Aplinkos tyrimai, inžinerija ir vadyba, 2012. Nr. 4(62), P. 30-38 *ISSN* *1392-1649*
Environmental Research, Engineering and Management, 2012. No. 4(62), P. 30-38 *E ISSN* *2029-2139*
http://erem.ktu.lt

Determination of Suitable Sites for Nuclear Power Plants in Ghana:-The Issues Involved

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crossref http://dx.doi.org/10.5755/j01.erem.62.4.2655

(received in October 2012, accepted in December, 2012)

To ensure availability of the adequate and reliable supply of electricity, Ghana is taking necessary steps towards the implementation of a nuclear power program in the country. Among the steps being taken is the determination of suitable sites for the operation of nuclear power plant. This paper outlines major factors which influence the site selection, i.e. geology, hydrology, seismicity, etc. proposed by the IAEA and some countries and relates them to the situation in Ghana. In this regard, the major issues that have come up in the site selection in Ghana are discussed. These include preference of coastal areas to the inland fresh water areas due to concerns about the site location in fresh water bodies and elimination of the areas with fault lines and relatively high level seismicity. Putting all factors together, site location has been limited to the areas along the coast at the west of the Akwapim fault. This area, which lies between 0^{o} 23’ west and 3^{o}06’ west, is being assessed to obtain a candidate site. On-going activities to identify candidate sites are presented and measures to deal with challenges associated with site selection are also discussed.
Keywords: Nuclear power plant, Nuclear energy, Earthquake, Hydrology, Geology, Seismicity

1. Introduction

In Ghana nuclear power is one of the options under consideration for electricity generation to meet long term energy needs. This decision was taken as a result of the increasing demand for electricity as well as the unreliable nature of the existing power supply system which comprises hydro and thermal power plants. Over the years, hydro power has been the main source of electricity. Currently it accounts for 54% of the total installed capacity which is about 2186MW. The remaining share is taken by thermal power plants which run on natural gas and light crude oil. Due to its dependence on the weather, there is a shortfall in power supply from the hydropower system during droughts. The thermal systems introduced in 1998 are expensive to run due to high cost of crude oil on the international market. Running them on relatively low cost gas from Nigeria is beset with the problem of intermittent supply. In 2008 the Government of Ghana took a decision to explore the possibility of generating electricity from nuclear power within a decade. That decision was taken following the country’s third major energy crisis which occurred from 2006 to 2007. The crisis was caused by a shortfall in power supply from the hydro system, high cost of crude oil on the international market, and delay of gas supply from Nigeria to run the existing thermal plants.

Following the Government decision, a technical cooperation project with the International Atomic Energy Agency (IAEA) on nuclear power planning was initiated in 2009. The project outlines a series of activities which have to be taken towards the implementation of a nuclear power program in the country. Among these activities is the selection of suitable sites for the construction of nuclear power plants. The selection of sites for nuclear power operation involves careful studies on various geographic features of the country such as seismology, hydrology and geology. This paper outlines the major issues that have to be addressed in the site selection process and the challenges that may confront this process. It proposes the means to address the identified issues which include seismology, geology, hydrology, etc. Site determination guidelines proposed by certain countries and some international organizations like the IAEA are also presented.

2. General siting considerations

A good site should minimize the plant's impact on the environment. The location should be such that radioactive releases to the public are minimal in case of a major accident. A large amount of rejected heat release should have little effect on aquatic life, or, if cooling towers are used, their effect on the micro-climate should be within tolerable limits. The site characteristics (population distribution, meteorology, hydrology, etc.) should be such that the effects of accidents are within acceptable limits (IAEA 1982).

Main parameters that need to be considered include seismology, geology, hydrology and grid infrastructure. Since the commercially available reactors are cooled by water, they have to be sited close to a large water body. The amount of water required depends on the type of a cooling system employed, i.e., whether it is a once through type or recirculation with cooling towers or cooling ponds. A 1000MW plant may require a water coolant flow rate of about 100 m^3/s (IAEA 1982). If recirculation is used, water make-up of 2%-5% of the above figure is required. Another important factor to be considered in the site's search is ground shaking during earthquake. In principle, nuclear reactors can be designed to withstand any ground shaking intensity, if the subsurface material is suitable. Seismic designs above ground shaking with the peak ground acceleration of 0.2 g (where g is acceleration due to gravity) are, however, expensive with the cost increasing more than linearly with intensity (IAEA 1982).The relation between the ground shaking intensity for plant safe shutdown and the percentage of plant cost in the US is shown in Figure 1 (Stevenson 2003). Proximity of the population to a nuclear plant site is another factor worth considering. A general principle guiding the population distribution around a nuclear facility is such as to allow a workable emergency plan to evacuate individuals in affected areas in case of an accident. An exclusion zone is therefore set around the reactor's facility, where public access is restricted. In addition, no permanent residence is allowed in the exclusion area. The size of the exclusion zone depends on several factors and differs from country to country.

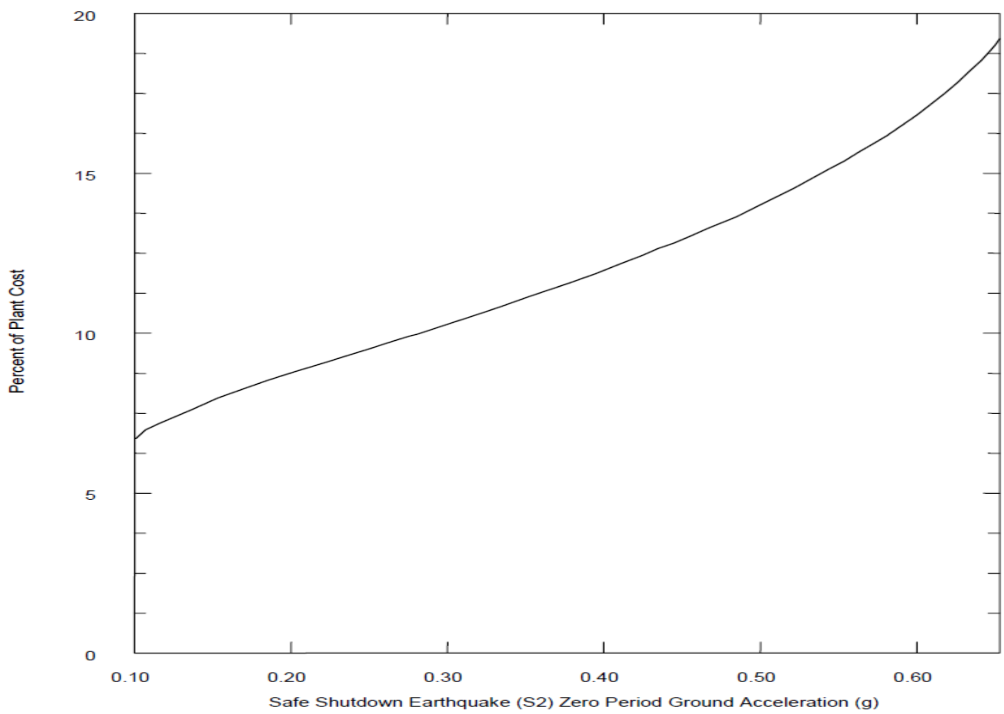

Fig.1. *Relation between ground shaking intensity for plant safe shutdown and percentage of plant cost (Stevenson 2003).*

In the US, for example, the size of the exclusion area is such that an individual, located at any point on its boundary for two hours immediately following the onset of postulated fission product release, would not receive a total radiation dose to the whole body in excess of 25 rem (0.25 Sieverts) or a total radiation dose in excess of 300 rem (3 Sieverts) to the thyroid from iodine exposure (US NRC 2012). In most countries the exclusion zone around a nuclear power plant is about 0.5 km to 1 km and may even be more in some countries (IAEA 1982).

Possibility of extreme natural events such as earthquakes, volcanic eruption, and flooding are also considered in site selection. In the case of earthquakes, the main phenomenon which is of great concern is surface faulting. This is the displacement of the ground during severe earthquakes caused by the faults that generated the earthquake (capable faults). Such displacement may reach several meters. Since it is very difficult to design plants against such a phenomenon, the practical solution is to locate the plants far away from the fault. In addition, plants have to be located away from the areas prone to volcanic eruptions due to the emission of lava flows and burning clouds. Nuclear power plants also have to be protected from both the static and dynamic effects of flooding. It is, therefore, necessary, in principle, not to locate plants in areas where flood hazards are severe. Nuclear power plants along rivers have to be protected against flooding due to precipitation and other events such as failure of water controlling structures such as dam collapse. Plants along the coast have to be protected against surges, tsunamis, and wind induced waves. The issue of flooding has caught world-wide attention due to the Fukushima accident in March, 2011, when a 14 m tsunami wave swept through a nuclear plant site in Fukushima in Japan destroying emergency generators and pumps. This led to the loss of the coolant flow resulting in the partial melting of fuel rods (IAEA 2011). In addition to natural phenomena, closeness to installations that handle explosions, military installations, aircraft flight paths, etc., are also considered. Closeness to existing grid network load centers is also a parameter considered in siting. This is necessary to do on purpose to reduce electricity transmission losses and, thus, transmission cost.

3. Some relevant geographical features of Ghana

Ghana lies almost in the middle of the west coast of Africa. The most southern tip of the country is about 750 km north of the equator with the country actually lying between latitudes 4° 41' and 11° 09' north and longitudes 3° 06' west and 1° 12' east. The longitudes and latitudes are generated with the Google earth software. The Greenwich Meridian passes through the port city of Tema, which is in the east of the country. It is bounded in the north by Burkina Faso, the east by Togo, the west by La Cote D'Ivoire and south by the Atlantic Ocean (Fig. 2) (Nations online 2012).

Although Ghana is remote from the major earthquake zones in Africa and other parts of the world, it is moderately seismically active along its coast in the south. Earthquake epicentres are shown in Figure 4 (Bacon and Quaah 1981). As shown in Figure 3, the earthquake intensities generally range from level V to VI on the modified mercalli scale (UN OCHA 2007). This is equivalent to the peak ground acceleration of 0.05g to 0.1g using the conversion presented in Table 1 (Stevenson 2003). Ghana has some earthquake data for analysis to a fair degree (Amponsah et al. 2012; Amponsah 2004). The earliest recorded earthquake dates back to 1615 with the most devastating earthquakes recorded in 1862 and 1939. These two earthquakes both with magnitudes 6.5 caused massive destruction in Accra, the capital city of the country. In the case of the 1939 earthquake, 17 fatalities and 133 injuries were recorded (Ambraseys and Adams 1986; Junner 1941). The computed peak ground acceleration ranges from 0.14g to 0.57g corresponding to VII to IX on the modified mercalli scale. The earthquake history of Ghana is summarized in Table 2 (Ambraseys and Adams 1986; Bacon and Quaah 1981; Akiti 2010; Amponsah et al. 2008). Fault lines exist within the major earthquake zone of the country. These include the Akwapim fault, the Eastern Boundary fault, the Western Boundary fault,and the Coastal Boundary fault (Fig. 5) (Amponsah et al. 2009).

With regard to drainage, Ghana has a number of rivers, most of which flow into the sea in the south. This includes the Pra, the Ankobra, and the Tano (Fig. 2). In addition, it has an artificial lake (the Volta Lake) formed by the construction of the first hydro-electric dam on the river Volta. This lake has a water volume of 187 km^3 and total surface area of 8500 km^2 (Volta River Authority 2012).This makes it the largest man-made lake in the world in terms of the surface area (Wikipedia 2012). Ghana also has a 539 km coastline as its southern border (Nations Encyclopedia 2012). The possibility of occurrence of tsunamis in Ghana came out for discussion during the Fukushima accident, which occurred in Japan in March, 2011. Most experts are of the view that the possibility of occurrence of such event in the Ghanaian seas, which form part of the Atlantic Ocean, is remote.

4. Issues confronting site selection

In line with the recommendations of the IAEA, eight working groups have been formed in connection with the nuclear power project. One of the groups is the Siting and Grid Infrastructure Assessment Group which is responsible for site determination as well as assessing the suitability of the Ghanaian and West African grid networks for nuclear power operation. The remaining groups are: Techno-Economic Assessment Financing and Procurement Group, Legal Group, Regulatory Group, Technology Assessment Group, Human Resource Development Group Stake-Holder Involvement Group, and the Environmental Group. The activities of these working groups are coordinated by the Nuclear Power Planning Unit of the Ministry of Energy. The Siting and Grid Infrastructure Assessment Group involves a number of organizations which include the Ghana Atomic Energy Commission, Geological Survey Department, Hydrological Services Department, Ghana Grid Company, Environmental Protection Agency, Meteorological Services Department, Volta River Authority, Ministry of Energy, Ministry of Lands and Mineral Resources, National Disaster Management Organization, Water Resources Commission, University of Ghana, and Kwame Nkrumah University of Science and Technology.

Fig. 2. *Map of Ghana (Nations online 2012)*

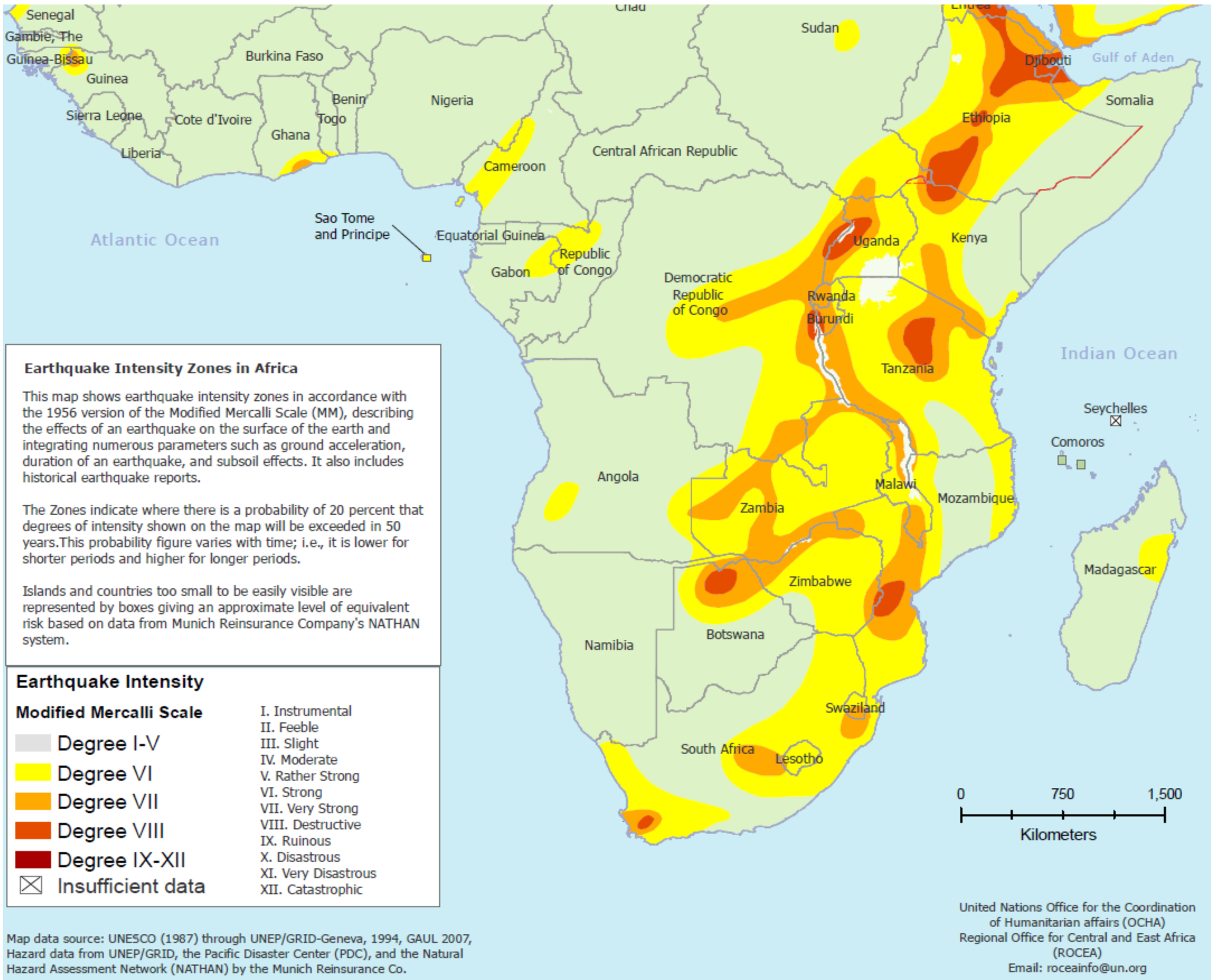

Fig.3. *Earthquake intensity zones in Ghana (UN OCHA 2007)*

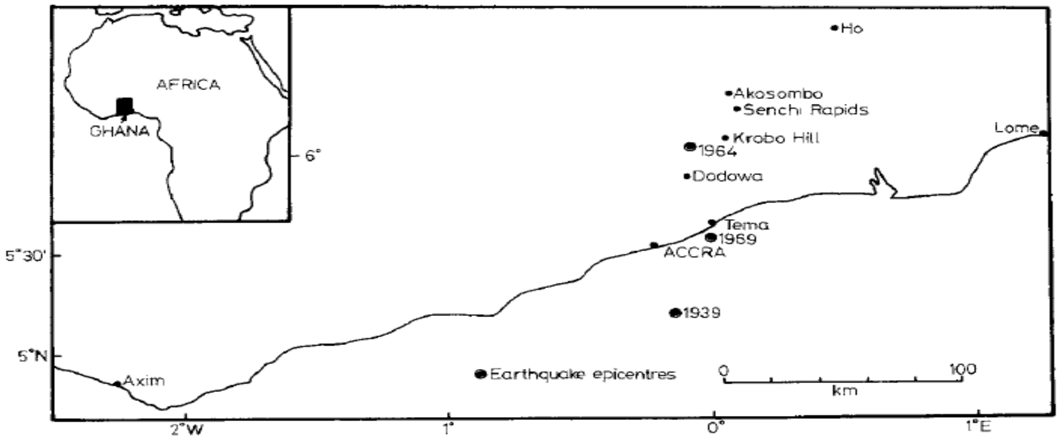

Fig. 4. *Recorded earthquake epicentres in Ghana (Bacon and Quaah 1981)*

Table 1. *Peak ground acceleration collated with intensity scales (Stevenson 2003)*

PGA (g)	MODIFIED MERCALLI	MSK-64 INTENSITY
>0.025	< IV	< IV
0.025	V	V
0.05	VI	VI
0.10	VII	VII
0.20	VIII	VIII
0.40	IX	IX
>0.40	X	X

Table 2. History of major earthquake events in Ghana (Junner 1941; Ambraseys and Adams 1986; Akoto and Anum 1992; Quaah 1982; Amponsah et al. 2012)

Year	Magnitude	Remarks
1615	-	Felt in Elmina
1636	5.7	Felt in Axim. Buildings as well as underground workings of Portuguese mines collapsed.
1862	6.5	Every building in Accra was razed to the ground. The OsuCastle and Forts in Accra were rendered uninhabitable. The shocks were felt in Togo where water in the Mono river fell much below its normal level.
1906	5.0	Many buildings in Accra particularly castles and forts were cracked. The earthquake was felt in other areas as far as Togo.
1939	6.5	Intensity was greatest in areas between Accra, Weija, Gomoa Fete and Nyanyanu. The computed peak ground acceleration ranges from 0.14g to 0.57g corresponding to VII to IX on the modified mercalli scale. In Accra 16 people were killed with 133 injuries.
1964	4.5	Felt mainly in Akosombo.
1969	4.7	Felt mainly in Accra.
1997	3.8	Felt mainly in Accra
2003	4.8	Felt in some parts of Accra

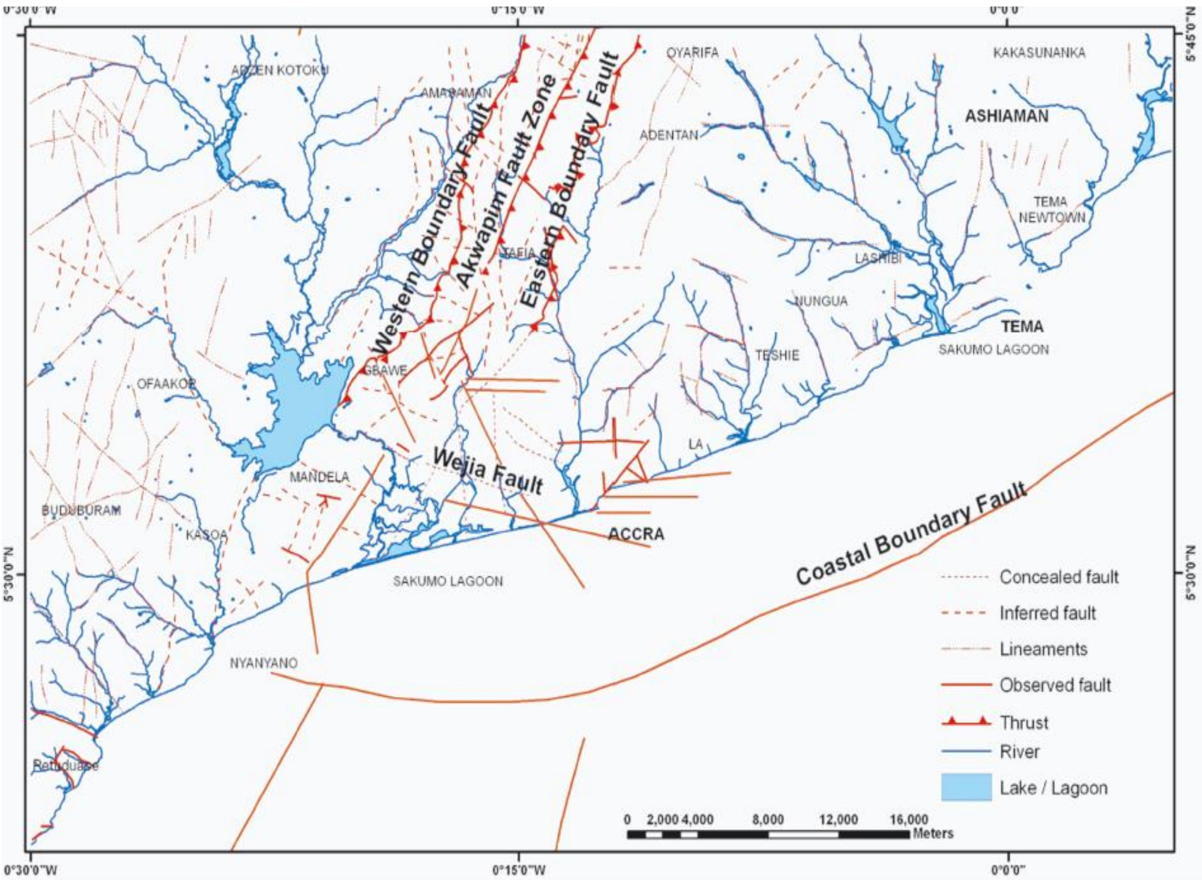

Fig. 4. Fault map of the Greater Accra Metropolitan Area (modified from Muff and Efa 2006)

The selection of sites involves a lot of activities which can be broken into two main stages. These are site survey and site qualification. Site survey involves general studies of the country to identify candidate sites. The selected candidate sites are subjected to systematic analysis to demonstrate that they meet at an appreciable level the laid down parameters for selecting suitable sites during the site qualification stage. The siting work in Ghana is in the site survey stage, where lands close to water bodies inland and areas along the coast are being screened to become candidate sites.

Considering the seismicity of the country and associated fault lines, areas at the east of the Akwapim fault are considered unsuitable. These include Accra, the capital town and areas around it. Areas along the Volta Lake are attractive due to their low seismicity and population density (Fig. 5) (Ghanaweb, Population Desnity 2012). The location of nuclear power sites along the Volta Lake has, however, raised debates among stake holders. The major issue is that, since the lake is a fresh water body, its contamination by radioactive substances, in case of a major accident, will create serious environmental problems. This view is, however, countered by the fact that there is a possibility of Burkina Faso, Ghana's northern neighbour, deciding to build a nuclear power plant. If this happens, it will definitely build it in the Volta basin, since it is a land locked country and has no big rivers. The issue of contamination also arises here in case of an accident. However, the general view among national planners and environmentalists is that the fresh water bodies need protection, and therefore any attempt to locate nuclear reactors along fresh water bodies are likely to meet stiff opposition. The location of reactor sites along river bodies is also affected by the same arguments that have been raised along the Volta Lake, since they are also fresh waters. In addition, there has to be the guarantee that the rivers will not dry up as a result of periodic droughts throughout the operational life of the nuclear power plants. Most nuclear power plants are licensed to operate for 40 years, and a number of them have received extension to operate for further 20 years (EPRI 1998). This means that these rivers must not dry up within the expected 60 year operation life time of the nuclear plant. Considering the effects of climate change, the massive loss of water in the river bodies is very likely. Studies have shown that most river bodies in Ghana will lose about 30 % to 40 % of their water by 2050 due to climate change (Kankam-Yeboah et al. 2010). Putting all these factors together, site location has been limited to areas along the coast at the west of the Akwapim fault. This area, which lies between 0^{o} 23'west and 3^{o} 06'west, is being screened to obtain candidate sites. The activities to be conducted in the screening process include detail seismic studies and analysis, meteorology, population distribution, social issues, protection of historical artefacts, and land acquisition issues.

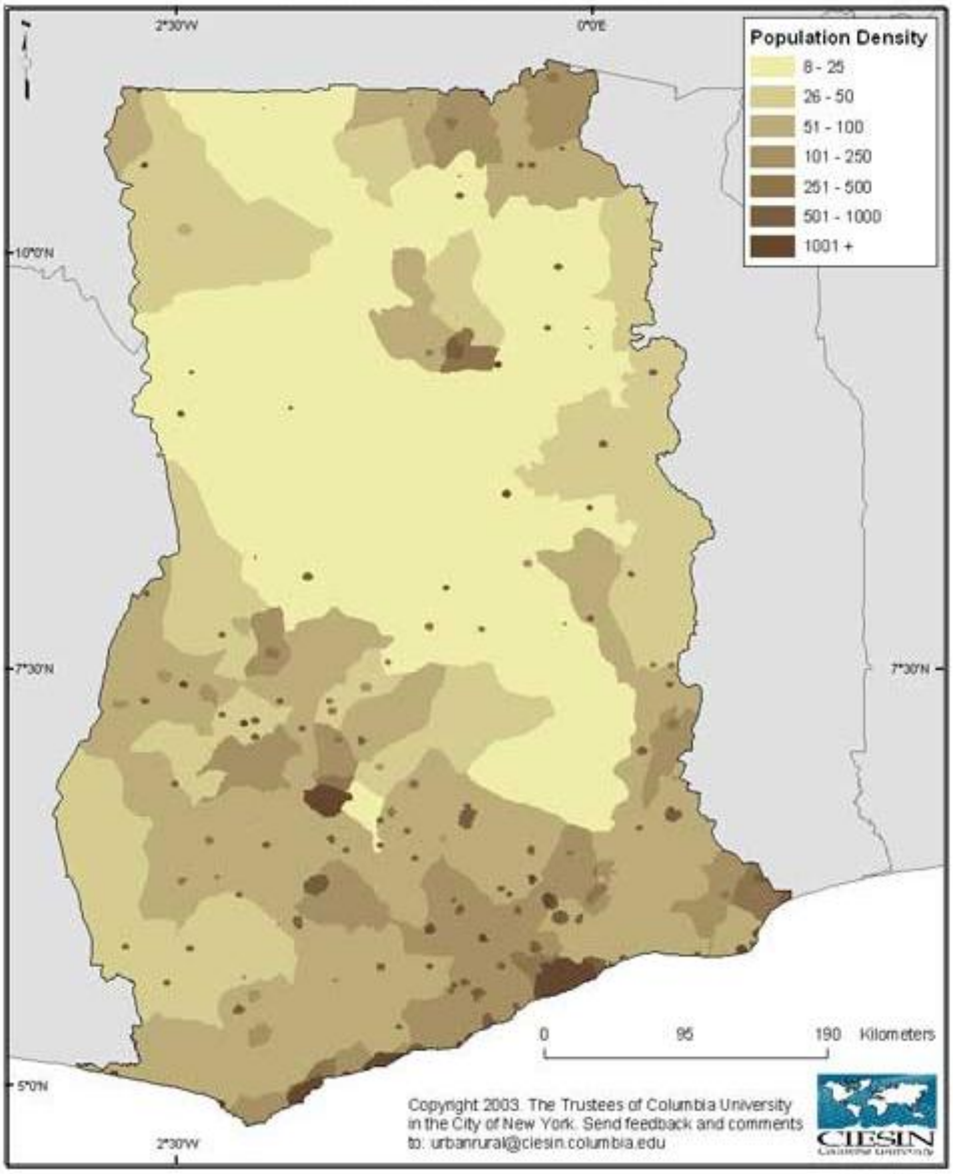

Fig. 5. Population Density of Ghana (Ghanaweb, Population Desnity 2012)

Though activities are on-going in connection with the nuclear siting project, some challenges have slowed down the progress. The first major challenge is change of the government in 2009 through the elections conducted in 2008. The change-over in administration led to a slowdown in the formation of the Nuclear Energy Program Implementation Organization (NEPIO), the IAEA recommended body, which is to coordinate all activities associated with the planning and implementation of the nuclear power program. This has slowed down the siting activities. In addition, since the site determination involves a lot of activities, its budget is high, and the possibility of delays as a result of lack of funds exists. In addition to this, most of the local experts engaged in the siting process have not got much experience in siting activities, because this is the first activity of this kind in the country. Another major issue is public concern about nuclear safety leading to possible opposition of nuclear siting by local dwellers.

5. Discussion and conclusions

In connection with the activities associated with planning and implementation of a nuclear power program selection of suitable sites is on-going in Ghana. Areas along the Volta Lake and other fresh water bodies have low seismic activities as well as low population density, making them suitable for site location. However, the preferential location of nuclear power plants outside the country's fresh water bodies has confined site location to areas along the coast. The eastern part of the coast is, however, excluded due to the high seismic risk of this area. Stakeholders have the onerous task of conducting further studies to identify the exact location of the sites. The nuclear plant site selection project is confronted with challenges including funding, requisite manpower, equipment, and possibility of public resistance. These challenges can be dealt with, if the Government maintains its support to the nuclear project and executes the project in line with laid down international regulations. In addition to this, assistance should be solicited from other countries and international bodies on the subject matter. There is already the on-going IAEA project on nuclear power planning in site selection. The IAEA has already assisted the country in many projects in the field of peaceful application of nuclear science and technology. The country is also a member of the International Framework of Nuclear Energy Cooperation (IFNEC). Apart from this, Ghana has recently signed a memorandum of understanding with the State Atomic Energy Corporation of Russia (ROSATOM). Both availability of the international assistance and the Government commitment allow the nation to be engaged in a successful site selection.

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Vietų, tinkamų atominei elektrinei statyti Ganoje, vertinimas

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(gauta 2012 m. birželio mėn., priimta spaudai 201 2m. gruodžio mėn.)

Ganoje pradedama įgyvendinti atominės energetikos programa, siekiant užtikrinti elektros energijos tiekimo patikimumą. Vienas iš šios programos įgyvendinimo etapų – nustatyti tinkamas vietas atominei elektrinei statyti. Šiame straipsnyje analizuojami svarbiausi aspektai (geologiniai, hidrologiniai, seisminiai ir kt.), pagal kuriuos vertinamas tam tikros vietos tinkamumas. Atlikus vertinimą, nustatyta, kad pati palankiausia vieta atominei elektrinei statyti yra priekrantės zona Akwapim rajone (0° 23‘ ir 3° 06‘ruože).