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Table of Content

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Review

A view of road transport in Africa

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Transport sector is usually divided into four main modes: road, air, maritime and rail modes. In sub-Sahara Africa, road appears as the dominant mode. Railways were developed during the colonial period but almost abandoned since the independence in most countries. Air transport once seen as sign of economic prosperity and instrument of sovereignty is far from being competitive. Maritime transport is mainly on coastal areas, and still controlled by foreign companies. In this context, road transport, favored by the low purchasing power of the population and the geography of the continent, made of landlocked territories, becomes the main mode of transportation. This mode however is facing many challenges including: Poor maintenance, pollution, frequent accidents, lack of local industry, etc. Therefore, critical thinking and innovative ideas from various actors of this sector will be important to bring solutions to most issues.

Key words: Road, transport, car, infrastructures, innovation.

INTRODUCTION

Transport is an essential component of the economy allowing people and goods to flow from one area to another. The evolution of transport in Africa is well understood if historical approach is applied. Three eras are distinguish (Tchanche, 2013): the precolonial, the colonial and the post-colonial period. The precolonial period is marked by low development of infrastructure. The colonial period saw a development of differentiated areas, cities where stayed rulers and sub-urban and rural where most indigenous people live. In this period most transport infrastructures were built, and in some countries cities' master plan still follow that established decades ago by colonial masters. Most roads were built around the area where civil servants were living and few linking residential areas and farms. Exploitation of natural resources was one of the main reasons for colonization, and as such laborers and transport infrastructures were needed as well. Railways were then built to transport cotton, rubber, diamond, gold, etc., from mines and farms located in mainland to the coastal areas where they could be shipped to Europe (Pourtier, 2007). After the independence, most countries decided to establish plan for long term development, and there appeared a shift in policy. Newly chosen or elected governments decided to build infrastructure that will connect all parts of the country and sustain economic growth. Then the rail that was seen as a priority was relegated to a second position, and this is how the road progressively became the main mode of transport. The growing African population is bringing a lot of challenges to governments.

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Among these are energy, water, food, transport and mobility. All those who have travelled in African countries would acknowledge the critical situation of road transports on the continent. After more than a half century of independence, African citizen were expecting good infrastructure and better mobility conditions but all turn to disappointment. This study aims at reviewing road transport and poor conditions surrounding mobility in Africa, before solutions can be proposed. The paper is divided into three main aspects: (1) road analysis, (2) problems facing road transport and (3) suggestions for better mobility in Africa.

ROAD TRANSPORT ANALYSIS

Road transport is made up of several sub-modes that will be described and analyzed here: walk, animal carriages, taxis, motor bikes, buses, etc.

The walk

Walking is a common thing in developing African countries (Kumar and Barrett, 2008; Faye, 2012; Tchanche, 2018). People walk in urban areas to reach their houses, their job place, schools, hospitals, markets, etc. Although other means exist, people would prefer to move by foot. In fact, in urban areas private and public transports co-exist. Public transport is represented by taxis (known through specific colors), motorbikes (imported from Asia), minibuses, buses and other transport cars. In African megacities like Dakar, Abidjan, Lagos, Accra, Cotonou, and Douala, more than 70% of population use their feet for short distances (Faye, 2012). The choice of the walk as main mean of mobility is justified by the low purchasing power of the population and low development level of infrastructures (Kumar and Barrett, 2008). Walk requires a minimum number of conditions to be met. First shoes wore should be well adapted to the foot and to the type of road and weather. Second, dedicated space should be made available. Walking implies muscular effort for the walker which translates into skin transpiration. Walk exposes to random atmospheric conditions, insolation, wind, dust, rain and even tornado in some cases.

Walkers in urban areas do compete with cars on streets. On pavements, due to the small width walkers are forced to leave more often and confront the lane dedicated to the motorized vehicles. In some places, pavements disappear when some sellers use roads as marketplace pushing the walkers to walk on forbidden zones and putting their lives at risk. Crossing roads can be a very difficult exercise (Tchanche, 2018). Traffic lights are not common on most roads and where they are present they are rarely functioning because of lack of maintenance or not respected when they are in good conditions. Pedestrians then put their life at risk, while crossing or will spend a lot of time waiting for a kind driver to stop and allow them to cross. Because of the high speed and frequent accidents, authorities find useful to install “speed bumps”, often poorly designed to force the drivers to slow the speed and in some areas, they install a bridge to allow pedestrians to cross safely. However, they are not always adapted for people with disabilities and some of these underground bridges, are transformed into traps during nights and people will be reported attacked by armed robbers.

Rural areas usually receive less investments for infrastructure development (Tchanche and Diaw, 2017). Roads are more often in poor condition, unpaved and limited to tracks that allow people to visit their neighbors or relatives and to move to farms. This situation hampers the development of these areas which present very few opportunities, and the peasants cannot transport safely and efficiently agricultural products on the markets and thus most of their harvest is wasted. Health care facilities are usually far from the village and people will move to the nearest city, and this does not allow patients to be transferred easily and safely.

Animal carriages

Animal carriage is a mode of transport that involves animals pulling a mechanical structure. Animals often chosen are cows, donkeys and horses. Usually, we have one or more animals in front of a tray mounted on two wheels. They serve in rural areas and in urban areas as well, for the transport of people and goods (Tchanche, 2018). They are very popular in some countries and offer some advantages: affordability and flexibility (Faye, 2013). The average price for a trip is usually low, affordable for populations with low revenues. They easily adapt to unpaved roads and can stop almost everywhere to carry and debark passengers. Their speed is higher than that of a walker but very low compared to motorized systems. The carriages are usually locally manufactured by self-taught craftsmen, and the manufacturing time around three months. For owners, it constitutes an important source of income. Animals must be fed and well maintained. This transport means although popular has not attracted a lot of attention and needs to be examined Tchanche (2018). The identification of carriages is not always addressed. Dedicated lanes are not developed and they hamper the movement of motorists. The signalling systems do not exist as well as the lighting system.

Taxi bikes

Motorcycles are first used as private means of transport, and are characterized by their limited number of places, normally two the most. These engines have gradually

been transformed into a means of public transport in the recent history of Africa (Kumar and Barrett, 2008). They are known with different names (Hemchi, 2013; Kassi-djodjo, 2013): boda boda, benskin, jakarta, etc. They display many advantages: low investment cost, low operating cost, service affordability and flexibility. Usually, the driver takes a passenger with reduced luggage. It is very useful on tracks and areas not reachable by cars. These motorcycles are imported from Asia and especially China for their low cost of about US$ 600. In many countries where unemployment rate is relatively high among youth, it is considered as a fulltime job (Tchanche, 2017). However, their activities are not regulated or recognized by the authorities. There is no training provided to drivers and they use to learn by themselves. As consequence, they don't have a stable activity and at any moment they could be forbidden or imposed a specific tax by authorities. They have no insurance, and frequent accident may leave some with disabilities or lead to death(Kumar and Barrett, 2008). Some have seen it as a lucrative activity and hold small companies with several motor bikes. In this case the driver has a fixed amount to deliver per day, 3 up to US$ 5.

Taxi cabs

Taxis in African cities are five seats vehicles painted with specific colour: yellow, green, mix of yellow and black, etc. Depending on countries or cities the driver could carry one or several passengers for one or several directions. The cost of the trip is either adopted by the government or negotiated with the passenger. A taxi may have a specific area or could move in the entire city. In many countries, drivers and owners use to organize themselves in unions to defend their interest. They need a license and regularly pay insurance and other taxes related to their activity.

Minibuses and buses

Minibuses have appeared in most megacities to complement the limited offer of taxis and buses. They generally serve the popular neighbourhoods located on the outskirts of the city. They operate on specific destinations, linking sub-urban areas with the centre of the city. They are known with various names (Kumar and Barrett, 2008): trotro (Ghana), ndiaga ndiaye or car rapid (Senegal), Gbaka (Ivory Coast), etc. Usually, drivers and owners have a specific station and organize themselves in trade unions. Like for taxis, owners acquire a license and pay relevant taxes. Cars used as minibuses are imported from other continents, then modified to increase the number of seats and maximize profitability. Two individuals, the driver and his assistant manage the vehicle. One drives while the other takes care of boarding the passengers. Intra-urban bus transport is an endeavour with more or less experience in African cities. In an effort to organize urban transport, some governments established public transport companies: Dakar Dem Dik (Senegal), Sotra (Ivory Coast), Stecy (Cameroon), etc. They are managed by two individuals, the driver and the ticket vendor. The routes are well determined but the stopping points are not always visible and clearly identified. Maps of the route are quite rare or do not exist.

ISSUES SURROUNDING ROAD TRANSPORT

Urban transport management

The management of urban transport is a real headache in developing countries. Very often, the central authorities intervene only to regulate or collect taxes, the structuring being left to carriers who manage their best to find solutions. In order to defend their interests, they are often organized in trade unions or associations whose relations with the authorities are often tumultuous. Creation of transport authorities have been observed across the continent, in Senegal, Burkina-Faso, Nigeria, or Ivory Coast (Godard, 2013). Their success is clearly linked to the way they are funded. The example of the city of Dakar in Senegal with CETUD (Conseil Executif des Transports Urbains de Dakar) shows the need for such instruments. Such centre will be more effective in organizing city transport if their missions are well defined such as to avoid conflicts with supervising authorities that are the Ministry of Transport on the one hand and the local authorities on the other hand.

Road design

It is widely accepted that there is a correlation between the number of vehicles per inhabitant and the wealth, related to the gross domestic product (GDP) or more exactly to per capita income (Pojani and Stead, 2015). A high income would likely favour the acquisition of vehicles by the households. However, in developing countries, revenues are generally low compared to those of developed nations. This is seen from the following figures, in developed nations, the ratio is about 300 to 500 cars per 1000 inhabitants, while in Senegal the ratio is just 30. Therefore, road infrastructures cannot be conceived in developing countries as in developed ones. In developing countries, more than 70% of trips are done by foot and sometimes by animal carriages. When designing roads, it is essential to take this reality into account. In this regard, wide strips should be reserved for pedestrians so as to avoid promiscuity and provide benches in case of fatigue and even places to drink or shelter (for example in case of rain or heavy heat wave).

In case animals are used (camels, horses and donkeys), it is necessary to envisage another band of circulation and to organize the collection of the poop, to place drinkers. The road will then be reserved exclusively for motorized transport (tram, train, motorcycle, and other vehicles).

The profitability of transport equipment

A commercial transportation system to last long must be profitable. The economic criteria must then be applied, taking into account the socio-economic context. Investment and operating costs must be well evaluated. Investments include the purchase, start-up fees, and the shipping costs. Operating costs include the driver's and assistance salaries, insurance, miscellaneous taxes, maintenance and fuel costs. The calculation must incorporate inflation on fuels whose price volatility is well known. In most African countries, equipment and spare parts are often imported. Very few experiences of local automotive industries exist in Africa. In many countries including oil producing ones, fuel consumed is often imported from western countries as well. Expenditures must therefore be offset by the ticket price coupled with the vehicle's capacity and the frequency of the trips. An economic context marked by imports, low competitiveness and the poverty makes the development of transport companies difficult.

The maintenance of the car fleet

The maintenance of the car fleet is an absolute necessity. A number of systems must be frequently controlled: braking system, engine, tires, etc. A guide is usually provided by the manufacturer to help customers. However, maintenance is not taken seriously at it should be most of time, and the owner or the driver will find himself into trouble because of lack of maintenance. Maintenance is useful not only for security but also for the good operation of the car by keeping it in good condition. It's the owner or the company who decide what needs to be done, and the maintenance becomes less important. In case cars are used for business, what is most important is the revenue generated not the state of the means of transport. In a context of widespread poverty, the cost of maintenance may sometimes seem prohibitive and not considered as a priority. Hence, car fleet in most African nations are in poor condition. Periodic technical control is an obligation in many countries. It is necessary to periodically check the vehicle, and an expert is supposed to testify the good condition of the vehicle. During this process, all compartments should be carefully examined. Depending on the country, it can be done in a specialized or approved centre. However, drifts are often observed where the controls are not strict, or when the process is limited to a visual control and no technical test carried out with dedicated devices. The amazing case is when the owner without showing the car pays the fees and receives a certificate testifying the good condition of the vehicle.

Drivers' training

In principle, any driver of any vehicle must have a driving license. It is then necessary to follow a training for several weeks and to pass a final examination. During the training period, the apprentice learns how to drive and to keep the car. However, it is observed that in many cities the process of acquiring a driving license is not strict or appropriate. If there is a fraction that actually follows the training, there is another fraction that escapes. The license is often obtained against payment without having followed the necessary training and exams. Others use false documents or that belonging to a third party. There are drivers who have learned illegally and drive without any documents. Training materials is questionable and seems not to be adapted to the reality. They are usually imported from abroad. Since most African countries do not have their own traffic laws, they use those of developed countries which in no way correspond to the local reality. The learner must master panels he will ever see on roads. The reality is made up of unpaved roads, dust, rain, disorderly traffic, and traffic jams.

Breakdowns and assistance on the roads

It is common to find vehicles parked in cities as on major roads or see vehicles that are regularly towed by others. Breakdowns in full circulation are frequent and generate traffic jams. They provoke roads accidents. Buses often leave passengers in disarray who have to spend hours on a road hoping for a possible solution. This generates loss of time and money. Embarked on a journey where we are supposed to do two hours we end up spending all day. A traffic control system or a garage tracking system could help rescue motorists. Insurers should take assistance into account but it is rarely integrated into the products offered, and motorists must rely on their friendships or family solidarity to find a solution.

Layout, parking and track maintenance

Three types of roads are usually observed: paved roads, unpaved roads and tracks. Asphalt roads can in turn be classified into several categories, two-way roads and highways. Two-way paved roads with narrowed widths dominate because of their less prohibitive costs. The urbanization observed in recent years has been

accompanied by mobility difficulties with the congestion of roads and the slowing down of traffic, which is causing considerable economic losses. It is therefore necessary to develop new ways or to enlarge existing ones or sometimes to simply reorganize transport. In some cities the authorities have introduced the tram, as in Algiers or Tunis. However, track maintenance is a real problem. Roads are often left without maintenance, and include potholes, water ponds, damaged signalization system, failed traffic lights, and so on. Failure in maintenance can be costly for the community when finally, the infrastructure becomes useless (Faye, 2013). In an attempt to avoid accidents, poorly designed speed bumps are installed, which considerably slow traffic and increase air pollution. Parking for cars in African megacities is a serious problem. Parking areas are usually not well limited if not provided while the number of cars is constantly increasing. As consequence, drivers are obliged to leave their vehicles on the road or at best on the sidewalk or could spend a lot of time while trying to look for a parking. It would therefore be appropriate when designing pathways to incorporate this issue.

Insurance system

In a modern state, insurance system is made to provide drivers and car owners' minimum protection and support after an accident. A contract is mandatory for any vehicle, as is the registration card and driver's license. Insurance companies offer several levels of insurance: liability, theft, broken glass, travellers' protection, etc. The cost depends on the level requested by the customer, the more you are covered the higher the amount of the contract. However, in a context of widespread poverty, many vehicles circulate without insurance or the owners prefer to take the minimum level of coverage. On the other hand, misunderstandings remain about the role of insurance. When signing the contract, the insurance company assures the customer that it will be rescued in case an accident occurs. But, usually mistrust persists between both parties. The duration of litigation can be long, discouraging customers who in case of accident prefer an arrangement, as long as it is possible. The products offered are often insufficient. For example, technical assistance is non-existent for many companies and some products are exclusively for vehicles of less than five years old, whereas the average age of fleets is close to twenty years, and the fraction of vehicles of less than five is negligible.

Lifespan of vehicles

Motorized transport in Africa relies mainly on imported vehicles from other continents. Formerly carried out only by Europeans, during the colonial period, automotive sales have become an important activity of the diaspora, and African seaports are flooded with vehicles of all trademarks. Assembly plants exist in several countries, like Nigeria, Senegal, South Africa and Morocco, but the competition is fierce. The experiences of African manufacturers are still very limited. The only regulations that are imposed on imported vehicles concern only the age that varies from one country to another. In Senegal, for instance, the five-year age limit increased to eight in 2012. The quality of the vehicles: pollution level, braking system, engine quality, etc., are not checked. The lifespan is infinite and vehicles of almost forty years old in poor condition are still found on roads. The average age of the car fleet in Senegal for example is twenty years Tchanche and Diaw (2017). The obsolescence raises the question of reliability, safety and air pollution.

DISCUSSION AND WAY FORWARD

Road transport as outlined earlier, is surrounded by a certain number of issues which of course need to be addressed. It is said having in mind this quote by Albert Einstein: "we cannot solve our problems with the same thinking we used when we created them," in: A life of a genius, by Alexander Kennedy. Critical analysis and innovation are therefore highly needed. Critical analysis helps understand the issue and establishes the causes that created it. From there innovative ideas will bring out the solution to the problem. Innovation here is seen as a new idea, a new technology or a new method and involves improvement, originality and effectiveness. Innovative ideas can thus be applied to transport systems to make them more effective.

Management of transport systems

In most developing African nations, management of transport systems is a major concern and most of them failed in setting up a transport agency which would have helped finding solutions to transport issues. This is due to the lack of concertation among actors, lack of funds and the fear from already established authorities to lose the control of the sector while transferring some competencies to the new body. Innovative ideas would be in the form of a suitable framework for dialogue and appropriate financial arrangements, this being by tax collection or subsidies from the government.

Information technologies and development of assistance service

Assistance service on roads is very important. It allows drivers and passengers to travel safely and be rescued timely. In developing African nations, breakdowns and

accidents are frequent and most people lose their lives because of lack of rapid and appropriate intervention. Using information technologies, repair shops, restaurants, hotels, police stations and hospitals can be mapped so as to provide these information to passengers through their phones.

Improvement of drivers' training

Drivers training are another important issue. In some countries the literacy rate is low, and therefore training for this category of people should be available, and measures taken to reduce fraudulent driving licenses. Moreover, the training should be customized and adapted to the country instead of being a copy of what is done in developed countries while the environments are completely different. Frequent updates should be taken by drivers in specialized centres so as to provide them with new knowledge.

Setting an age limit for automotive vehicles

The lifespan of automotive vehicles is a major concern in African developing nations. While the age of the car fleet is found around 7 years in developed nations, in Africa it is above 20. In order to reduce the average age of their car fleet, some countries have fixed the age of the incoming imported cars, but this is insufficient. While a five years old car would enter the country, it could remain forever as there is no plan to phase out old vehicles. An age limit should be set, after what a car should be recycled. A proper mechanism could be put in place in order to retrieve old vehicles and replace them by new or more comfortable ones. An important benefit will be the reduced level of pollution and better air quality.

Improving technicians' skills

Cars are usually repaired in artisanal repair shops, where technicians have not received proper training and have learned by themselves. Programs could be set to allow them to follow established curricula, and seminars to adapt to the changes taking place in the automotive industry. If this is not done, most of new developed high-tech cars will not be suitable and well adapted for Africa because of lack of skilled technicians.

Increasing profitability of transport business

In developing African nations, transport business is usually risky. Usually cars are imported along with spare parts and fuels. This makes transport expensive for passengers and lead to low profit for transport companies. A solution for high fuel cost will be the construction of local and well adapted refinery plants, instead of importing low quality and expensive fuels. In order to lower the investment costs in transport, local automotive industry should be developed or at least some spare parts manufactured locally and assembly lines established.

CONCLUSION

Road transport plays an important role in African economies. The often-insufficient human and financial resources limit the choice of states in the selection of modes of transport. As a result, road transport remains predominant in most countries. The road sub-sector is divided into several segments according to the type of equipment used: walking, horse-drawn, motorcycle, and automobile following the use, public and private. Each of them has its own mode of operation and organization. The main infrastructure is the road, which because of the multiplicity of actors that interact on it must be designed taking into account this complexity and satisfy all users. However, this complexity is not always taken into account and the road sector generally operates in anarchy, which costs a lot to the economy of the African countries. The search for solutions should be based entirely on the sense of innovation of the various actors, who must invent new rules that fit the realities of the territories

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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Full Length Research Paper

Assessment of radiological risk from the soils of artisanal mining areas of Anka, North West Nigeria

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Assessment of radiological risk was carried out on twenty soil samples collected from agricultural, mining and mine processing areas in Anka, Zamfara State, North Western Nigeria. The measurement of activity concentration of ^{226}Ra, ^{232}Th and ^{40}K was performed using the gamma-ray spectrometer equipped with a high purity germanium detector. The values of the activity concentration of ^{226}Ra ranged from 24.69±4.26 to 82.20±15.62 Bqkg^{-1}, with a mean of 47.06±14.01 Bqkg^{-1}; ^{232}Th ranged from 22.52±3.44 to 159.47±16.81 Bqkg^{-1}, with a mean of 75.97±9.11; while ^{40}K ranged from 27.20±8.03 to 542.64±156.93 Bqkg^{-1}, with a mean of 216.02±62.37 Bqkg^{-1}. The concentration of the Radium equivalent in the study area ranged from 60.41 to 307.30 Bqkg^{-1}, with mean value of 172.33 Bqkg^{-1}. The absorbed dose rate in air was calculated and the values ranged between 26.80 and 135.02 nGyh^{-1}, with a mean of 76.64 nGyh^{-1}. The external hazard index was computed and the values ranged from 0.163 to 0.830, with a mean of 0.465. This value is within the safe limit of 1. The annual effective dose rate was calculated from the activity concentration with the minimum value of 32.87 µSvy^{-1}, while the maximum was 165.58 µSvy^{-1}, with a mean of 93.99 µSvy^{-1}, which is higher than the world average of 80 µSvy^{-1} but less than the recommended annual effective dose safe limit of 1 mSvy^{-1}. Therefore, the soil does not constitute radiological threat to the local population in the environment.

Key Words: Anka, artisanal mining, radioactivity, radiological, radionuclide, soil.

INTRODUCTION

Naturally occurring radionuclides within certain environmental matrix are able to assume hazardous radiological proportions as the activity concentrations of radioactive materials in the Earth's environment vary according to the geological formation. This is largely responsible for the uneven distribution of radionuclides and natural resources in the earth environment. The soil serves as a means of migration for transportation of radionuclides to the environment, it is considered the principal indicator to the radiological contamination in the

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in the environment (Elsaman et al., 2018).

A huge occurrence of about forty to fifty various types of untapped sub-terrain resources buried under the soil in Nigeria has been reported (Merem et al., 2017). Anka, is noted for crude mineral mining and processing by artisans alongside farming and cattle rearing (Salisu et al., 2016; Plumlee et al., 2013). Minerals, such as gold, copper, lead and zinc are mined and pre-processed in Anka and environs. These minerals deposits exist in alluvial and eluvia forms, with some occurring as vein within the meta-sediments of the area. Anka came under the radar following the discovery of rise in ill health and mortality rates amongst children in the isolated communities by health workers in the area. Investigation by Lo et al., (2012), suggested that the mining and processing of lead-rich ore inside villages in Anka led to soil contamination and that the polluted soil and ore dust were probably the main sources of lead exposure affecting children resident in ore-processing villages.

The environment where artisanal mining and processing activities are carried out is considered a major source of exposure to varying degrees of ionizing radiation. This radiation emanates from natural radionuclides present in rocks, soils, plants and water bodies and mining and mineral processing increase the concentration of the end products. The measurement of gamma radiation dose from environmental sources is of significance because radiation of natural origin is the principal contributing factor to the external dose globally (UNSCEAR, 1988).

Therefore, as the spread of radioactive elements in the earth environment is unequal and the concentration enhanced during mining activities, the knowledge of their level of concentration and distribution within the environment plays a major role in radiation safety. This work seeks to evaluate the activity concentrations and absorbed dose from ^{226}Ra, ^{232}Th and ^{40}K in the soils within artisanal mining and processing areas of Anka. It was recommended by Innocent et al., (2013), that periodic radiological assessment of proper radiation monitoring of the mining sites. Apart from complementing the previous findings, the result would be used to assess the radiological risk from natural radionuclides in the study area.

MATERIALS AND METHODS

Study area

With a population of 263,400 (Buba, 2016). Anka falls between latitude $11^0$51′N and $12^0$08′N, and longitude 5°51'E and 6°08'E. (Figure 1). However, samples were collected from mining and mine processing sites in Dareta, Abare, Dan Kampani and Daki Takwas. The Anka River is the main water body in the study area; it lies about one kilometer to the north of the town and numerous seasonal streams dissect the landscape, pouring into the major river, the Anka river (Figure 1).

The geology of Anka is characterized by the Anka schist belt that hosts the lead mineralization, and the lead-copper-silver-gold poly-metallic association. Anka is well known for artisanal gold exploitation for several decades and the mineral is hosted by schists, phyllites and quartzites associated with sub-regional structural elements subsidiary to the Anka fault (Waziri et al., 2013).

Sampling technique and sample preparation

Twenty (20) soil samples were systematically collected within 50 m from mining and mine processing sites as well as agricultural land. The samples were collected at an average depth of 10 cm. The samples were transferred to the Material Science laboratory at the Centre for Energy Research and Training, Zaria, where they were prepared. The samples were dried in an oven at about 120 to 150°C and ground into fine powder, using agate mortar and pestle, made of 99% silica to avoid contamination. The ground sample was sieved to 250 µm. 200 g of the prepared samples was packaged and transferred to the laboratory of National Institute for Radiation Protection and Research for laboratory analysis. The samples were weighed again, packaged and sealed in plastic cylindrical beakers, where they were stored for 28 days to allow for secular equilibrium between ^{238}U and ^{232}Th with their daughters, prior to the analysis.

Sample analysis

Sample analysis was undertaken at the National Institute of Radiation Protection and Research, University of Ibadan, Nigeria. Measurement of activity concentration of ^{226}Ra, ^{232}Th and ^{40}K was carried out with the gamma-ray spectrometer equipped with a high purity germanium (HPGe) detector enclosed in a 10 cm cylindrical multilayer graded shield. The application of this method is based on the secular equilibrium between uranium and thorium with their daughter isotopes. Prior to the sample analysis, the background gamma radiation at the laboratory was measured with an empty sample container under similar environmental conditions. The value was later subtracted during the computation of the activity concentration.

Data analysis

Activity concentration

Calculations of number of counts per second for the photopeak and activity concentrations of each detected radionuclides was based on the concept secular equilibrium being. The activity concentration in Bqkg^{-1} (A) in the samples was obtained as follows (Uosif et al., 2015).

$$A = \frac{N_s}{\varepsilon \eta m} \quad (1)$$

Where, N_s is net counts per second (CPS) = (sample CPS – background CPS), ε is the abundance of the γ-line in a radionuclide, η is the measured efficiency for each gamma-line observed, and the mass of the sample in kilograms is denoted by m.

The 1764.8 keV of ^{214}Bi gamma line was used to determine the activity concentration of ^{226}Ra while the activity concentration of ^{232}Th was determined with 2614 keV of ^{208}Tl gamma line. The gamma line of ^{40}K was determined directly from 1460.8 keV gamma line.

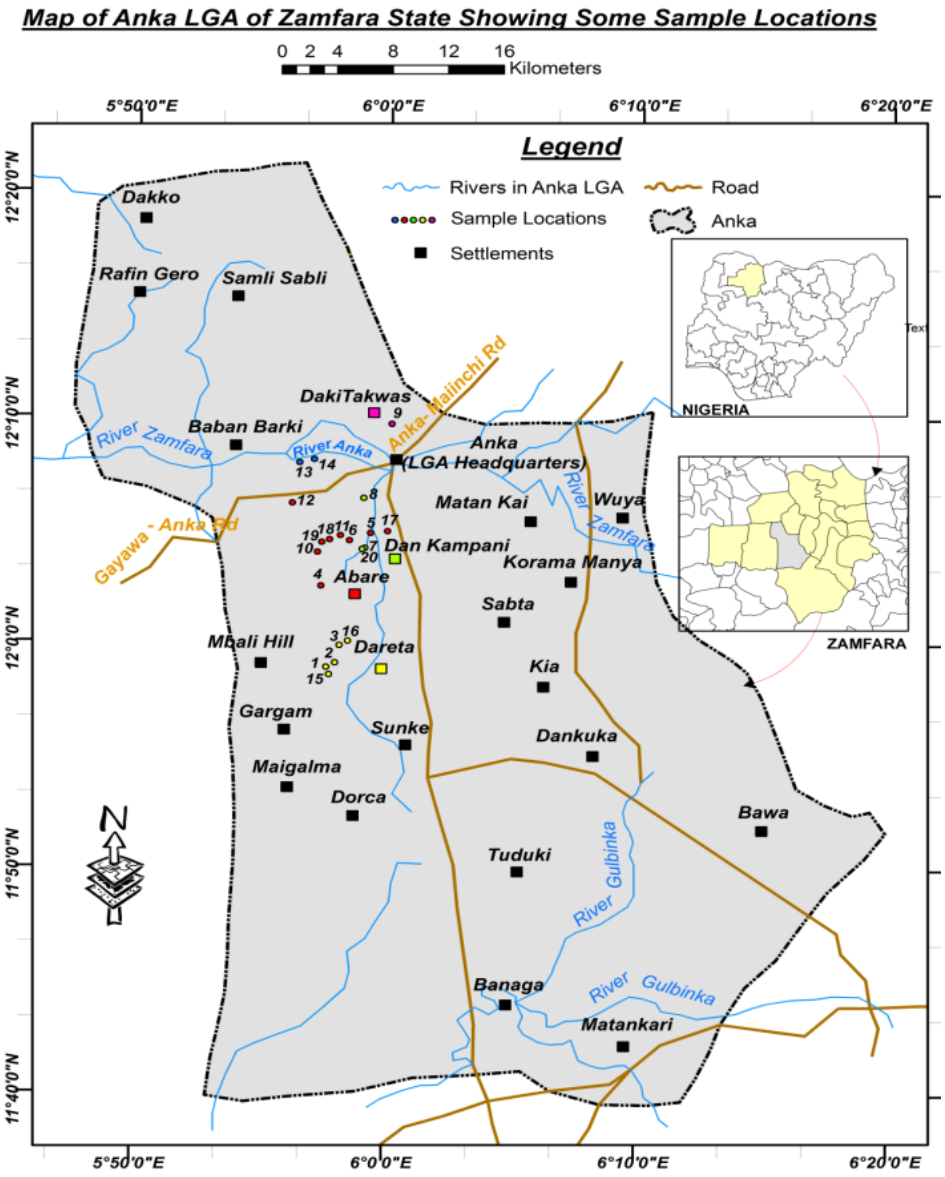

Figure 1. Map of Anka, Zamfara State, North Western Nigeria.

Radium equivalent (*Ra_{eq}*)

The radiological health effect can be determined by evaluating the radium equivalent effect because it is a measure of radiation hazard. This allows for uniformity in terms of radiation exposure and the comparison of the specific activity of materials containing different amounts of ^{226}Ra, ^{232}Th and ^{40}K (Mohamed et al., 2016; Uosif et al., 2015). Ra_{eq} is evaluated on the basis that the gamma dose rate produced by 370 Bqkg^{-1} of ^{226}Ra, 259 Bqkg^{-1} of ^{232}Th and 4810 Bqkg^{-1} of ^{40}K is the same (Mohamed et al., 2016).

$$Ra_{eq} = A_{Ra} + 1.43\,A_{Th} + 0.077A_K \quad (2)$$

where, A_{Ra}, A_{Th} and A_K are the activity concentrations of ^{226}Ra, ^{232}Th and ^{40}K in the samples.

Calculation of absorbed dose rate (D)

The outdoor absorbed dose rate at a height of 1 m above the ground level from terrestrial sources of gamma radiation can be determined by measuring the specific activity concentrations of the ^{226}Ra, ^{232}Th and ^{40}K in soil samples using the formula (Mohamed et al., 2016)

$$D\ (nGy^{-1}) = 0.462A_{Ra} + 0.604A_{Th} + 0.0417A_K \quad (3)$$

Where, D is given in nGy h^{-1}, A_{Ra}, A_{Th} and A_K are the specific

Table 1. Specific activity, radium equivalent, absorbed dose, Hazard index and annual equivalent dose rate for soil samples from Anka.

Sample code	Activity concentration (Bqkg^{-1})			Ra_{eq} (Bqkg^{-1})	Absorbed dose (nGyh^{-1})	H_{ex}	AEDR (μSvy^{-1})
	^{226}Ra	^{232}Th	^{40}K				
SL1	57.87±14.79	327.06±57.52	361.53±106.56	553.40	239.36±46.02	1.494	293.55
SL2	55.62±15.91	102.61±11.70	542.64±156.93	244.14	110.30±20.96	0.659	135.27
SL3	43.39±13.23	222.67±33.95	1052.34±305.67	442.84	198.42±39.36	1.196	243.34
SL4	31.40±6.29	325.22±45.23	342.19±100.49	522.81	225.21±34.42	1.412	276.20
SL5	26.11±8.19	22.52±3.44	27.20±8.03	60.41	26.80±6.20	0.163	32.87
SL6	24.69±4.26	39.02±7.30	173.55±50.51	93.85	42.21±8.48	0.253	51.77
SL7	54.55±13.80	55.66±7.91	174.39±50.75	147.57	66.09±13.27	0.399	81.06
SL8	42.46±10.58	346.99±50.49	794.38±231.38	599.82	262.32±45.03	1.620	321.71
SL9	60.10±15.03	88.47±11.75	332.73±96.46	212.23	74.31±13.70	0.573	116.60
SL10	47.06±12.79	34.59±4.84	106.52±31.09	104.73	95.08±18.06	0.283	57.73
SL11	28.28±14.27	54.62±7.40	184.79±53.83	104.73	47.08±10.13	0.283	65.93
SL12	34.84±15.35	64.25±8.43	439.55±127.23	120.62	53.76±13.31	0.326	89.81
SL13	54.53±14.51	73.32±8.56	194.63±56.56	160.56	73.23±17.49	0.434	89.81
SL14	53.02±14.32	111.16±11.84	123.70±36.18	174.36	77.59±14.23	0.471	95.16
SL15	75.38±16.72	362.30±35.49	542.16±159.20	221.50	96.79±15.28	0.598	118.71
SL16	31.17±13.82	209.07±36.53	940.66±274.38	635.22	276.26±35.80	1.715	338.81
SL17	17.99±1.24	92.43±12.25	85.91±25.57	402.57	179.90±39.89	1.087	220.63
SL18	23.84±3.48	193.14±25.76	508.27±148.88	156.78	67.72±9.04	0.423	83.05
SL19	51.05±10.69	63.33±8.52	299.24±86.71	339.17	148.87±23.38	0.916	182.57
SL20	18.72±2.02	234.62±32.90	761.69±221.86	164.65	74.31±13.70	0.445	91.14
Min	17.99±1.24	22.52±3.44	27.2±8.03	60.41	23.05±2.99	0.163	32.87
Max	75.38±16.72	362.30±57.52	1052.34±305.67	635.22	297.54±55.21	1.715	338.81
Mean	41.60±11.06	151.15±21.09	380.34±116.41	273.10	121.78±21.89	0.737	149.29

activity concentration of ^{226}Ra, ^{232}Th and ^{40}K, respectively.

External hazard index (H_{ex})

The external hazard index (H_{ex}) is widely used to reflect external exposure. It provides a solitary index that expresses the gamma yield from various combinations of ^{226}Ra, ^{232}Th and ^{40}K in the sample. It is defined as follows (Mohamed et al., 2016)

$$H_{ex} = \frac{A_{Ra}}{370} + \frac{A_{Th}}{259} + \frac{A_K}{4810} \quad (4)$$

Annual effective dose rate (AEDR)

The Annual effective dose rate (μSv y$^{-1)}$ was computed as described by Mohamed et al., (2016). The evaluation of year-long effective dose rates, the conversion factor from absorbed dose in air to the effective dose (0.7 SvGy^{-1}) and outdoor occupancy factor (0.2) given by Durusoy and Yildirim (2017) and Mohamed et al. (2016).

$$\text{AEDR}\ (\mu Svy^{-1}) = D(\text{nGyh}^{-1}) \text{x}\ 8760\ (\text{hy}^{-1})\ \text{x}\ 0.14\ (\text{SvGy}^{-1})\ \text{x}\ 10^{-3} \quad (5)$$

RESULTS AND DISCUSSION

The measurement of the radioactivity levels of ^{226}Ra, ^{232}Th and ^{40}K in soil samples collected from Anka was determined using the HPGe detector. These values including the Ra_{eq}, D, H_{ex} and *AEDR* are presented on Table 1. The values of the activity concentration of ^{226}Ra ranged from 17.99±1.24 (Abare) to 75.38±16.72 (Dareta) Bqkg^{-1}, with a mean of 41.60±11.06Bqkg^{-1}.

^{232}Th ranged from 22.52±3.44 Bqkg^{-1} (Abare) to 362.30±57.52 Bqkg^{-1} (Dareta), with a mean of 151.15±21.09; while ^{40}K ranged from 27.20±8.03 (Abare) to 1052.34±305.67Bqkg^{-1} (Dareta), with a mean of 380.34±116.41Bqkg^{-1}.

A summary of the activity concentraction of ^{226}Ra, ^{232}Th and ^{40}K is presented in Figure 2. Dareta accounted for the highest concentrations of ^{226}Ra, ^{232}Th and ^{40}K while Abare recorded the least values. Analysing the results obtained in this study, the mean activity concentrations for ^{226}Ra and ^{232}Th are higher than the world average of 35 Bqkg^{-1} and 30 Bqkg^{-1}, respectively (UNSCEAR, 2000).

The mean activity concentration of ^{40}K is lower than the world average of 400 Bqkg^{-1} (UNSCEAR, 2000). This generally suggests that the radioactivity concentration in the study area is higher than the world average.

The Ra_{eq} in the study area ranges from 60.41 to 635.22 Bqkg^{-1}, with mean value of 273.10 Bqkg^{-1}, which falls below the permissible limit of 370 Bqkg^{-1} set by

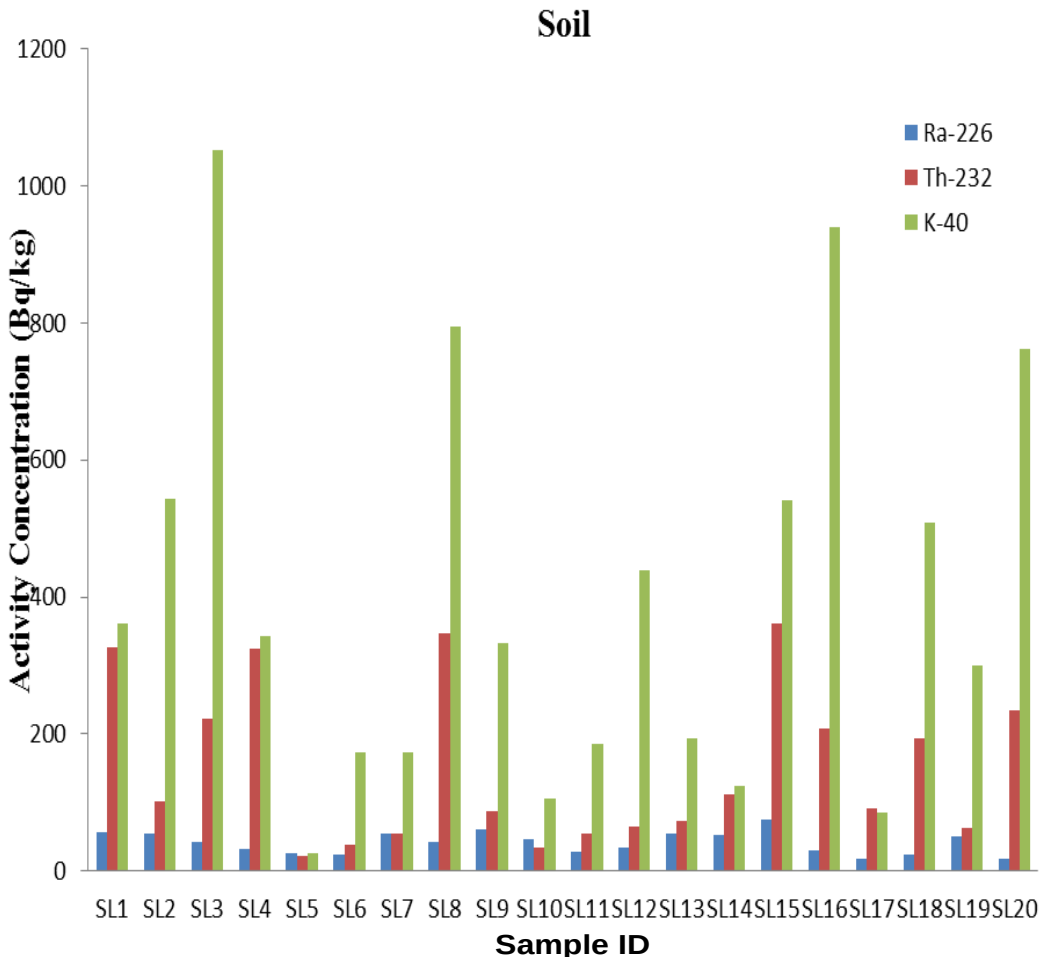

Figure 2. Activity concentration of ^{226}Ra, ^{232}Th and ^{40}K in soil samples of study sites.

Organization of Economic Cooperation Development (Miah et al., 2012).

The D in air values ranged between 23.05±2.99 $nGyh^{-1}$ and 297.54±55.21$nGyh^{-1}$, with a mean of 121.78±21.89 $nGyh^{-1}$. This value is higher than the world average value of 60 $nGyh^{-1}$(UNSCEAR, 2000), which indicates that the dose from the study area is higher than most places in the world.

The external hazard index values ranged from 0.163 to 1.715, with a mean of 0.737, which is less than the recommended limit of 1 (UNSCEAR, 2000). Generally, the radiation hazard in the study region can be assumed to be lower than the recommended limit but not insignificant as 33% of the sites showed high radiation hazard indices. The annual effective dose rate was calculated from the soil samples with the minimum value of 32.87 μSvy^{-1}. while the maximum was 338.81 μSvy^{-1}, with a mean of 149.29 μSvy^{-1}, which is higher than the world average of 80 μSvy^{-1}. This is less than 1 $mSvy^{-1}$, the limit on dose from public exposure.

Comparison of natural radioactivity levels in soils of Anka with those obtained from other studies within and outside Nigeria

A comparison of activity concentration of ^{226}Ra, ^{232}Th, ^{40}K and Ra_{eq} from different studies around the world and the present study has been carried out and is summarized on Table 2. For ^{226}Ra (47.06±14.01 $Bqkg^{-1}$), the minimum average concentration was recorded in Utagunmodi, Nigeria (Ademola et al., 2013) while the maximum average value of 102.08±3.96 $Bqkg^{-1}$ obtained was reported in Kedah, Malaysia (Alzubaidi et al., 2016).

The minimum average concentration of ^{232}Th of 11.41±3.28 $Bqkg^{-1}$ was recorded at Suez Canal region, Egypt (Fares et al., 2017) and the maximum average of 155.36 $Bqkg^{-1}$ was recorded in Kaduna, Nigeria (Gyuk et al., 2017). For ^{40}K, the minimum value of 102.8 ± 12.1 $Bqkg^{-1}$ was reported in Utagunmodi, Nigeria while the maximum average of 505.1 ± 7.1 $Bqkg^{-1}$ was reported in Utagunmodi, Nigeria (mining site) Ademola et al., 2013).

Table 2. Comparison of activity concentration and radium equivalent for soil of Anka with those of other regions/countries.

Country/region	Activity concentration (Bqkg^{-1})			Ra_{eq} (Bqkg^{-1})	Reference
	Ra-226	Th-232	K-40		
Panipat, India	30.24 ± 0.53	29.89 ± 0.61	291.06 ± 0.57	93.41	Kumar et al. (2017)
Malnichera Bangladesh	55.25 ±4.68	125.27± 5.81	497.91±43.83	269.24±16.06	Miah et al. (2012)
Zamfara, Nigeria	12.12±1.37	60.117±1.98	426.51±9.67	-	Innocent et al. (2013)
Kaduna, Nigeria,	62.28	155.36	459.56	-	Gyuk et al. (2017)
Balad, Iraq	-	-	-	33.241	Assie et al. (2016)
Kedah, Malaysia	102.08±3.96	133.96±2.92	325.87±9.83	458.785	Alzubaidi et al. (2016)
Punjab, India	56.74	87.42	143.04	192.76	Singh et al. (2005)
Suez Canal, Egypt	11.63±3.35	11.41±3.28	327.65±80.05	52.15	Fares et al. (2017)
Tulkarem, Palestine	34.5	23.8	120.0	72.0	Thabayneh et al. (2012)
Utagunmodi, Nig. Mining site	8.8 ± 1.9 55.3 ± 1.2	17.5 ± 2.7 26.4 ± 2.7	102.8 ± 12.1 505.1 ± 7.1	31.75 132.14	Ademola et al. (2013)
World	35	30	400	-	UNSCEAR (2000)
This study	41.60±11.06	151.15±21.09	380.34±116.41	373.10	

Table 3. Comparison of absorbed dose, external hazard index and annual effective dose rate for soil of Anka with those of other regions.

Country/region	Absorbed dose (nGyh^{-1})	H_{ex}	AEDR (µSvy^{-1})	Reference
Panipat,India	44.16		54	Kumar et al. (2017)
Malnichera, Bangladesh	124.12±7.59	0.601	152.23±9.31	Miah et al. (2012)
Zamfara, Nigeria	59.70±2.23	-	73	Innocent et al. (2013)
Balad, Iraq,	17.558	0.089	70	Gyuk et al. (2017)
Kedah, Malaysia	141.62	0.859	168	Assie et al. (2016)
Punjab and Himachal Pradesh,India	-	0.52	87	Singh et al. (2005)
Egypt. Suez Canal	26.12	0.14	-	Fares et al. (2017)
Tulkarem, Palestine	35.5	0.30	44	Thabayneh et al. (2012)
Utagunmodi, Nig. Mining Site	20.4±2.1 66.3±4.1	0.11 0.36	132.62 439.73	Ademola et al. (2013)
World	57	-	-	UNSCEAR (2000)
This study	121.78	0.737	149.29	

A comparison of the average radium equivalent activity Ra_{eq} indicates that the minimum average of 33.241 Bqkg^{-1} was reported in Balad, Iraq [(Assie et al., 2016) whereas the maximum average of 458.785 Bqkg^{-1} was reported in Kedah, Malaysia (Alzubaidi et al., 2016).

Table 3 summarizes the comparison of absorbed dose, external hazard index and the annual effective dose rate obtained from different studies. The average minimum absorbed dose and external hazard index were recorded in Balad, Iraq with values of 17.558 nGyh^{-1} and 0.089 respectively (Assie et al., 2016). However, Kedah, Malaysia Alzubaidi (2016) recorded the average maximum value of 141.62 nGyh^{-1} for absorbed dose and 0.859 for external hazard index. The average minimum of annual effective dose rate of 30 µSvy^{-1} was recorded in Suez Canal region, Egypt (Fares, 2017) while the average maximum of 439.73 µSvy^{-1} was recorded for mining site, Utagunmodi, Nigeria (Ademola et al., 2013). The result by the latter is however not consistent with those obtained from other studies considering the level of activity concentration of natural radionuclides from which the annual effective dose rate is evaluated. The values would have been much lower and consistent with the result of this study.

Conclusion

The gamma-ray spectrometer equipped with a HPGe detector was used in the measurement of activity concentration of ^{226}Ra, ^{232}Th and ^{40}K from soil samples in Anka, Zamfara State. From the result obtained in the

study area, the mean activity concentrations for ^{226}Ra and ^{232}Th are higher than the world average of 35 $Bqkg^{-1}$ and 30 $Bqkg^{-1}$, respectively (UNSCEAR, 2000). Generally, the radioactivity levels recorded in this study is higher than those recorded by Ademola et al. (2013) and Innocent et al. (2013) (Table 2). Hence, the increase in artisanal mining activities in the study area is increasing the external gamma radiation. The mean external hazard index was evaluated to be 0.737, which is less than the limit of 1. The annual effective dose rate is less than the limit on dose from public exposure (1 $mSvyr^{-1}$); this suggests that the risk of radiation hazard to humans and animals is insignificant. Hence, the soil does not constitute radiological threat to the local population in the environment.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interest.

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Exergy consumption analysis of the transportation sector of Senegal

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Exergy analysis has become widely recognized and adopted as a powerful tool for physical and engineering systems analysis. In this paper, it was applied to transportation modes. Transport is second after the residential sector in Senegal when it comes to energy consumption and relies on imported fossil fuels. In 2013, it consumed around 32 PJ which represented 30% of total energy consumed in the country. Exergy use dynamics shows that roadways dominate and have been experiencing an increase in exergy utilization since 2000. Air transport which played important role till 2006 has very little contribution in 2013. The mean weighted exergy efficiency is low, 13.74% that is, more than 80% of exergy used is lost. This low performance is partly due to poor infrastructure, old car fleet and low level of organization. Therefore, appropriate measures should be applied to modernize the transportation sector, and specifically reduce fossil fuels use.

Key words: Transport sector, exergy utilization, exergy analysis, exergy efficiency, fossil fuels.

INTRODUCTION

Transport is a critical component of the economy that assures the mobility of people and goods from one area to another. The infrastructure comprises roads, airports, seaports, etc. on which goods, people and equipment move. Equipment is set to allow the mobility by carrying a determined quantity of goods and a number of people. Transport is based on the use of energy or better said its conversion. Various types of energy fuels can thus be used and transformed by different kinds of machines. Machines and fuels have evolved along history. Nowadays, mankind has the possibility to choose among large set of equipment; automotive, train, plane, ferry, etc. Each of them uses specific types of fuels. In ancient times, only natural means of transport (walk, water, animal) were used, but this progressively changed, especially during the industrial revolution when steam engines where invented. Coal played an important role as it was considered the paramount fuel for ships and trains. It lost its prestigious role as the oil products became popular in newly designed motors, more adapted for road transport. However, their uses have brought serious damage to the environment, which includes pollution, drought, frequent typhoons, etc. Negative effects of fossil fuels and climate change are now pushing to a shift from traditional fossil fuels (gasoil, coal, gasoline) to cleaner and environmentally friendly fuels, such as electricity,

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biofuels and hydrogen in transport (Browne et al., 2012; Fayaz et al., 2012).

In Senegal for instance, and according to a previous study, transport accounts for more than 10% of the GDP (Gross domestic product) and consumes around 32 PJ which represent 30% of total final energy consumption (Tchanche and Diaw, 2017). It is a four-mode system that comprises roadways, seaways, airways and railways. They are all based on oil products; gasoil, gasoline and jet fuel. Roadways and highways dominate and accounts for large percentage in the mobility (Tchanche, 2017).

Large proportions of vehicles are second-hand imported mainly from Europe, while a small proportion is mounted locally. Around 600,000 vehicles made up the car national car fleet, 60% use gasoil, and the remainder gasoline. Maritime transport is developed on the Atlantic coast where ferries carry on regular base people between Dakar and The Casamance regions. Senegal hosts a dozen airports, distributed across the country. A new airport is located in Diamniadio, some 50 km from Dakar, and is designed to host at least 3 million passengers per year. The government recently decided to enhance national traffic by opening a new airline company, Air Senegal. Since the independence in 1963, railways have been progressively let apart as more roads were built in the country. This was also the consequence of social and economic transformation that took place in the past fifty years. The mainline Dakar – Bamako is in poor physical condition, as operators successively went bankrupt. In view of modernizing the rail infrastructure, a rehabilitation plan was set by the government and an electric railway called TER between Dakar and Diamniadio was inaugurated early this year.

In 2000s, the country faced a severe energy crisis as a result of high crude oil prices and the government decided to set an energy statistics office based in the Ministry of Energy. The office aims to collect and analyse data related to the energy sector for better planning and coherent policy. The energy system of the country despite the mass of available data already collected is still not well understood. In a recent study, an analysis was carried out, and the first results were extracted (Tchanche, 2018). Senegal's energy system relies heavily on biomass and fossil fuels. Biomass is used in residential sector for cooking activities, while fossil fuels are used mostly for transport and electricity generation. Another outcome was that the economy of the country is at risk due to fossil fuels imports. Senegalese have been enthusiastic as their country is poised to become in a near future an oil producing country as oil fields have been discovered and expected production could reduce imports and bring additional revenues to the State. The present study focuses on the transport sector, and the analysis is carried out from an energy viewpoint.

The novelty of the work resides in the approach that combines both energy and exergy flows. Energy analysis is based on the first law of thermodynamics, which is the principle of equivalence between different forms of energy. In view of better utilization of natural resources, many authors have recommended the exergy concept which integrates the interaction between systems and their environment (Vosough et al., 2011; Wall, 2011; Novak, 2017). Exergy is defined as the maximum work that can be extracted from a stream when it comes to equilibrium with the environment and this concept is based on the second law of the thermodynamics. Exergy analysis was applied to different types of systems; buildings (Xydis et al., 2009), renewable energy systems (Hepbasli, 2008; Wall, 2014), communications systems (Aleksic, 2013), heat engines and power plants (Tchanche et al., 2010; Marchionni et al., 2018), societies and states (Wall et al., 1994; Mosquim et al., 2018), etc. and proved to be a useful tool for decision making. It has been used recently for analysis of transport sectors for performance assessment (Jaber et al., 2008; Koroneos and Nanaki, 2008; Badmus et al., 2012; Mitra, 2014). The same approach has been applied here to determine the efficiency of the transportation systems in Senegal. The present study is structured into several sections; (1) methods where theoretical background of the work is introduced, (2) results which are subsequently analysed and discussed and (3) a conclusion given at the end.

METHODS

Energy and exergy of a fuel

A fuel is characterized by its lower heating value (LHV), which is the energy content. Take m as the mass of the fuel (in kg), the quantity of energy (En) it contains is given as:

$$E_{n,fuel} = m.LHV \quad (1)$$

The total energy used within the transportation sector is the sum of energy used in each mode by all engines. And therefore, it is given as:

$$E_n = \sum_i E_{n,i} \quad (2)$$

The exergy of a fuel (chemical exergy) is evaluated using the following equation:

$$E_{x,fuel} = m.\gamma_l.LHV \quad (3)$$

Where γ_l stands for the exergy factor based on lower heating value (LHV). Table 1 gives LHV for various fuels.

The total exergy used within the transportation sector is the sum of exergy used in each mode by all engines. And therefore, it is given as:

$$E_x = \sum_i E_{x,fuel,i} \quad (4)$$

Table 1. Lower heating value (HLV) of fuels (25 °C, 1 atm).

Fuel	LHV (MJ/kg)	Exergy factor, γ_l
Gasoline	44.300	1.07
Fuel oil	40.400	1.07
Diesel oil	43.000	1.07
Kerosene	44.100	1.07

Source: Badmus et al. (2012).

Energy and exergy efficiencies

The energy efficiency of a heat engine is the ratio of the useful power (W) produced to total energy input. It can thus be defined as:

$$\eta = \frac{W}{E_{n,fuel}} \quad (5)$$

The mean weighted energy efficiency of the transportation sector is the sum of energy efficiency of each engine category multiplied by the fraction (p_i) of fuel energy consumed. Therefore, the mean weighted energy efficiency can be written as:

$$\eta_g = \sum_i \eta_{m,i} . p_i \quad (6)$$

The exergy efficiency is the ratio of exergy contained in useful products to the exergy contained in all input streams. Thus, it is defined as:

$$\psi = \frac{W}{E_{x,fuel}} = \frac{\eta}{\gamma_l} \quad (7)$$

The mean weighted exergy efficiency of the transportation sector is the sum of the exergy efficiency of each type of engine multiplied by the fraction of energy consumed.

$$\psi_g = \sum_k \psi_{m,k} . p_k = \sum_{i.k} \frac{\eta_{m,i}}{\gamma_{l,k}} . p_k \quad (8)$$

RESULTS AND DISCUSSION

Data related to the transportation sector of Senegal were collected from the Ministry of Energy for the period 2000-2013 (MINEE, 2005; MEDER, 2006, 2014; MINE, 2007, 2013; MINCITAIE, 2010), and further analyzed from both energy and exergy viewpoints. Exergy consumption, energy and exergy efficiencies were determined. Motors used in the transport sector bear different efficiencies linked to their thermodynamic design and technology. Diesel engines are based on Diesel's cycle, gasoline engines operate on Beau de Rochas/Otto thermodynamic cycle, while propulsion systems used in aircrafts are based on Joule's cycle. Theoretical analyses give higher thermal efficiencies, close or above 50% for these cycles. However, practical design allows lower performance and manufacturers of internal combustion engines, give rated efficiency of 28% for diesel and gasoline engines, and 35% for gas turbines. Nevertheless, these values do not remain constant during their lifetime, and in operation, it is estimated that for a fleet of cars, 22% can be considered for road vehicles, 28% for aviation and 15% for marine engines. The above values were proposed by Reistad for the transportation sector of the USA (Dincer et al., 2004; Utlu and Hepbasli, 2006). In regard to the conditions surrounding transport sectors in developing countries, these values can be misleading. Badmus et al. (2012) mentioned it in their study and proposed to use 14.68% for roadways. Similar remarks can be drawn for other modes, but no alternative has been proposed. Therefore, for Senegal we will use 14.68% for road vehicles, 28% for airplanes and 15% for marine engines.

Exergy consumed in the transport sector shows irregular variation as can be seen in Figures 1 to 4. It is seen that exergy is consumed mostly on roads which at the same time show constant increase as shown in Figure 1. The constant increase is in line with the increase of the number of imported and registered vehicles in the country. This number as shown in a previous work is in constant increase (Tchanche, 2017). In the early 2000s, second hand vehicles could not be older than five years of age, but a new law was passed on in 2012 that sets a new limit at eight years. The import of second-hand vehicles has spurred in the country, as members of the Senegalese diaspora see automotive sales as lucrative business. Statistics on automotive sales also show that most vehicles sold are second-hand, and in poor conditions. These poor conditions mean high fuel consumption in comparison with a brand new car.

The air mode had important amount of exergy before 2006, but since 2007 the amount of exergy consumed has been drastically reduced as seen in Figure 2. A brief recall of the history of the Senegalese civil aviation is necessary to understand the dynamics in the exergy consumption. Air transportation by African airlines does not seem to be a good business, as many hurdles are present in the sector. Few airline companies however make the exception. By 1971, Senegal has interests in two companies, Air Afrique and Air Senegal. In 2002, Air Afrique went bankrupt as a consequence of a lack of

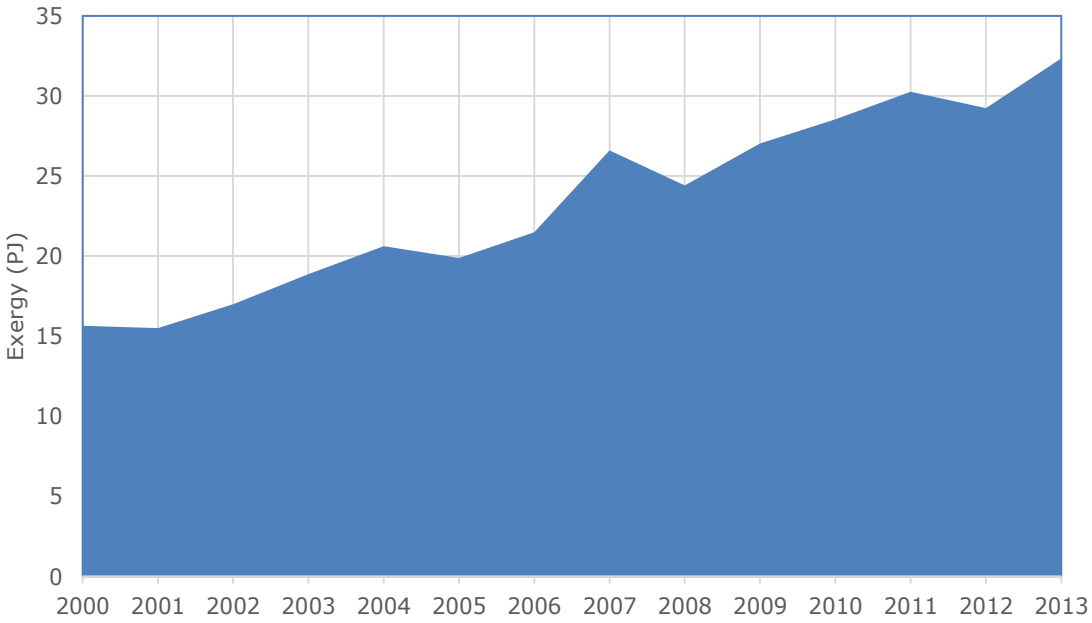

Figure 1. Exergy consumption dynamics on roadways.

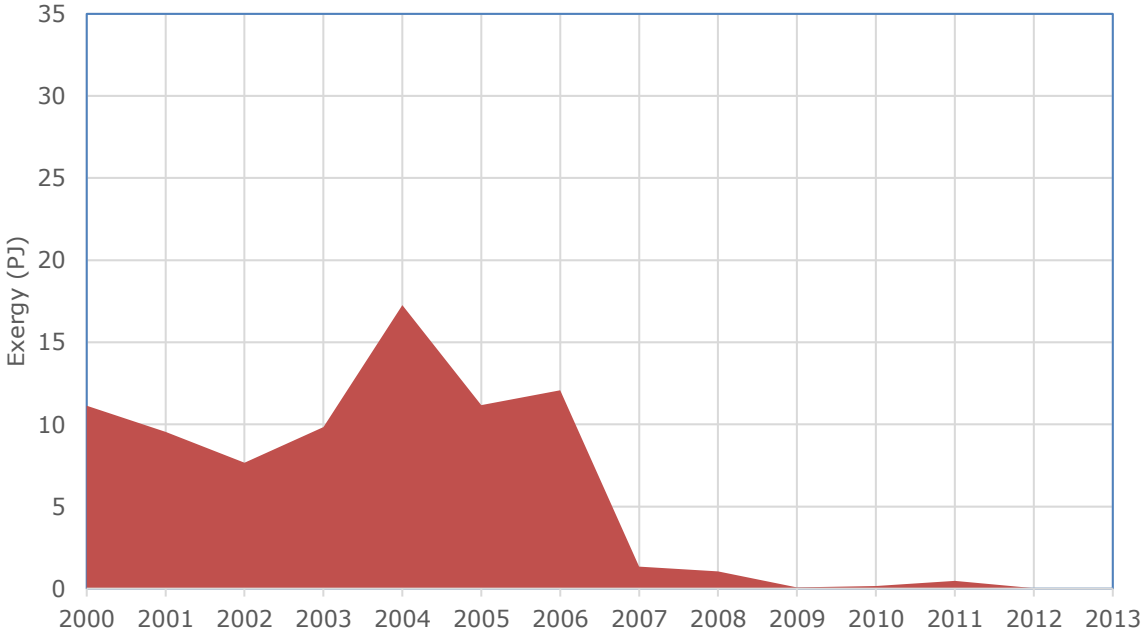

Figure 2. Exergy consumption dynamics in the aviation.

strategic management from member states that preferred their own national companies. Early in 2000, Air Senegal went bankrupt. The Senegalese government then decided to create a new company, called Air Senegal International (ASI). It started operating in 2001, but mismanagement and disagreements among partners didn't allow the company to live long, and then closed up in 2009. This explains why in Figure 4, from 2009 it does show very little or no exergy consumption. After the closure of ASI, some local businesses decided to team up with the government to found another company, Senegal Airlines, and its activities were launched in 2011. As you can see little exergy appears in 2011, but this other company went bankrupt and was dissolved in 2015. The amount of exergy consumed in the maritime subsector is relatively stable, around 1.4 PJ as can be

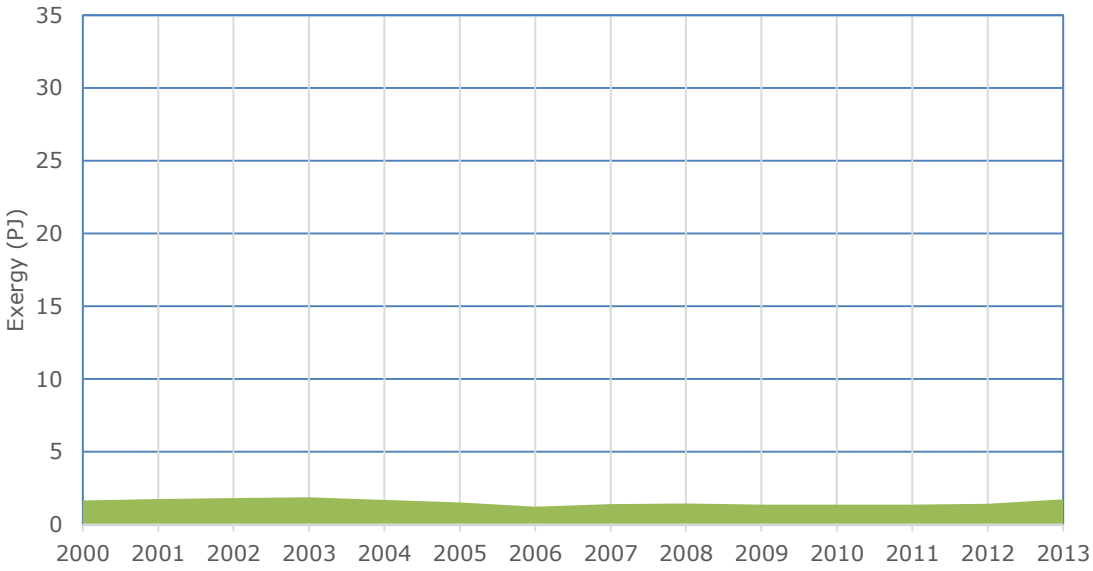

Figure 3. Exergy consumption dynamics on waterways.

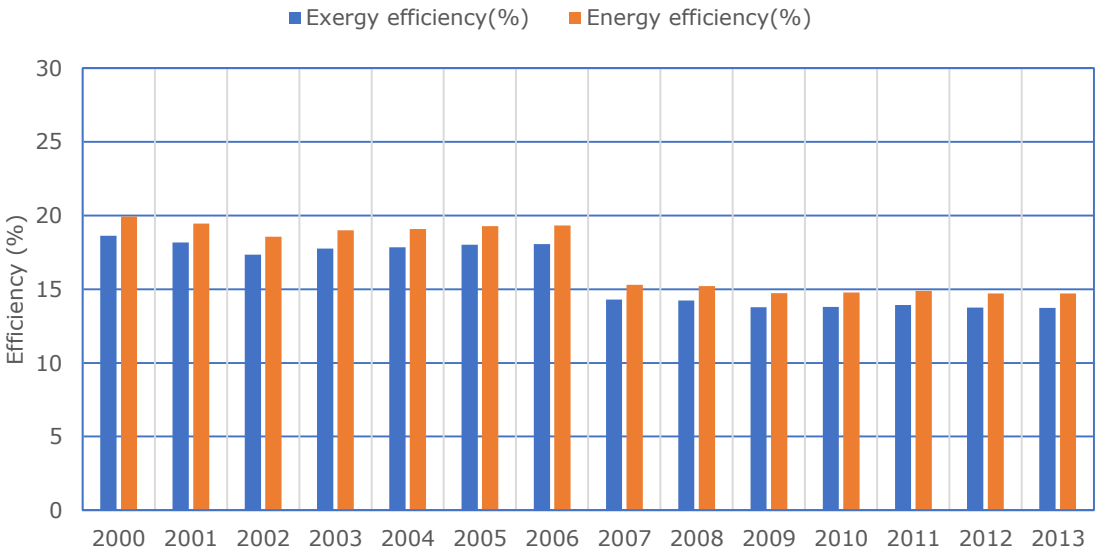

Figure 4. Mean weighted energy and exergy efficiency variation in the period 2000-2013**.**

seen in Figure 3. The exergy consumption here is due solely to ferries linking Casamance and Dakar regions and fishing activities. The traffic is not very important even though the number of passengers have been increasing. Political instability in the Casamance region and lack of investments in the maritime transport have prevented growth in this sector. It should be noted here that in the course of this study, railways were not taken into account due to lack of data. The amount of exergy displayed on different graphs is in line with the intensity of activities found within the transportation sector. It is here confirmed that road transport is the dominant mode and therefore have great impact on the development of the country.

Figure 4 shows the evolution of the energy/exergy efficiency of the whole transport sector. Energy efficiency is higher than exergy efficiency, but both decreased from 2006. Exergy efficiency shifts from its level of 18.62% down to 13.74% and energy efficiency from 19.92% down to 14.70%. The reduction in performance is due to low level of exergy consumed in the aviation mode – see exergy dynamics in the aviation on Figure 2. Results however, show poor performance of the transport sector and room for improvement. Excess exergy losses can be

Table 2. Exergy efficiency values in different countries.

Country	Exergy efficiency (%)	Reference
Saudi Arabia (Ro+Ai+Wa)-2000	21.84	Dincer et al. (2004)
Turkey (Ro+Ai+Ra+Wa)-2000	22.76	Ediger and Çamdali (2007)
Senegal (Ro+Ai)-2013	13.74	Present work
Jordan (Ro+Ai)-2006	22.70	Jaber et al. (2008)
Greece (Ro+Ai+Ra+Wa)-2000	21.23	Koroneos and Nanaki (2008)
China (Ro+Ai+Ra+Wa+Pi)-2008	20.41	Zhang et al. (2011)
Nigeria (Ro+Ai+Ra+Wa)-2010	13.85	Badmus et al. (2012)

Ro: road, Ra: railways, Ai: air, Wa: waterways, Pi: pipes.

attributed to many reasons. The poor engines operation of old cars is one, as the average age of the car fleet is 20 years (Tchanche, 2017). Low efficiency means also mean waste of fuels and increased carbon dioxide and particles matter emission. Another reason worth mentioning is the poor quality of road infrastructure, most kilometres of roads being unpaved and paved, are in poor conditions due to lack of maintenance. Senegal is a net-oil importer country which imports crude oil to be refined locally, and oil products of poor quality. In this context, increasing the performance of the transport sector would mean a lot of financial resources saved. Another advantage associated to the reduction of fossil fuels consumption is the improvement of air quality and less cases of respiratory illnesses and diseases. Air pollution from traffic has become a major concern in Dakar where concentrations of pollutants are usually above acceptable levels set by the World Health Organization (Faye, 2012). Therefore, it is absolutely necessary to curb down the quantity of fossil fuels used in the transport sector while modernizing the transport sector.

Table 2 gives values of exergy efficiencies in many countries. Most values are above 20%, and Turkey has the highest exergy efficiency. Lowest efficiency values are found for Senegal and Nigeria. These values were calculated based on the same hypothesis for road transport as they show similarities. Hypothesis used by most authors are based on Reistad's work (Utlu and Hepbasli, 2006), and could be misleading as values for engine's efficiency vary from one country to another. A sound approach would consist of considering measured values from a car fleet, and apply statistical analysis to extract representative values. However, exergy performance of transport sector obtained is low. Close to 80% of exergy consumed is dumbed in the environment. This calls for a new thinking.

Conclusion

Transport is an important component of the economy which assures the mobility of people and goods from one area to another, and requires a particular attention pertaining to its role. It becomes therefore a necessity to assess its performance using appropriate tools. In this study, exergy analysis was applied, and results show poor performance of the transport sector. It thus calls out for necessary improvements. For the specific case of Senegal, it is absolutely important that national car fleet be renewed and ways being sought to reduce the negative impacts of higher polluting diesel oil massively used on roads.

CONFLICT OF INTERESTS

The author has not declared any conflict of interests.

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Full Length Research Paper

Effect of seed pre-treatment and its duration on germination of *Detarium microcarpum* (Guill. and Perr.)

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Detarium microcarpum **Guill and Perr is a multipurpose tree species indigenous to semi-arid regions of Sub-Saharan Africa. It is being exploited to local extinction due to high dependence for fuelwood and other uses. The present study explored different pre-treatment methods for enhancing seed germination and growth of *D. microcarpum* in the Guinea savanna zone of Ghana. The experiment employed a 4 × 4 factorial design with seeds subjected to four pre-treatments (50% sulphuric acid concentration, 98% sulphuric acid concentration, cold water and hot water) at four pre-treatment time durations. Percentage germination varied significantly between pre-treatments ($p < 0.05$) with cold water treatment recording the highest mean germination (73.06%) and the 98% sulphuric acid concentration recording the least (47.72%). Germination rate had a moderate positive relationship with plant height ($r_{xy} = 0.49$) and collar diameter ($r_{xy} = 0.54$). The study recommends seed immersion in cold water for 48 h as the most efficient pre-treatment for *D. microcarpum.***

Key words: *Detarium microcarpum*, germination percentage, plant height, pre-treatment.

INTRODUCTION

Detarium microcarpum is a perennial woody plant indigenous to the semi-arid regions of Sub Saharan Africa which occurs predominantly in Benin, Burkina Faso, Cameroon, Central African Republic, Ghana, Guinea, Guinea Bissau, Niger, Nigeria, Senegal and Togo (Oibiokpa et al., 2014). There are two reported species of the genus with *D. senegalensis* growing in riparian and dry forests areas, whilst *D. microcarpum* grows in dry savannas (Tropical Plant Database, 2019). *D. microcarpum* thrives in a wide variety of soils including degraded and rocky areas with annual rainfall of about 600-1000 mm (Abreu et al., 1999). Although it is commonly found in fallow lands and wild bushes, it is sometimes retained on farmlands for soil improvement, fuelwood, food and medicinal purposes (Oibiokpa et al., 2014).

According to FAO (1995), *D. microcarpum* is a leguminous tree species which improves soil fertility when retained on farmlands through nitrogen fixation and leaf litter decomposition. The edible fruits of *D. microcarpum* are consumed by human and wild animals in regions where the species is found (Akpata and Miachi, 2001).

The fruit flour is reported to contain about 42% carbohydrates, 36% lipids and 11% protein (Anhwange et al., 2004). The fruit pulp is rich in minerals and essential

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vitamins such as vitamin C, E, B_2 and folic acid which which serve as a major food supplement during the dry season (Oibiokpa et al., 2014). These nutritional properties highlight the potential contribution of *D. microcarpum* to food security in Africa. The fruits are equally sold in local markets and contribute to economic empowerment in rural communities (Akpata and Miachi, 2001).

Moreover, *D. microcarpum* is used in traditional medicine for the treatment of various ailments including tuberculosis, meningitis and diarrhea due to its antimicrobial properties (Abreu et al., 1998). The seed coat is also reported to possess antimicrobial activity which could be used in the control of infectious diseases (Ebi and Afieroho, 2011). It also serves as a major fuelwood species with charcoal produced from the wood delivering about 1968 KJ/kg of caloric power (Kabore et al., 2005) and ranked among the most preferred fuelwood species in its naturally growing areas (Sawadogo, 2007).

The multipurpose uses have resulted in overexploitation of the species to local extinction in some areas (Kabore, 2005) mainly due to the high dependence on wild plant sources with little attention on domestication of the species. However, effective domestication will require knowledge on regeneration and other aspects of the plant biology (Bohra et al., 2018). Seed germination is known to be an important step towards raising a successful crop stand (Finch-Savage and Bassel, 2016), but there is a paucity of information on pre-treatment methods for *D. microcarpum* seeds. Kouyate and Van Damme (2006) recommended immersion of seeds in sulphuric acid as a good pre-treatment for *D. microcarpum* seeds but their study was not explicit on the recommended acid concentration and best duration of seed immersion in acid. The present study examined the percentage germination and initial growth performance of *D. microcarpum* using different pre-treatment methods.

MATERIALS AND METHODS

Study area

The experiment was conducted at the tree nursery of the Faculty of Natural Resources and Environment of the University for Development Studies, Ghana. It lies between latitude 9° 25' N to 10° 40' N and longitude 0° 58' N to 1° 12' W (Figure 1). The area records a monomodal rainfall pattern with a mean annual rainfall of 1127 mm. Mean monthly minimum and maximum temperatures are 26.6 and 35.6°C respectively, with a mean annual temperature of 29.7°C (SARI, 2016). The vegetation is dominantly grassland interspersed with indigenous and exotic tree species such as *Parkia biglobosa* (dawadawa), *Vitellaria paradoxa* (shea), *Lannea acida* (lanea), *Azardirachta indica* (neem), *Magnifera indica* (mango*), Tectona grandis* (teak), *Senna siamea* (cassia). Seed boxes were kept in a shade net with average light intensity of 11.19 Lux.

Seed collection and viability test

Fruits of *D. microcarpum* were collected from fallow lands of Nandom community in Upper West region of Ghana. Collected fruits were initially sorted to eliminate diseased and bruised fruits. The fruits were cracked to remove seeds for pre-treatment. Prior to the germination experiment, 50 seeds were sampled for a seed viability test using floating test.

Experimental design

Seeds were subjected to four pre-treatment methods at four pre-treatment time durations with the untreated seeds as control. The pre-treatment methods were;

(i) Seeds soaked in 98% sulphuric acid concentration for 1, 5, 10 and 15 min
(ii) Seeds soaked in 50% sulphuric acid concentration for 1, 5, 10 and 15 min
(iii) Seeds soaked in cold water for 12, 24, 36, and 48 h
(iv) Seeds soaked in boiled water (100°C) for 12, 24, 36, and 48 h
(v) Control (untreated seeds)

Each treatment combination had 45 seeds, making a total of 765 seeds for the experiment. The pre-treated seeds were sown in seed boxes (50 cm × 15 cm × 10 cm) half filled with topsoil. The seed boxes were arranged in a Completely Randomized Design with 15 seeds per box. Each treatment combination was replicated in three seed boxes. Seed boxes were watered twice daily with 1500 ml of water per box. Weeds were controlled by hand to prevent competition.

Data collection

Data was collected on seed emergence, plant height, collar diameter and root length. Number of seeds emerged was recorded daily per seed box from the day of first germination to the end of the germination period (4^{th} week after sowing). Growth parameters were recorded once every two weeks from the 4^{th} week after sowing to the 10^{th} week after sowing. Seedlings were uprooted after the tenth week for root length measurement. Plant height and root length were measured with a measuring tape whilst a caliper was used for collar diameter.

Data analysis

Percentage seed Germination (PG) and Germination Rate (GR) were estimated with following equations:

$$PG = \frac{SG}{TS} \times 100 \quad (1)$$

Where SG is number of seeds germinated and TS is total number of seeds planted.

$$GR = \frac{GP}{T} \quad (2)$$

Where, PG is Percentage Germination and T is Time taken in days.

Data set on seedling emergence proportions were arcsine-square root transformed before each factor was subjected to Analysis of Variance (ANOVA). Treatment means were separated with Bonferroni corrections at 95% confidence level. Pearson's correlation coefficient was used in establishing relationship between germination rate and plant size (plant height, collar diameter and root length). All analysis was done with Genstat 18^{th} edition.

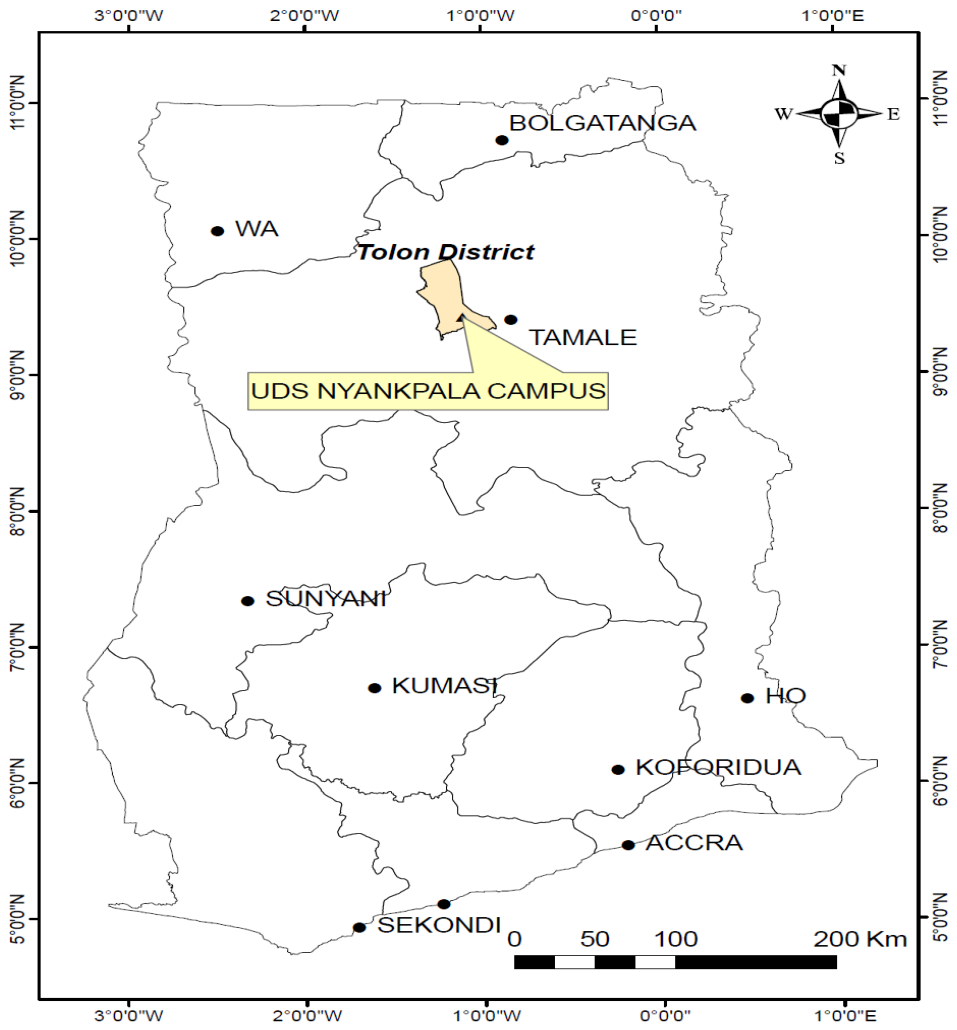

Figure 1. Map of the study area.

RESULTS AND DISCUSSION

Effect of pre-treatment methods on germination of *D. microcarpum*

Percentage seed germination varied significantly between pre-treatment methods ($P < 0.05$) with cold water treatment recording the highest mean percentage germination of 73.06% while seed soaking in 98% sulphuric acid resulted in the lowest germination (46.72%). Amongst sulphuric acid treatments, seed soaking in 50% sulphuric acid recorded higher germination (53.22%) when compared with seed soaking in 98% sulphuric acid (46.72%) (Figure 2).

Aside the general significant effect of pre-treatment on seed germination, the duration of seed immersion also had significant effect within treatments. For instance, percentage seed germination differed significantly between the four time durations of seed immersion in cold water with 48 h recording the highest germination of 86% (Table 1). Again, seeds immersed in 50% sulphuric acid concentration for 15 min had significantly higher germination percentage (68%) when compared with other time durations of immersion in 50% sulphuric acid. Pre-treatment method also influenced number of days to seed emergence. Seeds immersed in cold water for 48 h germinated earlier (8 days), whereas untreated seeds took longest time (12 days) to first seed germination.

The cold water treatment recording the highest percentage as well as shortest time to first seed emergence could be attributed to the ability of cold water to enhance seed coat permeability. This enabled gaseous exchange and enzymatic hydrolysis to transform the embryo into a seedling without negatively affecting the functional organs of the seed (Olatunji et al., 2013). This also agrees with Azad et al. (2011) who identified water as a necessary requirement for seed germination. *D. microcarpum* has a hard seed coat which needs to be

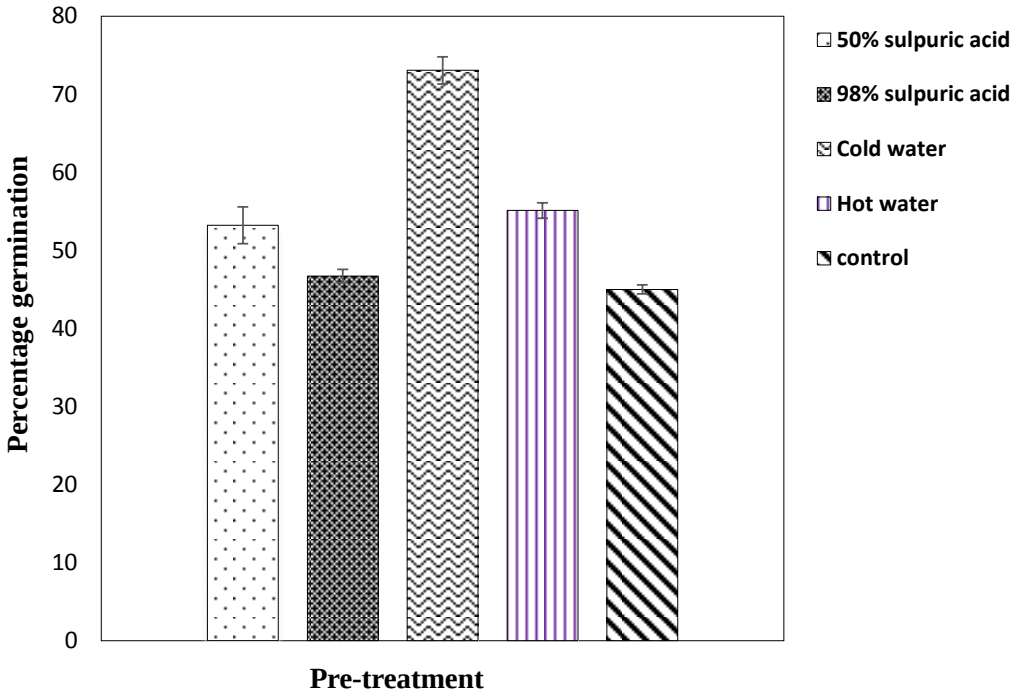

Figure 2. Effect of pre- treatment on percentage of germination of *D. microcarpum* seeds.

Table 1. Effect of different pre-treatment time on percentage germination, first seed emergence and germination rate of *D. microcarpum.*

Pre-treatment	Time	% germination	Days to emergence	Germination rate (seedlings/day)
50% Sulphuric acid	1 min	32.4^{a}	11	0.76
	5 min	62.3^{hi}	11	1.62
	10 min	50.0^{de}	11	1.48
	15 min	68.1^{j}	11	1.19
98% sulphuric acid				
	1 min	50.3^{fg}	11	1.19
	5 min	50.1^{ef}	9	1.18
	10 min	46.3^{cd}	9	1.43
	15 min	40.1^{fg}	9	1.10
Cold water				
	12 h	67.8^{cd}	10	1.62
	24 h	78.4^{gh}	11	1.86
	36 h	60.0^{b}	10	1.43
	48 h	86.0^{ij}	8	2.05
Hot water				
	15 min	58.0^{fg}	11	1.38
	30 min	56.4^{efg}	11	1.33
	45 min	46.0^{bc}	11	1.10
	60 min	60.0^{gh}	9	1.43
Control	Untreated	52.5^{ef}	12	0.92

NB. Means having a common superscript letter within a column are not significantly different at significance threshold of 0.05.

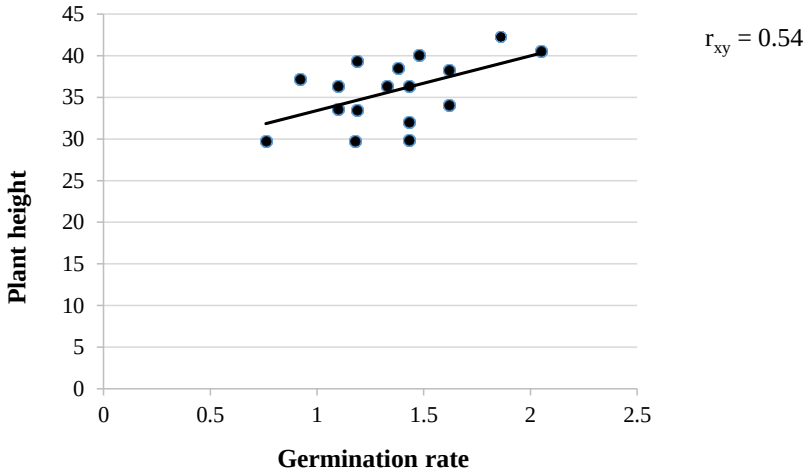

Figure 3. Relationship between germination rate and plant height in *D. microcarpum.*

ruptured before radicle and plumule emergence. Hence seeds that were immersed in cold water for a longer period (48 h) had an early seed coat rupture and permeability which facilitated a faster rate of emergence. This could explain the significantly higher percentage germination and early days to emergence recorded among seeds that were immersed in cold water for 48 h. This phenomenon confirms earlier reports by Missanjo et al. (2013) and Mwase and Mvula (2011), who reported seed coat permeability as one of the determinants of seed germination.

The relatively low percentage germination in 98% sulphuric acid as compared to control (Figure 2) seem to suggest detrimental effect of this chemical to *D. microcarpum* seeds at higher concentrations. This is in accordance with Asl et al. (2011), that sulphuric acid has a detrimental effect on seed embryo. This could be attributed to the fact that some enzymes have specific pH ranges, therefore higher acid concentration above this range tends to provide unfavourable pH conditions for normal enzymatic activity. However, at low concentrations, sulphuric acid could have a positive effect on seed germination; this was evident in the fact that 50% sulphuric acid had a higher percentage germination than the control treatment (Figure 2).

Time of immersion in sulphuric acid also had an effect on seed germination with germination percentage decreasing with increasing time duration of seed immersion in 98% sulphuric acid concentration (Table 1). However, in 50% sulphuric acid concentration percentage germination generally increased with increasing time of immersion. The effect of time duration of treatment on germination is not limited to *D. microcarpum*. This positive effect of time duration of pre-treatment on seed germination was equally reported in *Tamarindus indica* (Abubakar and Muhammad, 2013; Muhammad and Amusa, 2003).

Hot water pre-treatment resulted in a low germination percentage as compared to the cold water treatment probably due to the high temperature the seeds were exposed. This argument is supported by the findings of Singh et al. (2019) who indicated that hot water may tend to be detrimental to enzymatic activities at higher temperatures when used as pre-treatment. The higher percentage germination recorded in hot water treatment as compared to 50% sulphuric acid treatment is dissimilar to the response of *T. indica* to the same pre-treatments. *T. indica* seeds immersed in 50% concentrated sulphuric acid recorded a higher germination percentage than seeds that were immersed in hot water (Abubakar and Muhammad, 2013). Again, *Adonsonia digitata* seeds rather recorded a higher percentage germination in 80% sulphuric acid concentration as compared to cold water treatment for 72 h (Oboho and Ahanon, 2017). This variation in tropical plant species response to pre-treatments points out differences in the inhibitory factors to germination between plants.

The control treatment generally recorded low percentage germination as compared to most pre-treatments (Cold water, 50% sulphuric acid and hot water) which could be an indication of some level of dormancy in *D. microcarpum*. This suggests that pre-treatments have positive influence on germination of *D. microcarpum* which could be a boon to nursery managers and foresters for the domestication of the species.

Relationship between germination rate and growth of *D. microcarpum* seedlings

Germination rate correlated positively with plant growth parameters recording moderate positive relationships with plant height (r_{xy} = 0.52) and collar diameter (r_{xy} = 0.49) (Figures 3 and 4). However, root length had a weak positive relationship with germination rate (r_{xy}=

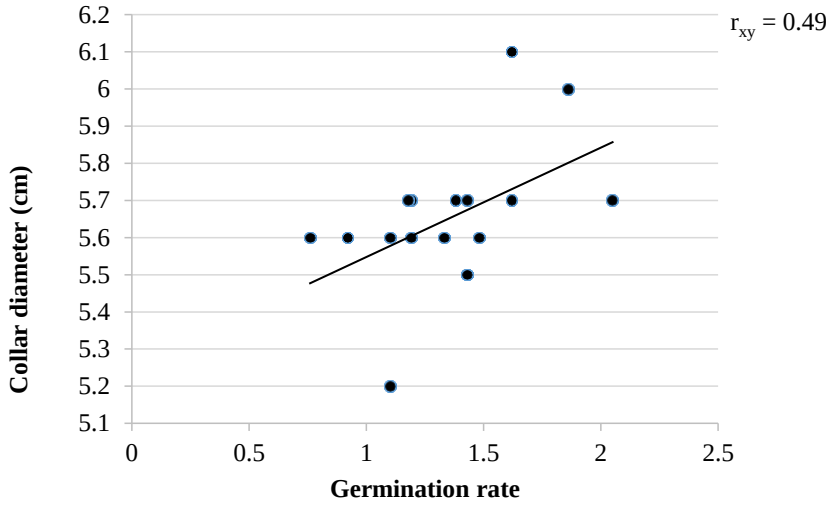

Figure 4. Relationship between germination rate and collar diameter.

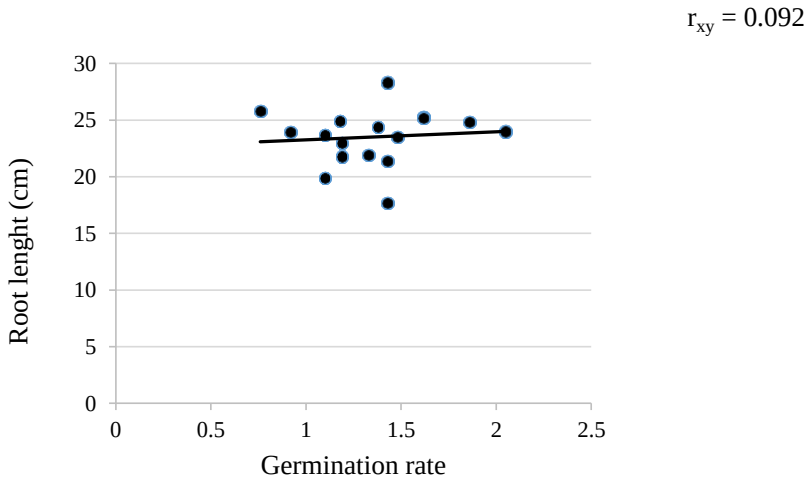

Figure 5. Relationship between germination rate and root length.

0.092). El-Bably and Rashed (2018) have reported positive effects of pre-treatment on growth of *Adansonia digitata* seedlings. The positive relationship between germination rate and seedling growth performance suggests that, effect of pre-treatment on germination of *D. microcarpum* also translates into seedling size. This is similar to the findings of Chubamerenla et al. (2015) who reported a significant variation in growth of *Delonix regia* seedlings that emerged from different pre-treatments. This equally reveals an indirect influence of pre-treatment on growth performance of seedlings. Therefore, the positive relationship between germination rate and growth parameters of *D. microcarpum* seedlings implies that, benefits of pre-treatment does not end in germination but also contribute to the survival and establishment of seedlings in the field (Figure 5).

Conclusion

The study concludes that both pre-treatment method and duration of treatment have significant effects on the germination and growth performance of *D. microcarpum.* Soaking *D. microcarpum* seeds in cold water for 48 h could be recommended for large scale production of seedlings as it resulted into 86% germination. Although acid treatment can equally enhance germination, higher acid concentration could result in detrimental effects. Similarly, cold water treatment resulted in an early germination of *D. microcarpum* seed as compared to hot water pre-treatments. Significant effect of pre-treatment on germination translated into a positive effect on seedling size with plant height, collar diameter and root length all positively correlated with germination. The

study therefore recommends cold water as an effective pre-sowing treatment for *D. microcarpum*.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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