DEVELOPING NATIONAL CAPABILITY FOR MANUFACTURE OF ACTIVATED CARBON FROM AGRICULTURAL WASTES

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ABSTRACT

Ghana imports large quantities of activated carbon annually and at very high cost. Studies on resource assessment of raw materials show there is more than enough of the agricultural waste raw materials available for activated carbon production to meet local demand. In view of these facts, the Institute of Industrial Research is developing local capability for the production of activated carbon from the agricultural waste materials: coconut shells, palm kernel shells and sawdust Assessment of various technology options for activated carbon production identified the Steam Activation process as the most suitable option. Projecting on the available raw materials, it is established that industrial demand for activated carbon can be met locally.

1.0 INTRODUCTION

Activated carbon is produced from organic based materials such as coconut shells, palm-kernel shells wood chips, sawdust, corn cobs, seeds etc. The raw material is carbonized to obtain the char or carbonaceous material, which is activated to yield the highly porous final product. Typically, surface areas ranging from 500- 1400m^2/g are obtained for the activated material [1]. The activated carbon particle has two types of pores existing in it by which adsorption take place. These are the macropores ($>10^{-1}$ um) and the micropores (10^{-3} - 10^{-1} um)

The macropores provide a passageway to the particle's interior and to the micropores but do not contribute substantially to the particle surface area. The micropores, on the other hand, are responsible for the large surface area of activated carbon particles and are created during the activation process [2]. It is in the micro pores that adsorption largely takes place. Thus, two main parameters are relevant to the performance of the activated carbon namely the surface area and the pore volume or structure. The pore volume limits the size of the molecules that can be adsorbed whilst the surface area limits the amount of material which can be adsorbed, assuming a suitable molecular size. Various methods are available for the activation process [3] but the most widely used are the treatment of the carbonaceous material with oxidizing gases such as air, steam or carbon dioxide and the carbonization of the raw materials in the presence of chemical agents such as Zinc chloride, Magnesium chloride, Calcium chloride or Phosphoric acid. The carbonized material is treated with oxidizing gas in a furnace or retort at 800-1000^{0}C under conditions that permit removal of nearly all the adsorbed hydrocarbons and some of the carbon to increase the surface area. Chemical treatment activation proceeds under conditions that prevent the deposition of hydrocarbons on the surface.

The raw material is mixed with the chemical agent, dried and calcined at temperatures up to 900^{0}C. Other methods such as activation of the carbonaceous materials or chars mixed with Potassium hydroxide hydrate as activating chemical [4], treatment of char with sulphur vapour at elevated temperatures and subsequent desulphurisation with hydrogen [5] and activation in an inert atmosphere under reduced pressure without the use of any chemical activator [6], are reported. Treatment of charcoal and carbon black with oxidizing solutions such as nitric acid or a mixture of nitric and sulphuric acid [7] also increase the surface area as well as introduce acidic oxides (carboxylic, phenolic and quinonic) to the carbon surface. Activated carbon has several important uses [3,8] including solution purification such as in the clean-up of cane, beet and corn-sugar solutions, removal of tastes and odours from domestic and industrial water supplies, vegetable and animal fats and oils, alcoholic beverages, chemicals and pharmaceuticals and in waste water treatment. It also finds use in purification of gases, liquid phase recovery and separation processes as well as its use as catalyst and catalyst supports. For liquid purification or decolorising purposes, it is normally used in the powder form whilst for vapour or gas adsorption, it is used in the form of hard granules. Liquid phase adsorption or decolorising activated carbons are usually light, fluffy powders produced from low-density material such as sawdust or peat. Gas phase adsorption activated carbons are hard, dense granular materials produced from high-density raw materials such as coconut shells, palm kernel shells, coal or coke.

Ghana has a high potential of organic base raw materials for the production of activated carbon. There is also a great demand for activated carbon in Ghanaian manufacturing. For the period (1992-1996) Ghana imported about

2,900,000 kg of activated carbon valued at nearly ¢8 billion [9]. There is however no production of activated carbon in the country. The Institute of Industrial Research in collaboration with the Forestry Research Institute (CSIR) is currently working on a pilot scale production activated carbon from agricultural waste materials.

2.0 TECHNOLOGY OPTIONS

Activated carbon production technology options were assessed to select the most feasible route for development in Ghana. Methods involving the use of chemicals for activation would immediately suggest high costs of production associated with imports. Selective oxidation of the carbonaceous material with carbon dioxide would require installation for the generation of this gas except in situations where it is available as a bye-product from another industrial process. On the other hand oxidation with air, an exothermic process, presents process control problems and yields only low-activity carbon [3]. The steam activation process, like the carbon dioxide activation, is an endothermic process. It is easier to control, yields high-activity carbon and in fact, is one of the generally used methods for activation. The Steam activation technology is the major route being pursued in the pilot plant studies.

3.0 DEMAND FOR ACTIVATED CARBON IN GHANA

Ghana imports substantial amounts of activated carbon annually. Table 1 shows that within the period 1992 to June 1997 Ghana imported a total of 4,681,866 kg of activated carbon valued at ¢ l2,706,290,380.

Table 1: Activated Carbon Importation Figures [9]

Year	QUANTITY (Kg)	CIF VALUED (¢)
1992	**245,855**	284,660,705
1993	569,465	979,027,289
1994	791,980	2,992,842,837
1995	2,015,445	3,099,005,876
1996	274,730	1,454,910,592
1997	784,391	3,895,843,093
Total	**4,681,866**	**12,706,290,390**

The major importers of activated carbon for the period were the gold mining companies, the brewery and the soft drink industries. Activated carbon is used in the gold mining industries to recover gold from cyanide solution using the carbon-in-pulp or carbon-in-leach processes. In the brewery and soft drink industries, activated carbon is used mainly to purify the water used in production.

Assessment of the quality of activated carbon on demand showed that gold mining companies would prefer the hard dense type of activated carbon produced from coconut shells in particular and to some extent that from palm kernel shells owing to their characteristic ability to with-stand attrition during usage. The breweries preferred activated carbon from coconut shells, palm kernel shells and sawdust, whilst the soft drink industries preferred products mainly from wood chips or sawdust.

4.0 RAW MATERIALS AVAILABILITY

Studies carried out at the Institute of Industrial Research on raw material resource assessment for activated carbon production, focused on wastes coconut shells, palm kernel shells and sawdust. Major producing areas of these wastes were at Akame, in the Volta Region, Asuansi and Shama in the Central Region, Benso, Ayiem and Axim in the Western Region, Kade in the Eastern Region and Juziben in the Ashanti Region. The study showed that the generation and availability of the raw materials coconut shells and palm kernel shells were linked to the production of the main products coconut oil, palm oil and palm kernel oil. Production of all these oils by the small scale or traditional producers is spread over various areas in the country, whilst the established industries engage mostly in the production of palm oil. Access to palm kernel shells is relatively easier as many of the established industries crack the nuts to produce the kernels and shells. The kernels are either further processed by the factory or sold, whilst the shells are dumped as waste. Coconut shell wastes, on the other hand, are spread over wider area in the country and collection will require more effort than that of palm kernel shells.

Both the coconut shells and palm kernel shells produced by the traditional producers are sold as fuel. For instance coconut shell sells between ¢18 and ¢25 per full piece of dry pod and a maxi bag of palm kernel shells sells at around ¢2000. In the established palm oil industries only about 5% of the kernel shells generated are sometimes burnt together with fibre to generate heat for the boiler. The rest dumped as waste could be available for activated carbon production at no cost, at least for the present time. Palm kernel shell generation at some of the established factories are shown in Table 2.

Table 2: Palm Kernel Shell Generation in some Factories

FACTORY	LOCATION	ANNUAL SHELL GENERATION (TONS)
Benso Oil Palm Plantation (BOPP)	Benso (Western Region)	4000-5000
National Oil Palm Plantation	Ayiem (Western Region)	1600
Ghana Oil Palm Development Corporation (GOPDC)	Kade (Eastern Region)	5000-6000
Ghana Oil Palm Development Corporation	Kwae (Eastern Region)	3000

Table 3 gives the total annual coconut production and estimated shell generation in Ghana from 1990 to 1996. The shell constitutes 10% by weight of the whole nut. The data also gives the production breakdown on regional basis as follows: Western Region ~ 80-85%, Central Region ~ 10-15%, Volta Region ~ 1%.

Table 3: Annual Coconut Production Figures [10]

YEAR	TOTAL AMOUNT OF NUTS (TONS)	TOTAL AMOUNT OF SHELLS (TONS)
1990	281,000	28,100
1991	281,000	28,100
1992	275,000	27,500
1993	275,000	27,500
1994	275,000	27,500
1995	275,000	27,500
1996	270,000	27,000

Table 3 shows no significant change in production from 1990 to 1996. The stagnating growth is attributable to the "Cape St. Paul Wilt" (or "Lethal Yellowing") disease which is currently devastating large acres of coconut plantations in the country. The Oil Palm Research Institute (CSIR) reports on development of hybrids of the coconut palm which could resist the disease. Also a rehabilitation programme of the coconut plantations by the Ghana government indicates prospect for the sustainability of the coconut industry.

Table 4: Sawmill Residue Generation in 1995 by Region [11]

REGION	SAWDUST (M^3)	SLABS/EDGINGS (M^3)	OFFCUTS (M^3)	TOTAL (M^3)
ASHANTI	107,886	264,284	49,280	421,450
WESTERN	42,204	101,662	18,621	162,487
BRONG AHAFO	26,148	61,071	17,063	104,284
CENTRAL	5,076	13,310	2,653	21,039
EASTERN	16,827	43,694	8,630	69,153
GREATER	1,720	4,039	718	67,475
TOTAL	**200,329**	**489,369**	**90,984**	**780,682**

Table 4 shows sawmill residue generation in 1995 in various regions of the country. Some of the mills use a considerable proportion of these residues to fuel their boilers. Though briquettes are also produced from sawdust, a considerable proportion of the waste, however, is left unused and could be available for activated carbon production.

Projecting on available raw materials, the country can install a capacity to meet the demand for activated carbon. For example, coconut shell generation of about 20,000 tons per annum and 50% availability applying steam activation process could yield 2000 tones activated carbon which exceeds the total figure of 784,391 kg or 784.4 tons of activated carbon demand for 1997.

5.0 PROCESS FLOW DIAGRAM AND EQUIPMENT FABRICATION

The process being developed at the Institute of Industrial Research for activated carbon production is shown in the flow diagram, Fig. 1.

The preparation of raw materials involves sorting out of dirt or separation of shells from husk in case of coconut and crushing of material to suitable size. The crushed material is dried to remove moisture. The moisture content of the raw material is an important parameter. If the moisture content is about 20%, the water driven off during the early stages of pyrolysis or carbonisation, reacts with off-gases or impedes their removal. This allows the off-gases to crack and restrict micropores openings in the product [12].

The Carbonisation or Pyrolysis Unit is being designed to make provision for collection of the distillate material which contains three main components:

- Condensable gases which yield tar.
- Non-condensable gases of high calorific value and which can be used to supplement fuel for heating.
- Aqueous phase containing pyrogenic acids.

The carbonised material may further be crushed to size, where necessary, before activation. The activation system consists of a boiler unit to generate steam and a furnace containing the activating stainless steel chamber. The activation shall be carried out under fluidised bed conditions to facilitate uniform heat distribution and uniform gas-solid contact. The steam activation reaction produces gases such as H_2, CO and $C0_2$. The hydrogen and carbon monoxide content of this gas mixture can be burnt in an auxiliary burner to provide supplementary heat for the boiler or for the carbonisation process.

The carbonised product, shall be ground into powder of specified mesh size for liquid phase or decolorising carbons. In the case of gas phase adsorbing carbons, the granular material shall be ground by tumbling with grit or using any other suitable technique, so as to smooth sharp edges that might abrade into powder during use.

6.0 CONCLUSION

There are potential raw material resources for the production of activated carbon to meet local industrial needs. In addition to the identified raw materials coconut shells, palm kernel shells and sawdust, other raw materials such as corncobs, rice hulls and vegetable wastes can also be used to produce activated carbon. Besides the gold mining industries, the breweries and soft drink industries that currently use activated carbon, other potential users such as corncobs, rice hulls and vegetable wastes can also be used to produce activated carbon. Besides the Gold mining industries, the breweries and soft drink industries that currently use activated carbon, other potential users such as the textile industries, soap manufacturing industries, vegetable oil nulls and the Water and Sewerage Corporation can also be sensitised to use this commodity thereby creating more market for the product.

The pilot studies to develop a national capability for the production of activated carbon will, among several benefits, contribute to measures for abating the environmental degradation caused by dumping of agricultural wastes.

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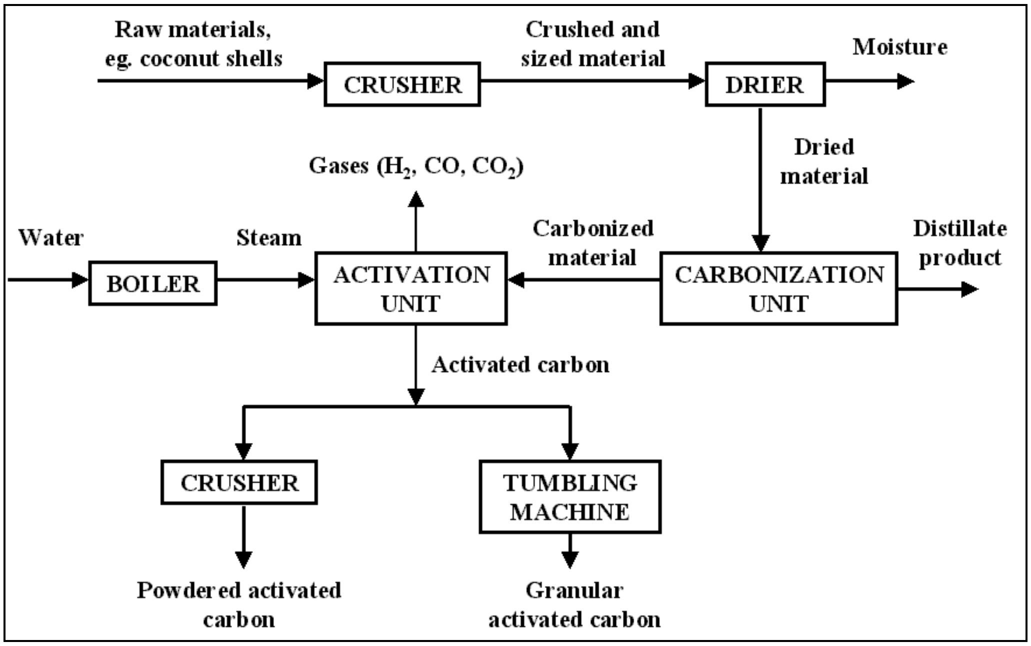
Fig. 1: FLOW DIAGRAM FOR ACTIVATED CARBON PRODUCTION



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