. In each of the survey locations, data was collected from respondents in SSS2 and JSS2 classes using self-administered questionnaires on reproductive health. A total of 556 youth, 295 males (53%) and 261 females (46%), were interviewed. Forty one (41) Science teachers were interviewed with a questionnaire and a checklist was completed to document their skills for the teaching of FLHE, attendance at seminars for reproductive health as well as their affiliation to professional associations.

Sampling

In- School

A three-stage cluster sampling technique was used to select in-school youths as follows: A list of all the rural and urban secondary schools in each senatorial district, stratified into private and public was constituted. Two schools each (1 private and 1 public) was selected based on accessibility and security/safety consideration because the State had some conflict zones as at the time of the study. Students in JSS2 and SSS2 were purposively selected to participate since the two levels are more stable in the school calendar year. One arm each from JSS2 and SSS2 was randomly selected from the participating private and public rural and urban secondary schools. All the consenting students from the selected arms of JSS2 and SSS2, present at the time of the visit, were interviewed.

Out-of-School youth

The communities where the selected schools are located were purposively utilized for the out-of-school youth for the purpose of comparative analysis. The following organized settings - motor parks, automobile mechanic shops, and professional like the vulcanizers, commercial motorcyclists, and a vocational training centre in the town where the selected schools were located were identified in the rural and urban areas of the three senatorial districts, and each of them were taken as a cluster.

Description of Data Collection Instruments

Quantitative Instruments: Questionnaire for In-school

A self-administered semi-structured questionnaire on Youth Reproductive Health Survey Questionnaire, developed by Cleland for the WHO (2001), was adapted to the study setting and utilized to obtain information from the respondents. It had 12 sections which elicited information on the respondents' socio-demographic characteristics, various aspects of their knowledge and perception about reproductive health, their sexual behavior as well as their reproductive health and social development needs.

Questionnaire for Science Teachers

A 14-item self-administered questionnaire was developed to take inventory of science teachers and collect their bio-data, which included socio-demographic characteristics, basic and post-basic qualifications, subject(s) taught, attendance at FLHE trainings and affiliation with professional bodies.

Validation of the Questionnaire

Adaptation of the structured content of the instrument was done by the research team and finalized with Project Team members of the Nigerian Academy of Science. The instrument was pre-tested in schools and communities prior to the actual survey, to enable further adjustments for ease of administration and for capture and documentation of the relevant information.

Ethical Approval

Ethical clearance was obtained from the Ethics Committee, Ministry of Health, Nasarawa State.

RESULTS

Socio-demographic characteristics of youth

A total of 556 in-school and out-of-school youth participated in the survey. The age and gender distribution of the participants are shown in Table 1.

Table 1: Socio-demographic Characteristics of the Youth in Nasarawa State, Nigeria

Age Group N=556	Frequency (%)
14 years and below	148 (26.6)
15 – 19 years	223(40.1)
20 years and above	185(33.3)
Gender	
Male	295(53.1)
Female	261(46.9)
Ever Attended School	
Yes	549(98.7)
No	3(0.5)
No response	4(0.7)
Level of Education N = 556	
Primary completed	121(21.8)
Secondary completed	317(57.0)
Technical completed	3(0.5)
Technical with secondary	6(1.1)
Teacher Training College	5(0.9)
University	45(8.1)
Postgraduate	12(2.2)
NA	9(1.6)
No Response	38(6.8)
Marital Status	
Never Married/Single	399 (71.8)
Widowed	30(5.4)
Divorced	12(2.2)
NA	15(2.7)
No response	100(18.0

Socio-Demographic Characteristics of the Science Teachers

The demographic characteristics of the science teachers interviewed and their levels of education and experience are summarized in Table 2. Out of a total of 69 Science Teachers in the five (5) schools surveyed, 41 were interviewed - 21 males and 20 females. There were more male science teachers (51.2%) than females (48.8%).

The records of teachers' attendance at training programmes to enable the acquisition of skills for teaching and providing information on FLHE to students are shown in Table 3. Only 12 (29.3%) of the 41 science teachers had any specialized training on how to teach and provide information about family life, sexuality and HIV/AIDS.

Table 2: Demographic Characteristics of Science Teachers in Nasarawa State, Nigeria

Age (in years)	**Male (%)**	**Female (%)**	**Total**
21-30	9 (42.8)	4 (20.0)	13 (31.7)
31-40	6 (28.6)	9 (45.0)	15 (36.6)
41-50	1 (4.8)	4 (20.0)	5 (12.2)
>50	0	0	0
No response	5 (23.8)	3 (15.0)	8 (19.5)
	21(51.2)	20 (48.8)	41 (100)
Qualification			
NCE	3 (14.3)	8 (40.0)	11 (26.8)
ND	1 (4.8)	1(5.0)	2 (4.9)
HND	2 (9.5)	2 (10.0)	4 (9.8)
Bachelor's degree	15 (71.4)	8 (40.0)	23 (56.1)
No response	0(0.0)	1(5.0)	1(2.4
	21(51.2)	20(48.8)	41 (100)
No. of years Since Basic Qualification			
0-5	11 (52.4)	4 (20.0)	15 (36.6)
6-10	7 (33.3)	10 (50.0)	17 (41.7)
>10	2 (9.5)	3 (15)	5 (12.2)
No response	1 (4.8)	3 (15)	4 (9.8)
	21(51.2)	20 (48.8)	41 (100)
Possession of Higher Qualification			
Yes	5 (23.8)	4 (20)	9 (22.0)
No	7 (33.3)	1 (5.0)	8 (19.5)
No response	9 (42.9)	15 (75.0)	24 (58.5)
	21(51.2)	20(48.8)	41(100)

Table 3: Teachers' Attendance at Training Programmes for FLHE and HIV/AIDS

Previous Training on FLHE	**Male No. (%)**	**Female No. (%)**	**TotalNo. (%)**
Yes	3 (14.3)	5 (25.0)	8 (19.5)
No	11 (52.4)	9 (45.0)	20 (48.8)
No response	7 (33.3)	6 (30)	13 (31.7)
	21	20	41 (100)
Previous Training on			
HIV			
Yes	4 (19.0)	8 (40.0)	12 (29.3)
No	10 (47.7)	5 (25.0)	15 (36.6)
No response	7 (33.3)	7 (35.0)	14 (34.1)
	21	**20**	**41 (100)**

Youth Access to Evidence–Based Information and Services for Reproductive Health:

A little less than half of the respondents (44.1%) considered the school teacher to be the most important source of information on sexual and reproductive health. The next most frequently cited current source of information were mothers (28.4%). The results also showed that mothers were the source of this information much more often than fathers, whether as the most important or the second most important source (Table 4).

Table 4: Important Sources of Information on Sexual Reproductive Health for the Youth

Most Important Source of Information on Sexual & Reproductive Health for the Youth	**Total (N=556)**
No. (%)	
School Teachers	245(44.1)
Mother	158(28.4)
Father	35(6.3)
Doctors/Health Workers	20(3.6)
Other Family Members	11(2.0)
Friends	6(1.1)
Books/magazines	2(0.4)
No response	79(14.2)
Second Most Important Source of Information on Sexual Reproductive	
Health for the Youth	Total (N=556)

No. (%)	
Mother	110(19.8)
Doctors/Health Workers	60(10.8)
Friends	53(9.5)
School Teachers	46(8.3)
Father	30(5.4)
Sister	28(5.0)
Brother	22(4.0)
Books/magazines	12(2.2)
Other family members	11(2.0)
Radio/TV	10(1.8)
Films/videos	3(0.5)
No response	171(30.8)
Most Preferred Source of Information on Reproductive Health	**Total (N=556)**
No. (%)	
Radio/TV	97(17.4)
Films/Videos	76(13.7)
Doctors/Health Workers	34(6.1)
Book/Magazines	27(4.9)
School Teacher	16(2.9)
Brother	16(2.9)
Sister	12(2.2)
Friends	10(1.8)
Other Family Members	10(1.8)
Mother	8(1.4)
Others	21(3.8)
No Response	229(41.2)

Only about one in a hundred considered their friends to be the most important source of family life and sexuality information while 0.4% considered books and magazines as the most important source of reproductive health information. While more than 70% of the students had their teachers and mothers as the most important source of information, only about 4% of them seem to like the situation as it is. More than one-in-three (36%) would prefer to obtain the information from sources such as radio, television, films, videos, magazines and books. More than 40% of the respondents expressed no preference

DISCUSSION

The findings from this study indicate that school teachers and mothers are the most important sources of sexual and reproductive health information for in-school youth in this part of North Central Nigeria. Yet, the teachers seem unprepared for this role, as less than one-third of them had undergone any specialized training on family life and health education or on the use of a curriculum to pass impart such knowledge to pupils.

Parents, teachers and peers play an important role in enabling access to information, as young people are easily influenced by both peers and adults like parents and teachers. It is obvious that a large segment of the youth covered in this survey obtained FLHE-related information from their teachers in school. The teachers however need to be able to acquire and understand the information first, as well as possess the capacity and willingness to disseminate the acquired information to youths. The quality of information available to teachers and parents and their willingness is therefore a key factor in enabling access to information by the youth (Oni, 2009). Schools are a central place in the community for meeting children's rights to health and development, by providing a safe and supportive environment; access to information and life skills, and opportunities to participate in decisions that affect their lives. In addition to schools' impact on the development of individual students, they can be a central point for development in communities, for disseminating information (e.g., AIDS, hygiene, clean water and sanitation), and for contributing to social change (Cohen & Vince-Whitman, 1997; Coleman, 2001).

The need to help young people develop a positive sense of self-worth by creating opportunities for them to consider all aspects of humanity, to ask important questions, and to understand that adults are available to support them is most essential (Philliber Research Associates, 2009). Understanding the facets of one's humanity is a lifelong process. It involves acquiring information and forming attitudes and values about identity, relationships, and intimacy (UNICEF, 1999; Barrington-Leach et al, 2007). FLHE presents a starting point for developing a comprehensive approach to 'Humanity' education. Appropriate FLHE should result in postponement or reduction in the frequency of sexual activity, more effective use of contraception and adoption of safe sexual behaviour. It is suggested that the teaching of family life education in schools will be a vibrant solution to adolescents' sexuality problems (AHI, 2010). The finding that students obtain FLHE information from their teachers more than any other source points to an appropriate point of intervention.

Since a strong plurality of the respondents considered the school teacher to be the most important source of information on the sexual and reproductive systems of men and women, improving the ability of the teachers to deliver the FLHE curriculum appropriately will go a long way in empowering the in-school youth to make informed decisions about their sexual and reproductive health through structured learning. Teachers need to be targeted as trainers and educators for this activity since they have direct supervision of students during school hours. For the teachers to do this effectively, they need initial and continuous education through retraining on how to integrate issues of health and development (Schinke et al, 1992; Larsen, 2010).

The students' choice of films/video and radio/television as the most preferred medium of information over teachers and family members, and the fact that relatively few of them considered books and magazines as important sources of information, underscores the dearth of a healthy reading culture among students, and the youth in general. There is need to kindle their interest in the printed word. The preference of electronic media by a large proportion of them is a fall-out of the increasing access to the internet and other social media facilities, which has been observed to take much of the time of both the in-school and out-of-school youth. This situation is reinforced by the absence of proper libraries (books, shelves, reading tables and chairs etc), librarians, and active literary/debating societies, and book clubs especially in the public schools (Knowles & Jere, 2005).

Family life health education is more comprehensive and encompassing than sex education in all ramifications. There is therefore a need to make the curriculum sensitive to the local culture and be acceptable to parents and all other stakeholders in education (NERDC, 2003; Nwagbara, 2003; YEN-WA, 2009) There is limited awareness of FLHE curriculum in Nigeria. There are also several reasons for its non-implementation and adoption of the available curriculum. These include inconsistency in federal and state budgetary provision and release of funds for the training of the needed personnel, limited awareness of the existence of the curriculum and an inadequacy of mechanisms for classroom implementation so that the components of the FLHE curriculum could be integrated into the standard educational curricula of the different educational grades in the junior and secondary levels of education (Dlamini et al, 2012).

The FLHE curriculum was developed to equip young people with the capacity to handle issues such as negotiation, assertiveness, coping with peer pressure; attitudes such as compassion, self-esteem, and tolerance; and adequate knowledge about HIV transmission. The pivotal themes around the curriculum's development were age specific and include human development, personal skills, HIV infection, relationships, society and culture (Main et al, 1994; Shofoyeke, 2008). The implementation of the FLHE Curriculum started in 2004 after the training of teachers and educational administrators on methodologies and content. Sadly, this initial step has not been adopted in many of the states in the country (AHI, 2010). The successful implementation of the FLHE curriculum is critical to the sustainable development of Nigeria youth through empowerment for better health and life outcomes. It is recommended that key education agencies at state & federal level should focus on effective implementation of the FLHE curriculum, strengthen advocacy to sustain and increase community support for comprehensive FLHE programming, and training of teachers for the transmission of FLHE knowledge to the youth.

Family life health education focuses on the way young people cope with what life demands through provision of information about their emotions, values, humanity and how to express it, and the skills with which to cope with the challenges. The findings from this study demonstrate that school teachers are already playing a pivotal role in getting this information across to the youth and that some of the best opportunities for positively influencing the health of young people and preventing the initiation of risky behaviour is the school setting. There is also some preference among the youth for getting such information through impersonal media such as video, films, television and magazines. Appropriate material should be prepared to reach the youth through these media.

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CONFLICT OF INTEREST

None declared

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EFFECT OF COMMERCIAL SAND MINING ON WATER QUALITY PARAMETERS OF NWORIE RIVER IN OWERRI, NIGERIA

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ABSTRACT

Nworie River, in the Imo River basin of Nigeria, roughly bisects Owerri municipality which hosts the administrative capital of Imo State of Nigeria. As a result of this location the river is vulnerable to potentially polluting human activities. A study of the water quality parameters was done in 2008 as a baseline for monitoring future changes in the river. That study recommended professionally supervised dredging to remove surplus silt and organic debris in some sections of the river. What followed in the past few years has been an unsupervised free-for-all commercial sand mining that has conspicuously degraded the physical characteristics of the river. The aim of this study was to investigate the effect of this sand mining on quality parameters of the river. A total of eleven(11) physico-chemical parameters were investigated. The study showed that major indicators of organic pollution like high ammonia-nitrogen, low dissolved oxygen and high carbon dioxide concentrations still persist and, in some cases, have become worse since the sand mining activities. The study recommends an immediate stop to the sand mining followed by a professionally supervised dredging to restore the physical and biological characteristics of the river.

Key words: Dredging, Nworie River, Pollution, Water Quality, Sand Mining.

INTRODUCTION

Nworie River in the Imo River basin of Nigeria has received considerable public attention as a typical freshwater resource under high urban pressure. It roughly bisects Owerri municipality which hosts the administrative capital, of Imo State of Nigeria. As a result of its location, the river is constantly under threat from a high level of anthropogenic perturbations. These were the considerations that motivated an earlier study (Okorie and Acholonu, 2008) which undertook an investigation into the longitudinal variations of water quality parameters along the 5km stretch of the river. This was followed by another study (Manilla and Njoku, 2009) which investigate thirteen physico-chemical parameters, including heavy metals, in Nworie River.

Immediately after these studies, Nworie River became the target of an unsupervised dredging operation. What was initially conceived as a dredging operation to remove accumulated debris on the riverbed and thus enhance river flow, soon turned into an uncontrolled and unsupervised free-for-all sand mining for profit. It was as if the riverbed was concessioned off in the same manner that oil blocs are allocated in prospective oil fields for exploration and exploitation. To further complicate issues, three bridges have been constructed across the river whose designs are considered not good enough to encourage natural river flow. Another item in the agenda of negative human activities is the encroachment of buildings on the river watershed, some now less than 50m from the river.

Okorie (2013),which showed pictures of silted portions of the river raised alarm on the high pollution level and the prospects of total drying up of the river in the future, starting with the formation of isolated seasonal pools in the next few years. Within this period, Duru and Nwanekwu (2012) investigated microbial parameters and identified such pathogenic organismsas Klebsiella, Vibrocholerae and Proteusin the river. Another study, Duru etal (2012) demonstrated consequences of long-term consumption of water from Nworie River in terms of haematological, hepatic and renal functions in rats.

Recently, Acholonu (2016) drew attention to the high coliform load - a bioindicator of faecal pollution – and the health hazard posed to segments of the inhabitants of Owerri who drink or bath in Nworie River.

The aim of this study is to investigate the impact of the various negative human activities, mainly uncontrolled sand mining, on the water quality characteristics of Nworie River, using the Okorie and Acholonu (2008) study which was done before the sand mining, as baseline. The present study is also restricted to the eleven(11) water quality parameters investigated in the baseline study.

MATERIALS AND METHODS

Five sampling sites used in the Okorie and Acholonu(2008) study were again used for this study. The sites were along the longitudinal stretch of the river: two sites upstream; two sites midstream: and one site downstream towards the confluence of Nworie River and Otamiri River. Water samples were collected in the sites for two consecutive days during the month of November,2016 which fell within the dry season in Nigeria. Water collection was done using clean plastic containers. These sample bottles were immersed below the water surface, filled to overflowing and the cap affixed securely to eliminate the possibility of an air bubble in the container. The water samples were transported immediately to the laboratory at Imo state University, Owerri. In the laboratory the LaMotte test Kits were used to perform various chemical pollution tests as directed by the manufacturer. The LaMotte test kits operated on a combination of titration and colorimetric procedures. Each sample was analysed three times and the mean value taken.

The chemical parameters tested were dissolved oxygen, carbon dioxide, pH, chloride, nitrate-nitrogen, nitrate, ammonia-nitrogen, hardness, orthophosphate, sulfide and silica.

The test results were analysed and compared with the results of the Okorie and Acholonu (2008) study which was done before the massive dredging/sand mining activities. Thus Okorie and Acholonu (2008) represent parameters before dredging while the present study represents parameters after dredging.

RESULTS AND DISCUSSION

Generally, what the sand mining has done to the physical conditions in the river, is to create alternating lotic and lentic habitats. Lacustrine (lake) condition prevail in areas of active sand mining followed by fast flowing (lentic) stretch of the river. Next, another artificial lake from sand mining followed by yet another fast-flowing stretch of the river.

To illustrate, first half of upstream (Upstream I) used to be fast-flowing, hardly up to 15m wide. Now, due to sand mining , it is over ten times wider and so deep that the water is almost static (Fig. I). Midstream I, which receives the 'over-spill' of the artificial lake formed upstream, is fast-flowing and barely 5m wide (Fig.2). Midstream II is yet another artificial lake formed from sand mining, so wide and deep as to create an almost stagnant pool (Fig. 3). This is followed again by another stretch of fast-flowing river downstream (Fig. 4). Siltation of the river is most pronounced in Upstream II (Fig. 5, 6) which is a discharge spot for large quantities of sewage and silt from the density populated Akwakuma District of Owerri Municipality.

Tables 1 – 5 present the chemical parameters before and after dredging in the five sampling stations. The study showed that in terms of water quality, key parameters in Nworie River like dissolved oxygen and carbon dioxide remain short of WHO/EPA standards. Similarly, all the indices of organic pollution remain pronounced in all the stations, especially in situations where near-stagnant lakes have formed as in Upstream I, Upstream II and Midstream II (Fig.1). For instance, dissolved oxygen levels have remained low or even fallen in many of the stations due probably to the utilization of oxygen for the decay process. Correspondingly, carbon dioxide levels have remained high due to accumulation of organic matter.

The high ammonia-nitrogen levels in some of the study stations confirm that large quantities of fresh untreated sewage were being discharged directly into the river.

Though chloride levels in the river are still far lower than WHO/EPA thresholds, their rise nevertheless raise fears about increasing faecal pollution. This is because, since human and animal excretion contain, on the average, 5g Cl- per litre (Cole, 1979), soluble chlorides may find their way into freshwater bodies through subsurface seepage from septic tanks.

Table 1: Comparison of Chemical Parameters Upstream (I) Before and After Dredging/Sand Mining Activities

S/No.	***Parameter	*Before dredging	**After dredging	WHO/EPA Standard
1	Dissolved Oxygen	3.0	2.8	4.0 - 5.0
2	CO2	20.2	18.5	10.0
3	pH	5.5	5.6	6.5 - 9.0
4	Chloride	20.5	18.7	250
5	Nitrate Nitrogen	0.4	0.3	10
6	Nitrate	1.76	1.63	1
7	Ammonia Nitrogen	< 1.0	3	N/A
8	Hardness (Total)	28.0	24.0	50
9	Orthophosphate	0.2	0.2	N/A
10	Sulphide	< 0.3	0.3	2.0
11	Silica	3.5	3.7	2 – 25.0

* Okorie and Acholonu (2008)
** This study
*** All parameters in parts per million (ppm) except pH

Table 2: Comparison of Chemical Parameters Upstream (II) Before and After Dredging/Sand Mining Activities

S/No.	***Parameter	*Before dredging	**After dredging	WHO/EPA Standard
1	Dissolved Oxygen	1.2	1.2	4.0 - 5.0
2	CO2	30.3	32.6	10.0
3	pH	5.8	5.7	6.5 - 9.0
4	Chloride	15.0	17.0	250
5	Nitrate Nitrogen	0.6	0.8	10
6	Nitrate	2.64	2.81	1
7	Ammonia Nitrogen	< 1.0	4.5	N/A
8	Hardness (Total)	16.0	18.0	50
9	Orthophosphate	0.3	0.4	N/A
10	Sulphide	0.3	0.4	2.0
11	Silica	4.0	3.5	2 – 25.0

* Okorie and Acholonu (2008)
** This study
*** All parameters in parts per million (ppm) except pH

Table 3: Comparison of Chemical Parameter Midstream (I) Before and After Dredging/Sand Mining Activities

S/No.	***Parameter	*Before dredging	**After dredging	WHO/EPA Standard
1	Dissolved Oxygen	3.2	3.5	4.0 - 5.0
2	CO2	18.5	17.3	10.0
3	pH	6.0	6.3	6.5 - 9.0
4	Chloride	12.0	13.5	250
5	Nitrate Nitrogen	0.1	0.1	10
6	Nitrate	0.44	0.34	1
7	Ammonia Nitrogen	4.0	<0.1	N/A
8	Hardness (Total)	8.0	12.0	50
9	Orthophosphate	<0.2	<0.2	N/A
10	Sulphide	<0.2	<0.2	2.0
11	Silica	3.2	3.4	2 - 25'

* Okorie and Acholonu (2008)
** This study
*** All parameters in parts per million (ppm) except pH

Table 4: Comparison of Chemical Parameter Midstream (II) Before and After Dredging/Sand Mining Activities

S/No.	***Parameter	*Before dredging	**After dredging	WHO/EPA Standard
1	Dissolved Oxygen	1.1	1.2	4.0 - 5.0
2	CO2	27.5	30.5	10.0
3	pH	6.0	6.0	6.5 - 9.0
4	Chloride	12.0	13.2	250
5	Nitrate Nitrogen	0.1	0.4	10
6	Nitrate	0.44	1.2	1
7	Ammonia Nitrogen	4.0	4.5	N/A
8	Hardness (Total)	8.0	9.0	50
9	Orthophosphate	<0.2	<0.2	N/A
10	Sulphide	<0.2	<0.2	2.0
11	Silica	4.0	3.5	2 - 25'

* Okorie and Acholonu (2008)
** This study
*** All parameters in parts per million (ppm) except pH

Table 5: Comparison of Chemical Parameters Downstream Before and After Dredging/Sand Mining Activities

S/No.	***Parameter	*Before dredging	**After dredging	WHO/EPA Standard
1	Dissolved Oxygen	3.0	3.2	4.0 - 5.0
2	CO2	13.0	12.5	10.0
3	pH	5.8	5.9	6.5 - 9.0
4	Chloride	12.0	14.0	250
5	Nitrate Nitrogen	0.2	0.3	10
6	Nitrate	0.88	0.75	1
7	Ammonia Nitrogen	3.0	3.5	N/A
8	Hardness (Total)	8.0	8.0	50
9	Orthophosphate	0.2	0.2	N/A
10	Sulphide	0.2	0.3	2.0
11	Silica	4.0	3.5	2 - 25'

* Okorie and Acholonu (2008)
** This study
*** All parameters in parts per million (ppm) except pH

These observations are in line with Duru and Nwanekwu (2012) study on the physico-chemical and microbial parameters of Nworie River. Though these two studies used slightly different criteria, the deductions are the same. For example, Duru and Nwanekwu (2012) noted total dissolved solids (TDS) of 250 – 320 ppm in some sections of the river which exceed the WHO drinking water standard of 250 ppm. Since there is no serious industrial activity in Nworie River watershed, the elevated TDS is mainly from sewage and urban run-off.

Another source of worry in Duru and Nwanekwu (2012) is their observation of relatively high concentrations of some metals. Their study reported an aluminum concentration of over 0.8 ppm which exceeds the WHO threshold of 0.2 ppm, and an iron concentration of 0.56 ppm which exceeds the WHO threshold of 0.3 ppm. Though these two metals are not toxic, their rise in concentrations may be as a result of deep excarvations during sand mining. One cannot rule out the possibility of appearance of toxic heavy metals in the future.

Okorie and Acholonu (2008) had recommended dredging of Nworie River under strict professional supervision to remove organic debris and silt without compromising its physical characteristics. What has taken place since that study can not be called dredging. Rather, what has taken place is a free-for-all commercial sand mining that has negatively impacted on the ecology of the river.

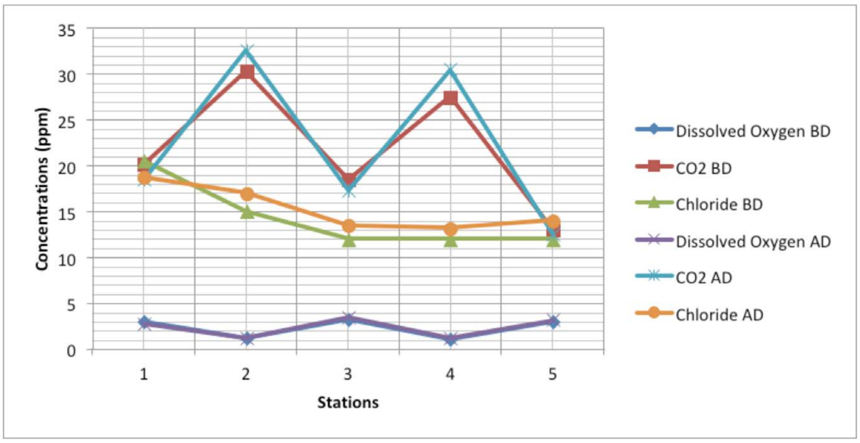

Fig. 1: Some key water quality parameters before and after dredging

Figure 1a. Upstream I

Figure 1b. Midstream I

Figure 1c. Midstream II

Figure 1d. Downstream

Figure 1e Upstream II

Figure 1f. Discharge spot for sewage

If the commercial sand mining is not stopped soon, the damage to the river may become irreversible. This study is strongly recommending that commercial sand mining should stop for a properly supervised dredging to restore important physical and biological characteristics of the river. Also land-use authorities should enforce the relevant environmental laws prohibiting construction activities on the immediate watershed of this river, realizing that it was deforestation and construction activities on the watershed that encouraged river siltation in the first place.

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SCIENCE EDUCATION IN SOUTH-WEST NIGERIA: IMPLICATION FOR EDUCATIONAL POLICY

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ABSTRACT

The demand for quality science education requires periodic assessment for its improvement especially in areas with previous challenges. This study was conducted to assess the current status of science education in Ekiti State, Southwest Nigeria. A cross-sectional design, combining a mixed method of quantitative and qualitative data collection approach, was used following a records review. Schools were selected using a cluster sampling technique. Science education status was ascertained by three parameters: students' pass rates in science subjects in the Senior Secondary School Certificate Examination, science teachers' profile (assessed with a 14-item self-administered questionnaire) and availability and functionality of infrastructure for science education using an observational checklist. In-depth interviews were conducted among relevant stakeholders using an in-depth interview guide. Quantitative and qualitative data were analyzed with descriptive statistics and a thematic approach respectively. Students' pass rates were below 50% in Mathematics and Biology but above in Physics, Chemistry and Agricultural Science. The science teacher: student ratio was 1:8 and 37.5% of the teachers were members of the Nigerian Science Teachers Association. One school (8.3%) had a computer library that was adequately equipped. Laboratory facilities were mostly multipurpose in nature. A quarter of the schools had no library while 33.3% had grossly inadequate library facilities. Opinions about science education status among the respondents was widely divergent with some feeling that it was good while others felt otherwise. This study revealed poor status of science education as evidenced by a low science teacher-student ratio and lack of basic infrastructure for science education. Interventions to improve these findings are recommended.

Keywords: Science Literacy, Secondary Education, Quality Learning, Science Teachers' Profile

INTRODUCTION

Science is an area of learning that is absolutely necessary for development because of its linkage to technology and industry (Batomalaque, 2015). Scientific development is essential for better quality of life, the sustainable development of the planet, and peaceful coexistence amongst peoples. From the immediate basic essentials of life such as access to water, food and shelter, to other issues such as management of agricultural production, water resources, health, energy resources, biodiversity, conservation, the environment, transport, communication, science provides the basis for action at local, regional, national and transnational levels (UNESCO, 2015). Science and technology have been identified as the key drivers for growth and sustainable social development and transformation of nations, which could lead to industrialisation (Uza, 2013).

The knowledge of science and its associated skills cannot be achieved without science education. The Declaration of Budapest argues that what distinguishes poor people or countries from rich ones is that not only do they have fewer possessions but also that the large majority remain excluded from the creation and the benefits of scientific knowledge (Budapest 1999). Science education aims at helping individual learner to gain a functional understanding of scientific concepts and principles linked with real life situations and acquire scientific skills, attitudes and values necessary to analyze and solve day-to-day problems (Batomalaque, 2015). This portends the reason why basic sciences are core subjects in the elementary and secondary schools world over. It emphasizes the fact that all citizens should achieve some degree of scientific literacy to enable them participate effectively as citizens in the modern societies. Lederman (2008) in his article about "Science Education and the Future of Humankind" argues that:

"We have arrived at a point in history where there must be a major increase in the capability of ordinary people to cope with the scientific and technological culture that is shaping their lives and the lives of their children."

Worthy of note is the fact that only quality science education can bring about effective learning among students which will eventually produce palpable development for any country. Quality science education is effective science teaching which occurs when students learn and achieve many scientific goals and not just being able to repeat scientific knowledge (Omoifo, 2012). During effective learning, student learn how to develop conceptual understanding and thinking skills in order to change their intuitive, everyday ways of explaining the world around them to incorporate scientific concepts and ways of thinking into their personal frameworks so as to enhance their ability to solve problems (Omorogbe and Ewansiha 2013). According to the Budapest Declaration (1999):

"Relevant and quality science education can develop critical and creative thinking, help learners to understand and participate in public policy discussions, encourage behavioral changes that can put the world on a more sustainable path and stimulate socio-economic development."

Opateye (2012), in his study on awareness and preparation for the challenges of vison 20:2020 among secondary school science teachers, noted that properly planned educational input, including scientific education, can lead to an increase in the gross national product and a general improvement to national development as a whole (Opateye 2012).

Rapid, worldwide change has dramatically altered global educational needs, challenging societies to transform the structures and processes of education (Hamilton et al., 2010). In developing countries, educational change means providing a quality of education that better addresses the needs of ever-expanding technologies in information systems, communications, medicine and engineering ((Halminton et al. 2010). Therefore, improving scientific education has become of paramount importance in determining a country's scientific status and its socio-economic power in today's open economies (Kalolo, 2015). The desire to develop scientific education is clear and in many countries there is an opportunity to ensure that quality, relevant and sustainable scientific education is provided for every student (Hestenes, 2013). However, many of today's youth do not have an interest in the study of science (Munro & Elsom 2000; Malcolm 1999). The fall in the number of secondary school leavers seeking careers in science, and the resulting situation where it is becoming difficult to find notable professionals in scientific fields, has become a matter of concern for most developing countries (Kalolo 2015), including Nigeria. It appears that while the global demand for skills in a technology-based economy is increasing rapidly, little effort has been made towards improving scientific education in schools.

Studies have shown that efforts to improve science education in most African secondary schools since the 1980's have been impacted by a number of global challenges with grave consequences on the practices in schools (Ogunmade 2005; Ogunniyi 1986, Kalolo 2015). These challenges include: changes in science as a discipline itself, the evolution of societal needs, rapid changes in technology, changes in scientific innovations, changes in the purposes of science education, the intensification of globalization, changes in new theories of learning, changing labour force demands and the evolution of the market forces in science careers. Such challenges have also led to a mismatch between the knowledge and skills that the schools offer, and the competencies that school graduates need for them to face their futures confidently (Kalolo 2015). Many of these challenges are also peculiar the situation in Nigeria.

Science education in Nigeria concentrates on the teaching of science concepts, method of teaching and addressing misconceptions held by learners regarding science concepts (Kola, 2013) but over the years, the situation has always been of concern to all including government and the society at large. This is evidenced by the poor/declining performance of students in science subjects (Ogunmade 2005). A highlight of students performance in SSCE showed that less than 50% of students passed their science subjects from 1995-2002 (Omorogbe and Ewansiha 2013). The proportions of students who had credits in biology, chemistry and mathematics from 2000-2004 were less than 50% in each of the subjects expect in 2003 when 51% had credit in chemistry (Omorogbe and Ewansiha 2013). A survey on the SSCE performance level of secondary school students in Ondo and Ekiti State from 2005 to 2009 showed that in each of the years, less than 40% passed mathematics and physics in both states while it was only in chemistry (2009) and biology (2005) that at least 50% of students passed in Ondo State (Adeyemi

2011). Some of the factors identified for poor performances in science from the various studies conducted in Nigeria were lack of motivation for most teachers, poor infrastructural facilities, inadequate textual materials, attitude of students to learning, lack of teaching skills and competence by science teachers, and lack of opportunities for professional development for science teachers (Braimoh & Okedeyi 2001; Folaranmi 2002; Olaleye 2002; Olanrewaju 1994). Other research findings had indicated that many students found science to be difficult, boring and not interesting to them (Salau, 1995; 1996). Large class sizes, inadequate funding, insufficient curriculum resources, poor teaching skills and lack of supports for teachers among other factors further limit the quality of science teaching and learning in Nigerian schools (Okebukola 1997). Recent studies have reported that quality of teaching and teachers were dominant factors for student poor performance in science subjects. Most teachers emphasizes theory rather than practical aspects of science subjects and most of them lack adequate knowledge of subject matter and the competence to deliver (Abdulahi 2007; Omorogbe and Ewansiha 2013). The teacher's academic qualifications and knowledge of subject matter, competencies and skills, and the commitment of teacher have a great impact on the teaching-learning process. Similarly, a study among Filipino students reported low performance in science subjects and some of the reasons were lack of science culture, deficiencies in school curriculum, the teaching learning process, instructional materials and teachers' training. Others factors include lack of textbooks, science equipment and facilities and poorly equipped laboratory rooms (Batomalaque, 2015).

Improving scientific education has become of paramount importance in determining a country's socio-economic development. This may be difficult to achieve without the understanding of the current status of science education. Anecdotal evidences showed that the tertiary institution graduates are not meeting up the challenges posed by our rapidly changing world. This may be explained from the poor quality of science education and the lack of interest of secondary school students in science. Science education especially at secondary level is very important for students of the 21st century. According to Iftekhar (2013), secondary education is the cornerstone of education system as it is the gateway to the opportunities and benefits of economic and social development. A situation whereby necessary functional scientific knowledge and skills are not achieved at the secondary school levels can adversely impact the youth application of scientific knowledge in the future especially the health sciences. A previous 5-year review (2005 – 2009) of the performance level of Ekiti State secondary school students in the core sciences including mathematics, using JSC (grade 9) and SSC (grade 12) examination revealed an abysmally low expectation (Adeyemi, 2011), especially as it is a state popularly tagged "the fountain of knowledge." Assessing the status of science education in Ekiti State in the current decade when Nigeria is far from achieving its education and health related goals may inform timely intervention to improve the current poor performance of students in the sciences because no nation can develop beyond her level of her scientific education. The rapidly demanding quest for quality science education in the secondary schools in today's world of ever-expanding technologies and health challenges requires periodic assessment for further improvement. This study was conducted to assess the status of science education in Ekiti State Nigeria by gauging the current level of students' performance (2009-2013) in the science subjects using Senior Secondary School Certificate Examination (SSCE), profile of science teachers and the availability, functionality of, and access to laboratory, library services and information, communication and technology (ICT) facilities.

METHODS

This study was carried out in Ekiti State. Ekiti State is located in the South-western geo-political zone of Nigeria. Administratively, the State is divided into three senatorial districts, 16 local government areas (LGAs) and 177 wards. With the population growth rate of 3.2%, the projected population as at 2013 was 3,025,427 while the population of youths (aged 10 – 24 years) was 1,088,704 comprising 557,509 male (51.2%) and 531,195 female (48.8%) (National Population Commission/Ekiti State Bureau of Statistics 2013). Ekiti State has a total of 330 secondary schools comprising 184 (55.8%) public and 146 (44.2%) private schools (Department of Planning, Research and Statistics 2013).

STUDY DESIGN

A review of records and cross sectional design were utilized to assess the quality of science education for this study. The descriptive method utilized a combination of quantitative and qualitative approach. The use of multiple instruments allowed triangulation of data as they provided opportunity to elicit information and have in-depth understanding of the situation of science education in Ekiti State, Nigeria.

Sampling Procedure

Quantitative approach

A cluster sampling technique was used to select schools. There are three senatorial districts in Ekiti State. The list of all the rural and urban secondary schools in each senatorial district, stratified into private and public sectors, was drawn. Two schools each (1 private and 1 public) were selected randomly by balloting from the list of rural and urban secondary schools in each senatorial district. Thus, a total of 12 secondary schools (4 per Senatorial District) were selected. All the selected secondary school and their science teachers were assessed.

Qualitative approach

A purposive sampling method was used to select relevant stakeholders. Those interviewed include the Honourable Commissioner for Education, Science and Technology and the Honourable Chairman, House Committee on Health and Social Services in the Ekiti State House of Assembly. Others were the Permanent Secretary, the Director of Science, Technology & Mathematics and the Director of e-Schools, all from the Ekiti State Ministry of Education, Science and Technology. The Director of Public Health, the principals of each of the selected schools or individuals nominated by the school authorities (school focal persons) were also interviewed.

Data Collection Procedure

Review of Records

Relevant records were reviewed and collated with respect to students' performance in science subjects in the preceding five years (2009-2013).

Quantitative Data: The quantitative information was collected using semi-structured questionnaire and observational checklist.

Questionnaire

A 14-item self-administered questionnaire was developed to take inventory of science teachers and collect their bio-data, which included socio-demographic characteristics, basic and post-basic qualifications, subject(s) taught and affiliation with relevant professional bodies. All the science teachers who were met in the selected public and private secondary schools at the time of research team's visit were requested to complete a questionnaire for science teachers. Repeat visits were made to administer the questionnaire to those who were not met at the first visit.

Observational Checklist

The observational checklist was used to collect information on schools' statistics with regards to number of students and their distributions by gender, class and subject, number of science teachers and subjects taught, and students' performance in science subjects. It also documented availability and functionality of laboratory, library and ICT facilities. The principal or the focal person nominated by the school authority in each of the schools with the research team jointly carried out the school inventory and documentation as they both went through and observed school facilities. The checklist was completed for each of the schools visited.

Qualitative Data

In-depth interviews were conducted among the specified stakeholders using an in-depth interview guide. The interviewers and interviewees were allowed to deviate from the prepared in-depth interview guide as new themes emerged from the conversations. The interview guide was used to elicit information on participants' perception of the quality of science education in the state.

Validity of Data Instruments

Content validity of the quantitative instruments was carried out by experts and more than 50% of each item was agreed to by them. All the instruments was pre-tested in a school which was not selected for the study. Findings of the pre-test exercise were used to assess the internal consistency for the instrument and Cronbach Alpha estimate was 0.77. The pre-test findings were useful in making appropriate adjustments to the questionnaire, where necessary.

Data Management

For the quantitative data, the teachers' questionnaire and observational checklist were manually sorted out, checked and carefully arranged according to school and community. Thereafter, the questionnaires were numbered serially for the purpose of data entry. Data was entered into the computer and analyzed using Statistical Packages for Social Science (SPSS) version 16.0.

Descriptive statistics were used to summarize the data, which were presented in frequency tables as means and standard deviation. Science education status was measured by students pass rates in the core science subjects (physics, chemistry, biology, agriculture and mathematics) using SSC (grade 12) examination for 2009-2013; profile of science teachers; and availability and functionality of infrastructure for science education.

Qualitative data was analyzed using thematic approach. The transcription of the audio-taped qualitative data was done verbatim. Firstly, necessary steps were taken in transcribing the content such as verbal and non-verbal sounds, inaudible information, overlapping speech, pauses, questionable text and sensitive information as required. Secondly, all transcriptions were reviewed for accuracy by proofreading against the audiotape and revising the transcript file accordingly. Thirdly, all transcripts were saved in a computer as a rich text file with adequate labelling. Guided by the project objectives, data were thematically analyzed with similar patterns of responses identified and described as themes. Furthermore, some of the transcriptions were reported verbatim to highlight some responses of the stakeholders.

Ethical Issues

Approval to conduct this project was obtained from the Research and Ethics Committee of the Oyo State Ministry of Health (as there was no functional review committee at that time in the Ekiti State Ministry of Health. Approval of the Ekiti State Government has been previously sought and obtained to carry out the project. Permission to collect relevant information was sought from the appropriate Commissioners and Directors such as the Commissioner for Education, Science & Technology; Director of Science, Technology and Mathematics and Director of e-Schools. Permission to collect relevant information from schools and science teachers was obtained from the Principals of selected schools in Ekiti State.

Results

In the 12 surveyed schools, there were 6,198 students: 3,168 males (51%) and 3,030 females (49%). The students in JSS class (7th – 9th grade) were 3,296 (53%) and those in SSS class (10th – 12th grade) were 2,902 (47%).

Status of Science Education

Pass Rate of Students in Science Subjects (Table 1):

Students' pass rate in Mathematics was generally low (average 46.3%) in both male and female students except in 2009 when slightly over 50% was recorded in both sexes. Male students also recorded 52.6% in 2013. Pass rate in Biology was low (average 39.5%) in both sexes except in 2010 which recorded slightly over 50%. Pass rate in Physics was consistently high (average 61.8%) from 2009 to 2013. Pass rate in Chemistry was generally fair (average 53.8%) except in 2012 when male students recorded 35.4% and female students recorded 30.8%. Similar to Chemistry, pass rate in Agricultural Science was generally fair (average 57.7%) except in 2012 when male students recorded 40.3% and female students recorded 37.1% (Ekiti State Ministry of Education, 2013).

Science Teacher/Science Students' Ratio

Out of 2,902 students in SSS category, 1,097 (38%) were science students, 919 (32%) were undertaking arts subjects and 886 (30%) were undertaking commercial subjects. The total number of teachers in the 12 surveyed schools was 459; out of these, 131 were science teachers. This gave a gross Science Teachers: Science Students ratio of 1:8. The ratios for individual subjects were however much lower than this. For Physics, the ratio of science teachers to students was 1:84. The ratios for Chemistry and Biology were 1:61 and 1:44 respectively.

Number of Teachers by Subject in the Selected Schools

The number of teachers available to teach science subjects in the selected 12 schools were as follows: Physics has 13 teachers (average of 1 per school), Chemistry - 18 teachers (1.5 per school), Biology - 25 teachers (2 per school), Agricultural Science - 26 teachers (2 per school), Mathematics - 36 teachers (3 per school) and Integrated Science - 21 teachers (1.5 per school).

Availability of Science Teachers

A total of 64 Science Teachers were interviewed. A majority (70.4%) of the science teachers were aged 40 years or less. Twenty-five (39.1%) were in the 21 to 30 years age-group and 20 (31.3%) were aged 31 to 40 years old. Most of the science teachers were male (51.6%). Majority of them had a degree qualification (76.6%) which had mainly been acquired in the previous five years (40.6%) (Table 11). Biology was the most common subject studied by the teachers (21.9%) followed by Chemistry (14.1%) and then Physics (12.5%). Most of the teachers also taught Biology (21.9%) followed by Chemistry (18.8%) and then Physics (17.2%) (Table 2).

Table I: Five (5) Years Students' Pass Rate in Science Subjects (2009 – 2013

Subject	2009		2010		2011		2012		2013	
	M (%)	F (%)	M (%)	F (%)	M (%)	F (%)	M (%)	F (%)	M (%)	F (%)
Mathematics	3,624 (56.4) N= 6,422	2,952 (51.6) N= 5,725	3,435 (44.4) N= 7,738	3,198 (46.6) N= 6,856	3,648 (43.0) N= 8,488	3,593 (43.4) N= 8,273	2,349 (38.8) N= 6,056	2,214 (40.0) N= 5,548	2,894 (52.6) N= 5,503	2,501 (46.4) N= 5,389
Biology	1,994 (30.7) N= 6,490	1,887 (32.2) N= 5,855	3,959 (51.2) N= 7,726	3,733 (54.4) N= 6,862	3,472 (39.1) N= 8,883	3,981 (48.3) N= 8,249	1,212 (20.1) N= 6,036	1,249 (22.8) N= 5,491	2,670 (48.7) N= 5,488	2,573 (48.0) N= 5,357
Physics	1,329 (54.5) N= 2,439	1,167 (52.5) N= 2,223	1,446 (49.0) N= 2,949	1,423 (50.1) N= 2,816	3,041 (79.7) N= 3,815	3,049 (87.1) N= 3,502	1,763 (69.5) N= 2,538	1,751 (67.0) N= 2,617	1,366 (55.9) N= 2,443	1,422 (52.5) N= 2,707
Chemistry	1,385 (56.6) N= 2,447	1,180 (53.0) N= 2,227	1,527 (52.0) N= 2,934	1,396 (50.8) N= 2,749	2,004 (55.5) N= 3,612	2,021 (57.2) N= 3,532	907 (35.4) N= 2,560	826 (30.8) N= 2,679	1,746 (71.7) N= 2,435	2,010 (74.8) N= 2,689
Agricultural Science	2,983 (54.7) N= 5,450	2,607 (56.8) N=4,589	3,807 (53.9) N= 7,061	3,329 (56.0) N= 5,944	4,982 (66.4) N= 7,507	5,015 (69.6) N= 7,205	2,184 (40.3) N= 5,422	1,791 (37.1) N= 4,832	3,673 (73.2) N= 5,016	3,364 (69.4) N= 4,844

N = Total number of students who took the examination in Ekiti State
Source: Ekiti State Ministry of Education (2013)

Table 2: Science Teachers' Socio-Demographic Characteristics, Course of Study and Subjects Taught

Membership of a Science Association

Only 24 (37.5%) of the science teachers were members of the Science Teachers Association of Nigeria (STAN), while the remaining 40 teachers (62.5%) were not.

Infrastructure for Science Studies

a. Laboratories

Age (in years)	
21-30	25 (39.1)
31-40	20 (31.3)
41-50	12 (18.8)
≥ 51	7 (10.9)
Gender	
Male	33 (51.6)
Female	31 (48.4)
Qualification	
NCE	10 (15.6)
HND	5 (7.8)
BSc/B Ed	49 (76.6)
Number of years since basic qualification was obtained	
0- 5 years	26 (40.6)
6-10 years	17 (26.6)
>10 years	21(32.8)
Possession of higher degree	
Yes	19 (29.7)
No	45 (70.3)
Course of study for basic qualification	
Physics	8 (12.5)
Chemistry	9 (14.1)
Biology	14 (21.9)
Mathematics	5 (7.8)
Integrated Science	7 (10.9)
Agriculture	7 (10.9)
Others	14 (21.9)
Courses taught in school	
Physics	11 (17.2)
Chemistry	12 (18.8)
Biology	14 (21.9)
Mathematics	9 (14.0)
Integrated Science	10 (15.6)
Agriculture	8 (12.5)
Years of teaching experience*	
0 - 5 years	21 (32.8)
6 -10 years	17 (26.6)
11-15 years	11 (17.2)
>15 years	8 (12.5)

7 respondents did not provide information on the number of years of teaching experience.

All the surveyed schools had a structure referred to as a Laboratory. In all schools, the laboratory was multipurpose in nature i.e. the same laboratory was used for the main Science subjects - Physics, Chemistry and Biology. All schools' laboratories had their equipment stored away in an adjoining room, but only 16.7 % of schools had an adequate structure, space and satisfactory equipment. About two thirds of the schools (66.7%) had a structure with space but had inadequate equipment while 16.7 % of schools had a structure but had limited or no space.

a. Library Facilities

Twenty five percent of the schools had no structure that could be referred to as a library while 33.3% of the surveyed schools had a structure referred to as a Library but these were grossly inadequate. The inadequacies observed include lack or limited tables and chairs with empty and poorly maintained shelves, where available. In two (2) schools where science books were sighted, the books were piled on top of each other and locked up in a cupboard. About forty two percent (41.6%) had a structure that was adequate in space and facility.

a. ICT Facilities

Only one school (8.3%) had a computer library that was adequate in structure, space and equipment. About two thirds of the schools surveyed (66.7%) did not have any structure called a computer library while 8.3% had a structure but this was limited in space and 16.7% had a structure with adequate space but inadequate equipment. There was no internet access in any of the schools

Students' Performances in Examinations (2009-2013)

Number of Students with at least 5 credits, including English and Mathematics:

Annual students' performance with respect to those having at least 5 credits and above including English and Mathematics during the period under review was poor as it ranged from 23% in 2012 to 33% in 2011 (Table 3).

Table 3: Number of Students Obtaining at Least 5 Credits, Including English and Mathematics (2009 – 2013)

Sex Distribution	2009	2010	2011	2012	2013
	N=12,358	N=14,613	N=17,149	N=11,956	N=10,896
Males	1,779	1,851	2,895	1,365	1,576
Females	1,580	1,616	2,792	1,375	1,473
Total	3,359 (27%)	3,467 (24%)	5,687 (33%)	2,740 (23%)	3,049 (28%)

N = Total number of students who took the examination in Ekiti State for the year
Source: Ekiti State Ministry of Education (2013)

Perception of Relevant Stakeholders as to the Status of Science Education in Ekiti State

Some of the stakeholders felt there was an improvement in science education in the State as they believed the government had a good intention to improve its current status through provision of necessary facilities. However, a divergent view is obtained from the FGD/IDI groups of the school population as they felt that science education was still suboptimal in the State.

> *"it is o.k, but there is a lot of improvement that is coming up now, like when I was in secondary school in Ekiti here, majority of us are on the science line, then along the line there was a decline in terms of laxity interms of government and governance but since the assumption to office of the current governor, there has been a lot of improvement even more than a thousand percent improvement because when you look at the time when you compare the result of the 2010 with that of 2013 then you will know what I am talking about. There is close to 80% pass mark and people are getting more interested in science again. the reason most of the students run away then was because of mathematics because if they*

don't have maths they may not be allow to enter school. With the investment the government had done in the education sector, provision of computer, i.e laptops to the student, provision of reading materials and other things that they have almost 100% free education that is going on, students are getting more interested now especially with the investment in science laboratory in secondary school. Science education is improving and you know we still have enough room to improve on it. All of them cannot do science and we cannot force them but with the present intervention, things have change" **IDI, a Legislature leader**

"It is one of the priorities of government to do next. Government has already yielded to their demands. This year budget should include that. Most of the buildings are being expanded. There renovating laboratories and the libraries. They have just concluded the infrastructure. If you go to all secondary schools you will see they are renovated". **IDI, Senior Officer, Ministry of Health**

''…..yes, I think the government has done much in that area, some schools have been renovated. I know some laboratories have been renovated too. the government is doing much interm of renovating the school, I think it is part of their plan to cover all the schools and make sure they have enough materials for their science courses." **IDI, NGO FEMALE YOUTH**

"though the state government has a good idea of giving laptops to Senior Secondary Students (SSS), the implementation was not encouraging because it was not well implemented. The problem was that they should not have given it to them to take home, when the project started, I was one of the people that said that this project will fail because of the model. There is way it is done and we need to learn from other countries. Countries have schools that have ICT in their classes. if you say we want laptops on every students table it is good, let us have an ICT center in every school, build a hall, equipped it with laptops, one it will be controlled and when you give them a server, there is a way you control what they can download. It is not something you give them to take home, I can have a big brother that is into yahoo yahoo and will use it. These laptops can even be configured in a way that no program will enter it. It depends on the applications you put there. This thing was not properly done and I know that the government had good intentions but they did not develop a good model and it was a huge investment. They should have just gone throughout the process, see it is not about doing things it is about doing it right. Even when they allow them to have an email, it should have been an intra net within the school, you have your friends email, you have your teachers and that of the principal and you can be monitored on the server. All those things should have been put in place and if you want to have a laptop on every desk let them have an ICT center. let us say they have 200 students in their SS1, build that hall and let us have the capacity and 200 laptops there, it is not compulsory to do it all at once. It is step by step". **IDI, NGO FEMALE YOUTH**

"2R: the status of science education in Ekiti state is very low, because in our school now we don't have functioning laboratories. the one we have is not even functioning again.
2R: they are chemistry and biology lab but it is only the chemistry lab that is functioning, eveb the chemistry lab is not well equipped because there are some equipment that we need that are not in the lab
3R: we don't have biology, we don't have physic, even the chemistry we have is not well okay." **Male FGD, SSS Rural Public School**

"I: o.k, fine you as a counselor in this school, I believe the school have laboratories, would tyou say they have adequate science teachers
R: no
I: the science teachers are not enough in comparison to the number of students here, what about the laboratories. you have laboratories in this school
R: yes, but we don't have enough, we need more, we don't have a standard one
I: the ones you have are they functioning
R: there is need for improvement " **IDI, Female School Staff, Urban Public School**

DISCUSSION

This study was conducted to assess the status of science education in Ekiti State using students' performance in science subjects, profile of science teachers and availability of functional science laboratories, libraries and ICT facilities.

On the average, students' pass rate in selected science subjects for most of the years under review (2009-2013) was below 50% for both sexes, but pass rates above 50% were reported for Chemistry, Physics and Agricultural Science. These findings demonstrate that students' performance in these science subjects has improved compared to what was obtained in the 5-year review from 2005-2009 by Akinyemi (2011) where students performance in all the core sciences was below 40% in each of the years reviewed. This supports the perception of some of the key informants who reported perceived improvement in science education in the State. The findings of Omorogbe and Ewansiha (2013) of pass rates less than 50% for 1995-2002 and 2000-2004 were for a much wider area that includes Ekiti State, but these also support the views that the status of science education had improved in the State. However, all the reports are still in keeping with low quality of science education. The level of poor student performance observed in this and previous studies are indicators of the poor quality of science education available in schools in the State.

Majority of the science teachers in this survey had a basic degree qualification. This is quite commendable as evidence has shown that the learning experience of students in enhanced where the teachers have degree qualifications and higher degrees as compared to the possession of lower qualifications such as the National Certificate of Education (NCE) (Darling- Hamond

2000; Akiri 2013). Quality of teachers has been linked to students' achievement and the criteria for determining such quality include their academic and professional qualifications, participation in in-service refresher courses and training, teachers' years of experience, teachers' remuneration and availability of quality teaching–learning resources. All these factors affect the way science is taught in schools (Omorogbe and Ewanisha 2013). In a bid to improve the quality of teaching, the Federal Ministry of Education had set a benchmark that the majority of teachers in Nigerian secondary schools should hold a degree qualification (FMOE 2005). There have also been calls for experienced teachers to be retained within the educational system as students achieve more from such category of teachers (Darling-Hammond 2000). Teacher qualifications and the years of teaching experience have been found to contribute to the quality of education. Higher qualifications and a greater number of years of teaching experience are both positively correlated with students' academic performance (Akinsolu 2010). In this survey, most of the teachers had less than 10 years of teaching experience and only 8 of them had taught for more than 15 years. This may be a disadvantage to the students as the experience of teaching garnered over the years serves to make the teacher much more effective in helping the students to learn. Other factors that have been identified to be associated with poor students' performance in science subjects are the absence of science laboratories, inadequate science equipment and specimens (Ajileye 2006).

Evidence has shown that the teacher-student ratio has a bearing on the quality of science education provided and the recommended international standard is a maximum of 30 students to one science teacher (UNESCO 2000; Huebler 2008). In Nigeria, the National Policy on Education advocated for a science teacher-student ratio of 1:40 (NPE 2004); though this is lower than the international standard, it is not envisaged that this will adversely affect the quality of science education to a large extent. However, it has been found that teaching effectiveness is improved with low ratios (Huebler 2008). In the schools surveyed, teacher- student ratio for the individual core science subjects ranged from 1:44 to 1:84, which were lower than the 1:40 recommended by international and national educational organizations recommendations (UNESCO 2000: NPE 2004). More teachers are needed for these subjects. Less than 40% of teacher's interviewed were registered members of a Science Teachers' Association. This implies that many of the teachers do not avail themselves of the opportunity of continuing professional development that such associations provide. This also has negative implications for the quality of teaching they can offer the students. Science teachers particularly at the secondary school level are in a unique position to lay the foundation for the transfer of this scientific knowledge to the next generation.

The infrastructure for the teaching and studying of science was found to be inadequate in most of the schools. Research has shown that such inadequacies contribute to the poor performance of students in science subjects (Ajileye 2006). It was also noted that there was inadequate access to ICT by the in-school youth. This is of great disadvantage to the youth in Ekiti State as the need for the possession of ICT skills among young people cannot be over emphasized in this technology driven age. Such skills not only engage students and help them to relate school experiences to work practices but also prepare them for their future role as productive individuals in the work force of the nation (Adomi and Anie 2006; Adomi and Kpangban 2010; Osakwe 2012). Furthermore, the lack of exposure to ICT threatens the ability of youths to compete in on-line national and international examinations such as the University Matriculation Examinations (UME) and post-UMEs conducted by universities.

Our survey found inadequately equipped laboratories in majority of the schools. This was in contrast to what Daluba and Mama (2012) observed in Kogi State, Nigeria, where almost two thirds of the schools surveyed had well equipped laboratories. In this study, three quarters of the schools surveyed had a structure referred to as a library but all of these were grossly inadequate. The availability of adequate infrastructure for science studies cannot be over emphasized if quality science education is to be achieved. The science laboratories serve to demonstrate reality to the abstraction of science subjects and hence foster a greater understanding of the concepts to students and by extension facilitate better students' performance. This has been documented by researchers as library materials and science laboratory equipment, and have been found to be positively related to students' performance (Orji 2006). Access to reference materials such as textbooks and e-books by students is very essential. It had been observed that students need to be proficient computer users for them to be able to function effectively and be productive in the technology driven world of today (Eisenberg and Johnson, 1996). Our survey discovered that only one school had adequate facilities to ensure such proficiency among the students. A similar situation has also been highlighted by other researchers who have observed the low level of computer usage in Nigerian secondary schools (Adomi and Kpangban 2010). This has implications for national development especially when considering the speed at which various new technologies are being developed worldwide to make the execution of tasks more effective and efficient. Inadequate supply of equipment and facilities for teaching science has been associated with poor performance (Ajileye 2006). The face of teaching and learning globally has been positively changed by the advent of information communication technology (ICT) and the need for the acquisition of ICT skills by students to facilitate their learning and contribute to the growth and development of the nation has been identified (Osakwe 2012). Challenges facing ICT development presently in Nigerian secondary schools range from inadequate curriculum content, lack of basic infrastructure and inadequate funding to lack of qualified personnel (Osakwe 2012). To ensure that young people are able to develop properly and compete favourably with their contemporaries in other countries requires a concerted effort of the government and other stakeholders to address these concerns.

This study is descriptive in nature, so no causal relationship could be drawn. Further studies to explore the effect of teachers' profile on the performance of students in science education is thereby advocated. Although this study involved rural-urban, public-private schools, this report was not stratified to include results based on the different locations because of limitations of sample size. Since the influence of location and types of school is important to the quality of science literacy, a future study is hereby recommended that would have a large enough sample to permit such stratification. School enrolment was not reported because it was not specific for science subjects.

This study demonstrated that the status of science education in Ekiti State as assessed by average pass rates in science subjects, science teacher-student ratio and availability of basic infrastructure for science education shows a lot of areas where intervention can lead to a marked improvement. The State Government and other stakeholders need to increase the amount of resources made available for the support of science education. There is a need to enhance teachers' professional training and development, and to institute retention programmes for experienced teachers. There is a need to renovate the laboratory and library facilities in the schools.

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CONFLICT OF INTEREST

The authors declare that they have no conflict of interest

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