International Journal of Engineering Science Invention
ISSN (Online): 2319 – 6734, ISSN (Print): 2319 – 6726
www.ijesi.org Volume 2 Issue 7 ǁ July. 2013 ǁ PP.25-30

Towards a Win-Win Scenario in National Energy and Food Security: The Role of Comprehensive Extraction of Uranium from Phosphates

S. O. Obaje
Nigerian Geological Survey Agency, P.M.B. 1423, Ilorin, Kwara State, Nigeria

ABSTRACT: *The main aim of this paper is to draw policy attention to the comprehensive extraction of uranium from phosphates so as to achieve a win-win scenario in energy and food security in Nigeria. Nigeria is located on latitude 10^0 North and longitude 8^0 East surrounded in the north by Niger and Chad and in the east by Cameroun and in the west by Benin Republic. The Nigerian, Sokoto phosphate rock contains significant quantities 65 ppm of uranium that meets the minimum international benchmark for uranium extraction from phosphates and phosphogypsum. Nigeria's current energy generation is 2,987.6 MW using hydropower and gas plants. However, for Nigeria to meet her energy security need, the comprehensive extraction of uranium from phosphates is imperative. This is because the recovered uranium can be used as nuclear fuel to generate energy for national development, besides other benefits such as environmental/health, social and economic impact, respectively. It has been confirmed that the safest and greenest source of energy generation is nuclear energy.*

KEYWORDS: *National energy security, food security, uranium extraction, phosphates*

I. INTRODUCTION

Energy and food security via the comprehensive extraction of uranium from phosphates in Nigeria is the focal aim of this paper. Nigeria is located within the Equator and the Tropic of Cancer on latitude 10^0 North and longitude 8^0 East. Nigeria is surrounded in the north by Niger and Chad and in the east by Cameroun and in the west by Benin Republic (Fig. 1). It occupies an area of 923,768 m^2 made up of landmass of 910,768 m^2 and water area of 13,000 m^2. The Nigerian coastline is 853 km. The seat of government is Abuja. Nigerian has stable democratic system of government and the present President of the country is Dr. Goodluck Ebele Jonathan, GCFR. According to Wikipedia (2012), Nigeria's population is 170 million people with three major tribes, namely: Hausa/Fulani, Yoruba and Ibo. The official business language is English and the currency is Naira (₦) which has an exchange rate of ₦159.98 to US Dollar ($1) as at June 2nd, 2013. The major religions practised in Nigeria are Christianity and Islam, while there are minor adherents of indigenous religions, Hinduism, Buddhism, Baha'i and other faiths. Nigeria is a tourism and investment destination despite the recent security challenges. Nigeria has 4,660 km of standard/narrow gauges rail network across the entire country. Other modes of transportation are road network of 195,000 km, sea, inland water ways and air transportation. Nigeria has several international sea-ports (Lagos, Port Harcourt, Warri, Calabar, Onne and Sapele) and international air-ports (Abuja, Lagos, Kano, Port Harcourt, Enugu, Kaduna, Maiduguri, Yola, Calabar, Sokoto, Owerri, Jos and Ilorin) and local air-ports (Gombe, Minna, Yola, etc). The temperature ranges from 22 – 36^0c. There is rain forest in the South and savannah vegetation in the Northern part of the country (Wikipedia, 2012).

II. GEOLOGICAL SETTING OF NIGERIA

The geology of Nigeria is composed of 4 main groups, namely: the Basement Complex, Younger Granites, Sedimentary series and Tertiary-Recent Volcanic rocks. The Basement Complex is made up of the migmatite-gnesis complex, pegmatites, the schist belts composed of metasedimentary and metavolcanic rocks and the pan-African Granitoids comprising the Older Granites and the associated charnockitic rocks. The Younger Granites are of Jurassic age and they are found as ring-complex outcrops within the Basement Complex areas. The Younger Granites are rich in minerals such as columbite, cassiterite, etc. The sedimentary series are made up of seven basins, namely: Niger Delta, Dahomey, Anambra, Bida, Benue Trough related to the opening of the Gulf of the Guinea and the Sokoto (Illummeden) and Chad basins are parts of larger basins that extend beyond Nigeria.

Fig. 1. Location map of Nigeria (Source: Magellan, 1992)

The Tertiary-Recent volcanic rocks are found in Biu and Longuda plateaux, Jos Plateau and the Benue Trough. Though phosphate occurrences in Nigeria have been reported in four States such as Sokoto, Ogun, Edo and Imo (Tian and Kolawole, 1999; Ojo, 2003), in this paper the focus will be placed only on the first two mentioned occurrences because only the phosphate occurrences in Sokoto and Ogun States are in commercial quantities (Akinrinde and Obigbesan, 2006).

2.1 Phosphate Deposits in Sokoto and Ogun States

According to van Straaten (2002), the five major types of phosphate resources in the world are marine phosphates, igneous phosphates, metamorphic phosphates, biogenic and phosphates from weathering. Sedimentary, marine phosphate rock deposits provide 75% of the world's phosphate resources, while 15 – 20 % come from igneous and weathered deposits and only 1 – 2% from biogenic (mainly from bird and bat guano accumulations) resources (van Straaten, 2002). In Nigeria, the phosphate deposits are of the sedimentary, marine origin.

In Sokoto State, phosphates of Paleocene sedimentary deposits occur in the Dange Formation. The Dange Formation also contains gysiferous shales and phosphate nodules (Kogbe, 1972, 1976). The overlying Paleocene Kalambaina and Gamba Formations are dominated by limestones and laminated ('paper') shales. A horizon with phosphate pellets within the Gamba Formation (Kogbe, 1976, quoted by van Straaten, 2002) is probably equivalent to the phosphate-containing marine sequence in neighbouring Niger and Mali (Wright et al., 1985, Hanon, 1990). The exploration work by the Geological Survey of Nigeria (now called Nigerian Geological Survey Agency) also established the occurrence of phosphate nodules and pellets in Dange, Gidan Bauchi, Illela, Gada and Kalambaina (Ogunleye et al., 2002). The thickness of phosphate deposits ranges from 1 – 5 m in the Dukamaje Formation and the phospatic nodules/pellets occur in sizes of 0.1 – 1 cm with varying concentration in different locations (Etu-Efeotor, 1998; Okosun, 1997, quoted in Ogunleye, 2002). The Sokoto phosphates have an estimated reserves of 5 – 10 million tonnes (Akinrinde and Obigbesan, 2006).

According to van Straaten (2002), Lower Eocene sedimentary phosphates have been known from south-western Nigeria since 1921 (Russ, 1924, quoted in McClellan and Notholt, 1986). Phosphate rocks are found in Oja-Odan and Ifo areas of Ogun State. Detailed work is needed to establish the actual reserves of the deposits. However, there are several conflicting reserve figures for the same deposits. Akinrinde and Obigbesan (2006) quoted 0.5 million tonnes, while McClellan and Notholt (1986) gave values of 1 million tonnes and the Ministry of Solid Minerals Development (2000) quoted 40 million tonnes as the reserves for the deposits. The phosphate rock deposits in Ogun State occur in nodules, granular and vesicular forms (Sobulo, 1994; Adediran and Sobulo, 1998; Adegoke et al., 1991; Akinrinde and Obigbesan, 2006).

III. COMPARATIVE GEOCHEMISTRY OF NIGERIAN PHOSPHATES

According to Akinrinde and Obigbesan (2006), Sokoto phosphates have calculated average percentage of 30.5 – 36.6% P_2O_5, while the Ogun phosphates have 26.3 – 32.0% P_2O_5. The above average values for the Nigerian phosphates compare favourably with the Togo phosphate which have the values of 28.0 – 36.6% P_2O_5 (Akinrinde and Obigbesan, 2006) and imported to feed the superphosphate fertilizer plant in Kaduna, Nigeria (Ogunleye et al., 2002). Table 1 shows the oxide percentages of the Sokoto and Ogun phosphates. On the other hand, Table 2 indicates the comparative geochemical analysis of trace elements of the Nigerian and Togo phosphates. Plate 1 indicates a photograph of uranium yellow cake (U_3O_8).

Table 1. Oxide Weight Percentages of Sokoto and Ogun Phosphate Rock Deposits (Source: [1]Akinrinde and Obigbesan, 2006; [2]NIPC, 2009)

	[1]SOKOTO	[2]SOKOTO	[1]OGUN (%)
P_2O_5	32.50	36.25	30.50
CaO	44.23	52.30	19.23
F	-	3.84	-
$CaCO_3$	79.0	-	34.30
MgO	0.95	-	1.35
Fe_2O_3	3.19	1.50	7.28
Al_2O_3	1.79	1.50	6.91
SiO_2	4.20	3.44	6.68
H_2O	-	0.75	-
Solubility in 2% citric acid	45.55	-	38.42
Cd (mg Kg^{-1})	0.63	-	9.70

Table 2. Trace Elements in PPM of Nigerian and Togo Phosphate Rock Deposits (Source: [1]Adesanwo et al., 2010; [2]Ogunleye et al., 2002)

ELEMENT	[2]SOKOTO (MEAN)	[1]OGUN (MEAN)	[2]TOGO (MEAN)
Cr	28.00	613.75	75.00
V	65.00	330.50	68.00
Ba	397.00	327.75	302.00
U	**65.00**	**22.50**	**72.00**
Th	3.20	9.25	17.40
Zn	59.00	126.00	143.00
Sc	11.80	12.00	11.60
Zr	810.00	89.75	765.00

Plate 1. Photograph of Uranium Yellow Cake (U_3O_8)

3.1 Suitability of Nigerian Phosphates for Fertilizer Production

The Nigerian phosphates have been proven to have very high reactivity, thus making it very suitable as fertilizer material even for direct application to the soil to improve soil fertility and higher crop productivity (van Straaten, 2002; Akinrinde and Obigbesan, 2006; Okosun, 1997). However, in view of the high content of uranium especially in the Sokoto phosphates, the need to comprehensively extract out the uranium from the phosphates has become very imperative for the cogent reasons on the grounds of livestock and human health, environmental, surface and ground-water pollution control and energy sufficiency.

3.2 Fertilizer Production

Phosphate rock (phosphorite) is a marine sedimentary rock which contains 18 – 40% P_2O_5, as well as some uranium and all its decay products, often 65 to 200 ppm U, and sometimes up to 800 ppm. The main mineral in the phosphate rock is apatite, and most commonly, fluorapatite - $Ca_5(PO_4)_3F$ or $Ca_{10}(PO_4)_6(F,OH)_2$. This is insoluble, so cannot directly be used as a fertilizer (unless in very acidic soils) so must first be processed. This is normally in a wet process phosphoric acid (WPA) plant where it is first dissolved in sulphuric acid. About 2 – 4% fluorine is usually present. When phosphate rock is treated with sulphuric acid in sub-stoichiometric quantity, normal superphosphate is formed. If more sulphuric acid is added, a mixture of phosphoric acid and gypsum (calcium sulphate) called "phosphogypsum" is obtained. After the gypsum is filtered out, the resultant phosphoric acid can be treated to recover uranium (World Nuclear Association, 2012).

The basic reaction is:

$$Ca_3(PO_4)_2 + 3H_2SO_4 + 6H_2O \Longrightarrow 2H_3PO_4 + 3CaSO_4.2H_2O \text{ - exothermic}$$

The process used produces different varieties of calcium sulphate such as anhydrous: $CaSO_4$, hemihydrate: $CaSO_4.½H_2O$ or dihydrate: $CaSO_4.2H_2O$. The Phosphoric acid is treated with ammonia produced from natural gas (Haber process) to produce diammonium phosphate or DAP as final product, which is adjusted to industry standard composition of 18-40-0 in N-P-K.

$$2NH_3 + H_3PO_4 \rightarrow (NH_4)_2HPO_4$$

IV. EXTRACTION OF URANIUM FROM PHOSPHATES

Phosphate rock is digested with sulphuric acid to produce a phosphoric acid solution (called wet process phosphoric acid) and an insoluble calcium sulphate (gypsum). Sokoto Phosphate rock contains significant quantities 65 ppm of uranium (Ogunleye et al., 2002).

Attempts to recover uranium values from wet-process phosphoric acid have centred on the use of solvent extraction processes in which the uranium values are transferred to an organic phase, stripped from the organic phase and subsequently recovered as a uranium precipitate. The uranium-free wet-process phosphoric acid is then processed conventionally to form various phosphate-containing fertilizer products.

Uranium from phosphate extraction using a mixture of di(2-ethylhexyl) phosphoric acid (DEPA) and tri-octylphosphine oxide (TOPO) dissolved in an organic diluents have a high affinity for uranium in the hexavalent oxidation state by using H_2O_4 oxidation agent. Uranium extracted as yellow cake (U_3O_8) and the phosphoric acid free of uranium is recovered for fertilizer production for food security. The gypsum is also of economic importance. Many countries such as USA, Canada, Belgium, Syria, Israel, Taiwan, Egypt, Morocco, etc. have active process plants for the extraction of uranium from phosphates. The yellow cake is used as nuclear fuel for electricity production.

Nigeria has some fertilizer production plants such as the Superphosphate Fertilizer Company located in Kaduna, Fertilizer production at Crystal Talc Limited at Kagara, Niger State, Fertilizer Concentrate Company, Edo State and the National Fertilizer Company of Nigeria (NAFCON), Port Harcourt, Rivers State. Presently, there is no uranium from phosphates extraction plant in Nigeria.

4.1 Why Comprehensive Extraction of Uranium from Phosphates in Nigeria?

The comprehensive extraction of uranium from phosphates has three implications, namely: environmental/health, social and economic impact, respectively. Unrecovered uranium in phosphates will eventually pollutes our environments, contaminate our surface and underground water resources and consequently affect human, livestock and plants health. The comprehensive extraction of uranium from phosphates is a social licensing gain via poverty eradication, jobs creation and economic development. The recovered uranium may be used for energy sufficiency and independence. The phosphate freed of uranium will be used for fertilizer production for food security. National prosperity is directly related to energy generation and consumption. Thus improved energy generation coupled with food security will greatly stimulate economic growth and development of the nation.

V. DISCUSSION

As at December 17, 2013 electricity power, herein referred to as energy generation in Nigeria was 4,349.7 megawatts (MW) but declined to 2,987.6 MW on April 6, 2013 (*Saturday Punch*, 2013). The drop in energy generation has untold negative economic impact on the people and businesses. In Nigeria, energy is generated via hydropower and gas plants. Other sources of energy generation are wind, solar, petrol, coal, biofuel and nuclear. The safest and greenest source of energy generation is nuclear energy. However, necessary regulatory and safety measures must be engaged to prevent any mishap like the case of the Japan's Fukushima Daiichi Nuclear Power Plant accident. US$2 billion Nuclear Power Plant can produce 1,000 MW that can run for 40 years. One kilogram of natural uranium can release about 20,000 times as much energy as the same quantity of coal (World Nuclear Association, 2012, 2013). According to the *Saturday Punch* (2013), the Late President of Nigeria, Alhaji Musa Yar'Adua promised to deliver 5000 MW of energy to Nigerians in 2008, but in 2013 Nigeria has not achieved that goal. The author strongly believes that the investment into four to five nuclear power plants will help Nigeria achieve energy security.

The uranium in phosphate rock deposits in Nigeria and phosphogysum must be comprehensively recovered for nuclear fuel, while the phosphate freed of uranium may be used for fertilizer production for food security and the gypsum may be used as very useful industrial raw material for cement production and other important uses. Thus, sustainability and sufficiency in Energy and Food Security will become a Win-Win scenario for all stakeholders (Nigerian government, people and environment). It has been established that the cost of nuclear fuel is very minimal (US$40 per Kilogram of U) and so it is very attractive cost savings option for energy security in comparison to other energy generation sources (IAEA, 2004).

On the other hand, the absence of the Win-Win Scenario can predicate social unrests, riots, poverty, starvation, terrorism, political collapse, environmental pollution, diseases, etc.

VI. CONCLUSION AND RECOMMENDATIONS

In Nigeria, the phosphate deposits are of the sedimentary, marine origin. In Sokoto State, phosphates of Paleocene sedimentary deposits occur in the Dange Formation. The exploration work by the Geological Survey of Nigeria (now called Nigerian Geological Survey Agency) also established the occurrence of phosphate nodules and pellets in Dange, Gidan Bauchi, Illela, Gada and Kalambaina (Ogunleye et al., 2002). The thickness of phosphate deposits ranges from 1 – 5 m in the Dukamaje Formation and the phospatic nodules/pellets occur in sizes of 0.1 – 1 cm with varying concentration in different locations (Etu-Efeotor, 1998; Okosun, 1997, quoted in Ogunleye, 2002). The Sokoto phosphates have an estimated reserves of 5 – 10 million tonnes (Akinrinde and Obigbesan, 2006).

According to van Straaten (2002), Lower Eocene sedimentary phosphates have been known from south-western Nigeria since 1921 (Russ, 1924, quoted in McClellan and Notholt, 1986). Phosphate rocks are found in Oja-Odan and Ifo areas of Ogun State. Detailed work is needed to establish the actual reserves of the deposits. However, there are several conflicting reserve figures for the same deposits. Akinrinde and Obigbesan (2006) quoted 0.5 million tonnes, while McClellan and Notholt (1986) gave values of 1 million tonnes and the Ministry of Solid Minerals Development (2000) quoted 40 million tonnes as the reserves for the deposits. The phosphate rock deposits in Ogun State occur in nodules, granular and vesicular forms (Sobulo, 1994; Adediran and Sobulo, 1998; Adegoke et al., 1991; Akinrinde and Obigbesan, 2006). According to Akinrinde and Obigbesan (2006), Sokoto phosphates have calculated average percentage of 30.5 – 36.6% P_2O_5, while the Ogun phosphates have 26.3 – 32.0% P_2O_5. The above average values for the Nigerian phosphates compare favourably with the Togo phosphate which have the values of 28.0 – 36.6% P_2O_5 (Akinrinde and Obigbesan, 2006) and imported to feed the superphosphate fertilizer plant in Kaduna, Nigeria (Ogunleye et al, 2002). Comparative geochemical analysis of trace elements of the Nigerian and Togo phosphates indicated that the Nigerian phosphates meet the minimum international benchmark for uranium extraction from phosphates and phosphogypsum.

The Nigerian phosphates have been proven to have very high reactivity, thus making it very suitable as fertilizer material even for direct application to the soil to improve soil fertility and higher crop productivity (van Straaten, 2002; Akinrinde and Obigbesan, 2006; Okosun, 1997). However, in view of the high content of uranium especially in the Sokoto phosphates, the need to comprehensively extract out the uranium from the phosphates has become very imperative for the cogent reasons on the grounds of livestock and human health, environmental, surface and ground-water pollution control and energy sufficiency.

Attempts to recover uranium values from wet-process phosphoric acid have centred on the use of solvent extraction processes in which the uranium values are transferred to an organic phase, stripped from the organic phase and subsequently recovered as a uranium precipitate. The uranium-free wet-process phosphoric acid is then processed conventionally to form various phosphate-containing fertilizer products. Uranium from phosphate is extracted using a mixture of di(2-ethylhexyl) phosphoric acid (DEPA) and tri-octylphosphine oxide (TOPO) dissolved in an organic diluent. This extraction mixture is known to have a high affinity for uranium in the hexavalent oxidation state by using H_2O_4 oxidation agent. Uranium extracted as yellow cake (U_3O_8) and the phosphoric acid free of uranium is recovered for fertilizer production for food security. The gypsum is also of economic importance.

For Nigeria to join the League of Nations such as USA, Canada, Belgium, Syria, Israel, Taiwan, Egypt, Morocco, etc. that have achieved energy security, the following far-reaching recommendations are proffered:

(a) That basic legal framework should be set up for the comprehensive extraction of uranium from phosphates.
(b) That the existing fertilizers in the country should be assessed to ascertain their uranium concentration.
(c) That necessary policy should be developed to mitigate possible environmental pollution and contamination from uranium in farmlands, surface and underground water systems.
(d) That necessary publicity and enlightenment/awareness campaigns involving all stakeholders with respect to the comprehensive extraction of uranium from phosphates before they are used for fertilizer production should be carried out.

REFERENCES

[1]. Adediran, J. A. and Sobulo, R. A., 1998. Agronomic evaluation of phosphate fertilizers developed from Sokoto rock phosphate in Nigeria. *Communication in Soil Science and Plant Analysis vol. 29*, pp. 2415-2428.

[2]. Adegoke, S.O., Ajayi, J.A., Rahman, M.A. and Nehikhare, J.I., 1991. Fertilizer raw material situation in Nigeria. In: Anonymous (Ed.), Proceedings of the National Organic Fertilizers Seminar held at Kaduna, March 26-27, Federal Ministry of Agriculture, pp. 51-66.

[3]. Adesanwo, O.O., Dunlevey, J.N., Adetunji, M.T., Adesanwo, J.K., Diattas, and Osiname, O.A., 2010. Geochemistry and mineralogy of Ogun phosphate rock. *African J. Environ. Sci. Techn.vol. 4, no. 10*, pp. 698-708. Available at http://www.academic journals.org/AJEST.

[4]. Akinrinde, E.A. and Obigbesan, G.O., 2006. Benefits of phosphate rocks in crop production: Experience in benchmark tropical soil areas in Nigeria. *J. Biol. Sci. vol. 6 no. 6*, pp. 999-1004.

[5]. Etu-Efeotor, J.O., 1998. A review of the mineral resources of Sokoto basin, northwest Nigeria. *Journal of Mining and Geology, vol. 38, no. 2*, pp. 171-180.

[6]. Hanon, M., 1990. Notice explicative sur la carte geologique de L'Ader Doutchi. Ministere des Mines et de Recherches Geologique et Minieres, Niamey, Niger, 36 pp.

[7]. IAEA, 2004. Recent developments in uranium resources and production with emphasis on in-situ leaching mining. Proceedings of a technical meeting organized by IAEA in cooperation with OECD Nuclear Energy, the Bureau of Geology, and China National Nuclear Corporation held in Beijing, 18-23 September, 2002, IAEA-TECDOC-1396, Vienna, 332 pp.

[8]. Kogbe, C.A., 19972. Geology of the Upper Cretaceous and Lower Tertiary sediments of the Nigerian sector of the Illummeden Basin (West Africa), Geol. *Rdsch. vol. 62*, pp. 197-211.

[9]. Kogbe, C.A., 19976. Outline of the geology of the Illummeden Basin in North-Western Nigeria. In: Kogbe, C.A. (Ed.), Geology of Nigeria. Elizabethan Publ. Co., Surulere (Lagos), Nigeria, pp. 331-343.

[10]. Magellan, 1992. Nigeria Atlas: Maps and Online Resources. Available at www.infoplease.com/atlas/country/nigeria.html.

[11]. McClellan, G.H. and Notholt, A.J.G., 1986. Phosphate deposits of sub-Sahara Africa. In: Mokwunye, A.U. and Vlek, P.L.G. (eds.). Management of nitrogen and phosphorus fertilizers in sub-Sahara Africa. Martinus Nijhoff, Dordretch, Netherland, pp. 173-224.

[12]. Ministry of Solid minerals Development, 2000. An inventory of solid minerals potentials of Nigeria. Prospectus for Investors, 15 pp.

[13]. NIPC, 2009. Rich deposits of phosphate rock found in Northern Nigeria. *Nigerian Investment Promotion Council (NIPC) web publ.*, April 22, 2009. Available in *www.tradeinvestnigeria.com/investment_opportunities/183759.htm*

[14]. Ogunleye, P.O., Mayaki, M.C. and Amapu, I.Y., 2002. Radioactivity and heavy metal composition of Nigerian phosphate rocks: possible environment implications. *J. Environ. Radioactivity vol. 62*, pp. 39-48.

[15]. Ojo, O.D., 2003. Growth, development and yield of amaranth (*amaranthus cruentus L.*) varieties in response to different sources of phosphorus. Ph.D. dissertation, University of Ibadan, Nigeria, 300 pp.

[16]. Okosun, E.A., 1997. The potential application of Sokoto phosphate for the manufacture of fertilizer. *Journal of Agricultural Technology, vol. 5, no. 2*, pp. 59-64.

[17]. *Saturday Punch*, 2013. Nigerians lament drop in power generation. Nigerian newspaper issued June 29, 2013, *vol. 7182, no.* 1682, p. 47. Available at http://www.punchng.com/feature/power-talkback/nigerians-lament-drop-in-power-generation/.

[18]. Russ, W., 1924. The phosphate deposits of Abeokuta Province. *Geol. Surv. Nigeria, Bull. 7*, 43 pp.

[19]. Sobulo, R.A., 1994. Final report on agro-mineral project. Raw Materials Research and Development Council and National Fertilizer Company of Nigeria, Port Harcourt, Nigeria.

[20]. Tian, G. and Kolawole, G.O., 1999. Comparison of various plant residues as phosphate rock amendment on Savannah soils of West Africa, *vol. 27*, pp. 571-583.

[21]. Van Straaten, P., 2002. *Rocks for crops: Agro-minerals of sub-Saharan Africa*. ICRAF, Nairobi, Kenya, 338 pp.

[22]. Wikipedia, 2012. Nigeria. Available at https://en.wikipedia.org/wiki/Nigeria.

[23]. World Nuclear Association, 2012. World nuclear industry status report: The independent assessment of nuclear development in the world. Available in www.worlsnuclearreport.org/the-world-nuclear-industry-status.html.

[24]. World Nuclear Association, 2013. The economics of nuclear power. Available in www.world-nuclear.org/info/economic-aspects/economic-of-nuclear-power/.

[25]. Wright, J.B., Hastings, D.A., Jones, W.B. and Williams, H.R., 1985. *Geology and mineral resources of West Africa*. Allen and Unwin, London, UK, 187 pp.