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The Ancient Alkali Production Technology and the Modern Improvement: A Review

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ABSTRACT
Local production of ash-derived alkali was assessed in this review. Detailed information on local production of ash-derived alkali is rare in literature. Hence, the technologies, materials, probable criteria for selection of materials, processes, use, limitations, problems and areas needing further research in the local production of alkali were assessed. Visitation was made to some traditional alkali-producing factories as well as interaction with other local alkali producer. The traditional technology was found very interesting, while the corresponding laboratory set-up showed an improvement over the traditional one. Local production of potash-an impure form of ash-derived alkali, was observed to be a cheap alternative source of this much needed chemical used in the production of soap and other alkali-based products.

Key words: Potash, alkali, ash, production technology

INTRODUCTION
Alkali refers to a soluble base, usually the hydroxide or carbonate of potassium or sodium. Locally, it could be produced from ashes by extraction with water. When produced this way, it is usually referred to as potash. It is generally believed that the highest soluble metal is potassium, though this depends on the species of the plant material and the type of soil where the plant grows. In previous works on plant materials, Taiwo and Osinowo (2001), Kevin (2002) and Afrane (1992) reported that the alkalis from the ash were mainly carbonate of potassium and sodium. In the work of Onyegbado *et al.* (2002), Nwoko (1980), Onyekwere (1996) and Kuye and Okorie (1990), it was reported that the alkalis were hydroxides of potassium and sodium. Adewuyi *et al.* (2008) confirmed that the alkalis were mainly carbonates of sodium and potassium. As it shall be discussed later, it could be observed that the soluble mineral in ashes is not always mainly alkali: high potash content may yield very low alkali, depending on the sources of the ashes. The term soda ash instead of potash may be used if the major alkali metal contained is sodium.

Potash has been described as a white crystalline residue that remains after aqueous extract from ashes is evaporated (Kevin, 2003). It is an impure form of potassium carbonate mixed with other potassium salts (Wikipedia, 2007). The production and use of potash date from the ancient times in several countries of the world. It was first used in crude way as a domestic cleansing agent (Nwoko, 1980) by using ashes mixed with water to wash oil-stained materials. Potash has found a considerable use in Africa and Nigeria in particular, from the primitive till date

(Onyegbado *et al.*, 2002). There had been trades in potash (Townships Heritage WebMagazine, 2002); used as active ingredient in the production of local soap (Taiwo and Osinowo, 2001) and a useful raw material for some potash-based industries. With time, improvement in its production gave rise to extraction with water, which some times was boiled down or concentrated by evaporation. If the concentrated solution is left for some days, some crystals could be observed growing either on the wall of the container, or as a layer on the solution, or settling at the bottom of the container.

An extensive review on local production of potash is rare in literature. Some technologies and processes described in this review are being reported here for the first time in literature. To make up this report, oral interview was conducted with some traditional potash producer as well as interaction with some other local producer. Again, this review is necessary; one, to help those who are already in the business of potash production and any intending local producers on materials and technology for better production; two, to help some researchers who may think there is nothing or no much to be researched into on potash; that is, to shed some light on possible areas of potash that need to be researched into.

Wood ash: Studies of chemical composition of wood ash in the past have primarily been restricted to the elemental composition (Baker *et al.*, 1964) because the focus had always been on agricultural application of wood ash in which it was used as a liming agent and as a source of nutrients for agricultural plants (Campbell, 1990). Analysis of extracts from ashes by Nwoko (1980) and others (Onyegbado *et al.*, 2002; Onyekwere, 1996; Kuye and Okorie, 1990) showed that the extract was chiefly potassium hydroxide with some quantities of sodium hydroxide, while other metallic ions constituting about 2% were Ca^{2+}, Cr^{2+}, B^{3+}, Zn^{2+}, Fe^{3+}, Pb^{2+} and Ni^{2+}. Naik *et al.* (2003) tested different sources of wood ash from USA and Canada; the major elements in the wood ashes tested were carbon (5 to 30%), calcium (7 to 33%), potassium (3 to 4%) and sodium (0.2 to 0.5%).

Ash source: Ash is sourced from various materials. Several agro-wastes of vegetable origin have been shown to yield high potash when combusted. These materials include plantain peel, cocoa-pod husk, palm bunch and wood (Edewor, 1984). Traditional folks who major in the production of potash as a trade, especially for the production of local soap, either collect the ashes from wood industries where mixed sawdust of various species of wood as a waste is combusted, or from houses as domestic ash waste from combustion of firewood. It is very important to know that the plant material determines the potash yield. The process of combustion also contributes to the quality and quantity of ashes and consequently the quality and quantity of potash. When the vegetable materials are combusted slowly and at low temperature, the materials are not totally combusted to ashes; some black particles and some particles not combusted at all may be observed. These may impart colour to the extracted potash. Hence, most potash produced traditionally is usually coloured brown. To show an improvement in combustion, some experts have used special combustion pans; however, combustion in a temperature-controlled furnace could give the best result because there will be a fast and complete combustion.

Potash content: Several authors have studied the potash content of some plant materials: 40-60% (Afrane, 1992) and 56.73±0.16% (Taiwo and Osinowo, 2001) were obtained for cocoa husks; 78% for ripe plantain peel and 94% for fresh plantain trunk (Ankrah, 1974); 82% in unripe plantain peel (Onyegbado *et al.*, 2002); 43.15±0.13% in palm bunch, 16.65±0.05% in groundnut shell and 12.40±0.08% in sorghum chaff (Taiwo and Osinowo, 2001).

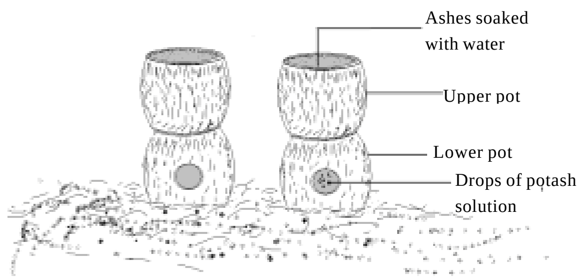

Fig. 1: Traditional potash extraction set-up

Extraction: There are various local extraction technologies, depending on the desired quality, quantity and intended use of the resulting potash. Generally, containers made of aluminum are to be avoided since alkali attacks aluminum. Figure 1 shows a typical ancient traditional extraction technology. It consists of two clay pots (of about 50 L each) mounted on each other. The one on top is open at the base, with radius about half the open top. The open base is completely blocked with pieces of sticks, followed by a layer of wood charcoal. The remaining space on top is then packed with ashes which had already been moistened with water for some days to aid quick extraction. Water is then carefully poured on top, as to only saturate the ashes and not to leach the desired component yet. After few hours, when the ash would have completely absorbed the water and every large pores and air spaces blocked, sufficient water is then carefully poured on top. The water slowly leaches the potash into the lower pot, the ash itself serving as a filter. Perhaps the charcoal removes some unwanted organics from the leaching potash. As mentioned earlier, the potash produced this way is usually coloured brown and may have contributed to the black colour of the local soap produced with it.

Laboratory experimental set-up used by Kevin (2002). At the top is a transparent plastic bottle of about 2 L capacity and at the base is a beaker. The bottle is filled with ashes to about one-third. Sufficient water is added, capped and then shaken thoroughly to dissolve the soluble components. The ash is allowed to settle, till a clear liquid is observed at the top. One or two pin-holes are made at the bottom and then placed on the beaker, while the cap is removed. The solution on top is filtered by the ashes as it leaks into the beaker. The potash solution obtained this way is usually clear, that is, colorless, although it also depends on the source of the ash.

Adewuyi *et al.* (2008) had a similar experimental set-up. A 4 L keg is filled to about one-third with ashes. Distilled water is added, capped and then thoroughly shaken. It is left for about twelve hours to ensure maximum dissolution of the soluble minerals in the ashes. The keg is then clamped on a retort stand at an angle of about 45° to ensure that an insignificant amount of the solution is retained at the end by the ashes in the keg. About two pin-holes are made at the vertex pointing downward, the cap removed, so that the extract leaks into a collecting bucket under. The solution obtained here is also clear, but depends on the source of the ash as well.

Concentration: Concentration is generally achieved by evaporation. In the traditional method, the metal container to be placed on fire for evaporation is usually that coated within and without with silicate material. The solution is boiled down till some pop sounds are heard, if it is meant for production of local soap. In the laboratory, the beaker and its content may be placed in the oven initially set at about 60°C and the solid residue obtained may then be dried at about 105°C.

Evaporation at higher temperatures may bring about flying up of some particles from the concentrated solution.

Purification: The potash obtained is a mixture of potassium carbonate, sodium carbonate and some chlorides and sulphates; the one to be predominant depends on the plant species and the nature of the soil where it grows. To achieve a high level of purification, there is the need for a thorough knowledge of solubility, availability of appropriate apparatus and expertise resulting from repeated practices. As a general principle, the crystals obtained are re-dissolved in a volume of water sufficient enough to completely dissolve the crystals. The solution is heated and evaporation is allowed to take place till there is an appearance of some precipitates. It is then allowed to cool gradually. The soluble components at the lower temperatures remain in solution while the insoluble ones precipitate out and may thus be separated.

Sometimes, the soluble non-alkali content may be extremely higher than the alkali content. Research could be made to determine the exact soluble non-alkali component; this could be a viable and sustainable source of an important industrial chemical raw material.

Determination of alkali and non-alkali content: The alkali content is either potassium carbonate or sodium carbonate. Total alkali may be determined by titration with an appropriate mineral acid (preferably, HCl):

$K_2CO_{3(aq)} + 2HCl_{(aq)} \rightarrow 2KCl(aq) + CO_{2(g)} + H_2O_{(l)}$, or
$Na_2CO_{3(aq)} + 2HCl_{(aq)} \rightarrow 2NaCl_{(aq)} + CO_{2(g)} + H_2O_{(l)}$

Calculation of percentage purity may be used to evaluate the alkali and non-alkali content.

Potash: A potential source of laboratory reagent: Plantain peel had been studied to have high potash content (Onyegbado *et al*., 2002). The alkali content of potash obtained from ashes of plantain peel was determined to evaluate the possibility of use as laboratory reagent. The results are shown in Table 1 and 2. In Table 1, the ash content was 10%; in terms of waste management, the volume of plantain peel waste had been reduced by 90%. Potash yield was 74.37%. The final amount of ash disposed as waste would be 25.63%, which implies an effective waste management by reuse. Table 2 shows the result of determination of alkali content using titrimetric method of analysis. The purity was found to be 84.60%, implying non-alkali content (the impurity) of 15.40%. Purification could be attained through recrystallization. The result may render it a useful reagent in the laboratory. Further work on this is recommended.

Table 1: Ash and potash yield of plantain peel

Sample (g)	Ash (g)	Ash (%)	Potash (g)	Potash (%)
1500	150	10	111.56	74.37
1500	150	10	110.20	73.47

Table 2: Determination of alkali content of potash obtained from plantain peel, using titrimetric method of analysis

Titres (mL)							
1	2	3	4	5	Mean (mL)	Concentration (moldm^{-3})	Purity (%)
16.90	16.90	17.00	16.80	17.00	16.92	8.46×10^{-2}	84.60

Selection of wood species for potash production: Some physical and chemical parameters determined during potash production from African wood species have been used to evaluate some important relationships which may be used in the selection of wood materials for potash production and in addition, may aid in wood classification. Wood has found various physical and chemical uses since the ancient times. Among the various ways and forms in which it is used, it has the widest and increasing use in various construction activities. Hardness, weight and colour are some of the properties considered in the selection of wood types for various purposes. The ease of resistance to degradation by water, weather and insects are also considered. The terms hardwood and softwood have been used to classify some species of wood.

The parameters for wood classification are rarely those of wood density, ash content and chemical content like potash. Wood density gives an idea about the packing and quantity of matter in the wood, ash content evaluates the mineral content of the wood and the potash content gives an idea of the soluble mineral content of the wood. If these properties are therefore properly evaluated, they may distinguish one wood species from another. Wood species and the nature of soil where the plant grows determine the composition of ashes resulting from the combustion of the wood (Kevin, 2003).

Materials for potash production have been sourced from various agricultural wastes, including woods (Irvine, 1961). Materials from woods have been a consistent and more reliable sources, especially in Nigeria where wood industries are established in thousands and 30, 064, 320 m^3 of wood wastes are generated annually (Babayemi and Dauda, 2009). For maximum economic advantage, selection of materials, especially high potash-yielding wood species, is very important. From the available literature, it is noteworthy that this is the first report to compare these characteristics for African wood species.

Table 3 shows the result of various species of wood analyzed for Moisture Content (MC), Dry Matter content (DM), Wood Density (SD) and Ash Density (AD) (J.O. Babayemi, personal communication, Bells university of Technology). The species are: *Cola gigatia* (SP_1), *Ficus exasperate* (SP_2), *Albizia zygia* (SP_3), *Irvigia gabonensis* (SP_4), *Ceiba pentandra* (SP_5), *Celtis zenkerii* (SP_6), *Funtumia elastica* (SP_7), *Annogissus celocarpus* (SP_8), *Terminalia superba* (SP_9) and *Cordia millennii* (SP_{10}). And Fig. 2 to 9 show the relationships established statistically. If R^2

Table 3: Some physical parameters of wood species

	SP_1	SP_2	SP_3	SP_4	SP_5	SP_6	SP_7	SP_8	SP_9	SP_{10}
MC	13.54	16.42	12.99	12.99	12.50	13.28	18.16	12.84	12.77	13.08
DM	86.46	83.58	87.01	87.01	87.50	86.72	81.84	87.16	87.23	86.92
SD	0.16	0.12	0.15	0.23	0.06	0.15	0.13	0.23	0.17	0.14
AD	0.05	0.20	0.20	0.12	0.09	0.24	0.12	0.32	0.40	0.13

MC: Moisture content (%w/w), DM: Dry matter content (%w/w), SD: Sawdust (wood) density (g mL^{-1}) and AD: Ash density (g mL^{-1})

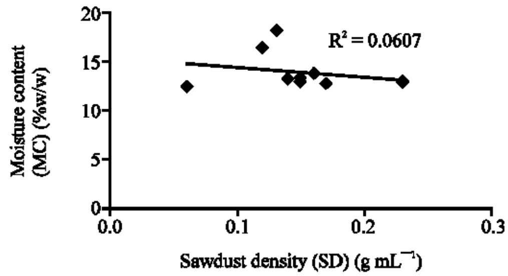

Fig. 2: Graph of Moisture Content (MC) against Sawdust Density (SD)

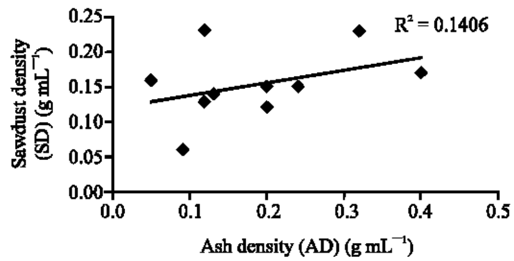

Fig. 3: Graph of Sawdust Density (SD) against ash density (AD)

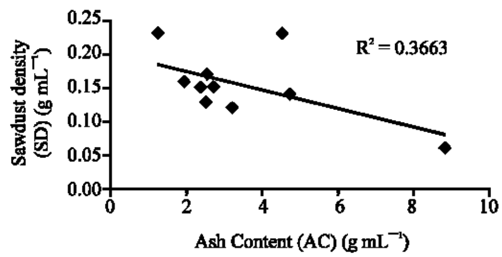

Fig. 4: Graph of Sawdust Density (SD) against Ash Content (AC)

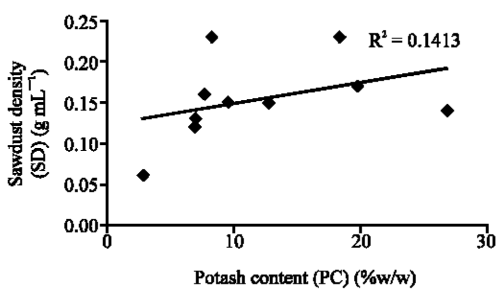

Fig. 5: Graph of Sawdust (wood) Density (SD) against Potash Content (PC)

approaches 1.0, it means there is a very high relationship between the compared parameters; otherwise, there is little or no relationship. Figure 2 shows little or no correlation between the moisture content and the density of the sample. Positive relationship exists between the wood density and the ash density (Fig. 3): a wood species of high density is likely to give ashes of high density. Figure 4 shows a positive relationship between wood density and ash yield, though the correlation coefficient is very low; it could be inferred that woods with high density are likely to give high ash yield. Figure 5 compared wood density with potash content. There was little relationship ($R^2 = 0.3821$): the lower the wood density, the more the potash content. In Fig. 6, there was little relationship between ash density and potash content ($R^2 = 0.1466$): the lower the ash density, the more the potash content. Figure 7 shows a negative correlation: the lower the ash yield, the more the potash yield. In Fig. 8, the relationship shows that the higher the potash yield, the more the alkali content; experimentally, this may not be very true. The same thing applies to non-alkali content in Fig. 9.

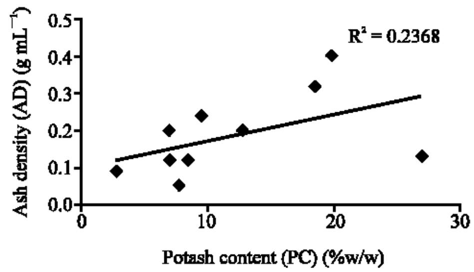

Fig. 6: Graph of Ash Density (AD) against Potash Content (PC)

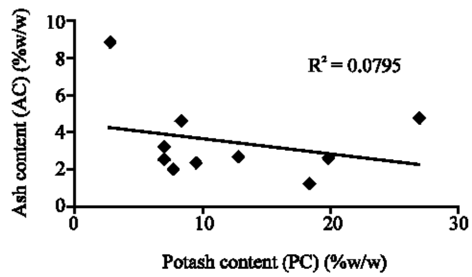

Fig. 7: Graph of Ash Content (AC) against Potash Content (PC)

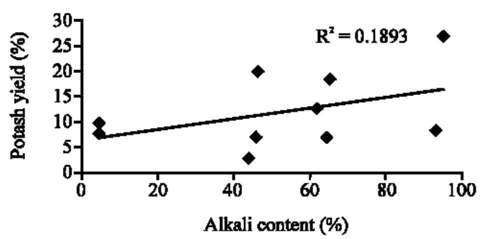

Fig. 8: Graph of potash yield against alkali content

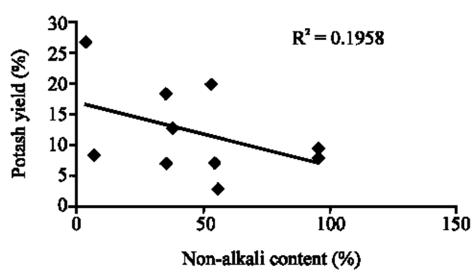

Fig. 9: Graph of potash yield against non-alkali content

Potash production as a way of managing wood and ash wastes: It has been observed that combustion of wood wastes to ashes reduce the wood waste volume by 95% (Babayemi and Dauda, 2009). Hence, plant wastes could be reduced in volume by combustion and the resulting ashes exploited for potash production.

Harmful effects of potash: Like any other mineral alkali, potash at high concentration could burn skin. Therefore, necessary precautions must be taken during production and use.

CONCLUSION

The current local production of ash-derived alkali is an improvement that trailed the path of the ancient traditional technology. Local production is a cheap method, which if well explored, could meet the need of this chemical as raw material in industries. Further research is needed for a more advanced technology for production of alkali from ashes.

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