CHARCOAL PACKED FURNACE FOR LOW-TECH CHARRING OF BONE

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SUMMARY: A low-tech furnace for charring of raw bone using char coal is developed and tested. The furnace consists of a standard oil drum, fitted with simple materials as available in every market in small towns in developing counties. 80 kg of raw bone and 6 kg of charcoal are used for production of 50 kg of charred whole bones. This yields about 30 kg of useful bone char grains. Special arrangement is developed in order to fire the produced evil-smelling gasses, without introducing oxic conditions in bone charring chamber. The furnace is scalable according to the capacity needed.

Key words: Charring of bone; Bone char preparation; Furnace; Low cost furnace; Low-tech furnace: Fluoride; Defluoridation; Developing countries.

INTRODUCTION

For decades, bone char has been manufactured in large industrial scale to be used mainly as a colour sorbing agent in preparation of suger.[1] Also for many years bone char has been known and used as a defluoridation agent in municipal water treatment.[2] Initially, it was considered to be less suitable for use by individual households,[2] but this point of view never became widely accepted. The bone char-based household defluoridator was proposed as early as 1961,[3] initially for use in New Zealand.[4] Later it was modified as the ICOH defluoridator for use in Thailand and advocated by WHO for use in households of developing countries.[5] Only recently it became known that the implementation of the ICOH defluoridator in Thailand is limited, both geographically and in numbers.[6] Attempts to implement the ICOH defluoridator in Tanzania have not been successful so far.[7]

All through its history,[2-7] the use of bone char in individual household has encountered three major mutually related problems:

1. The bone char is not comfortably available in markets for the potential users, especially in not in developing countries.[4, 5]
2. The bone char, especially when prepared locally, may impart the water quality by giving the water unpleasant taste and/or smell or colour. Alternatively the defluoridation capacity of the product may be imparted.[4, 8]
3. The local production of bone char may, it self, be repulsive due to emission of evil-smell, which at the final end may discourage people from local production of the medium and the use of the method.[4, 6]

In order to resolve these problems the Danida-Enreca assisted Defluoridation Technology Project in Ngurdoto, Arusha Region, Tanzania, adopted a programme for development of an appropriate furnace. The objective of this paper is to describe one of the developed approaches; a charcoal packed furnace for low-cost preparation of bone char.

THE FURNACE

Charring process. Charring of bone is normally a process of heating to high temperature under restricted access of atmospheric oxygen, i.e. pyrolysis. Under such a treatment the organic materials in the bone crack to low molecule volatile compounds which evaporate. The residual organic carbon mineralises to graphite.

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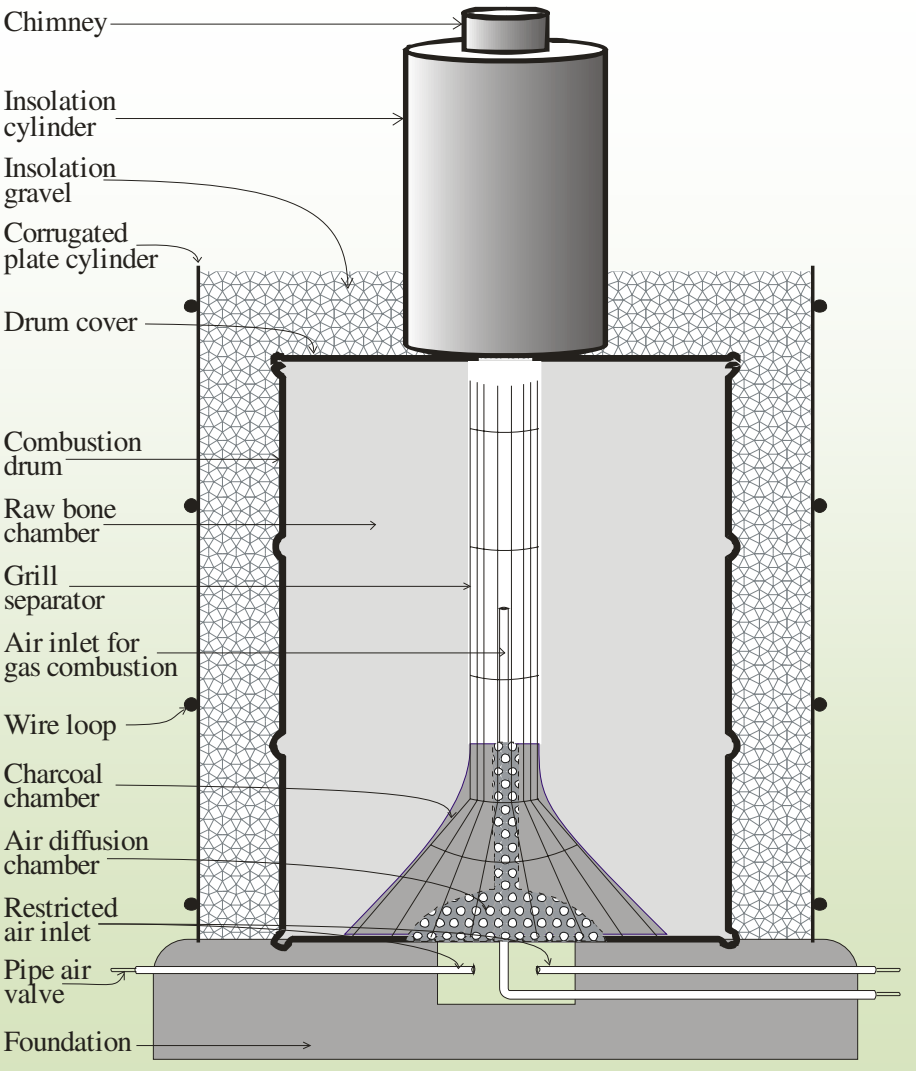

FIGURE 1 The low-tech drum furnace for charring of bone.

The graphite remains in the porous apatite structure. Properly charred bone does not add colour, taste or smell to the water. In the contrary it is capable, apart from removing fluoride, to remove discoloration, and bad taste or smell from the water.[8] In the developed furnace the heat is generated in part through controlled combustion of packed charcoal, in part through controlled firing of the organic materials in the raw bone. Heated fresh air is admitted at the smoke outlet in order to fire the produced nasty gasses before passing out to the chimney.

Construction. The furnace is made of a standard oil drum, 68 cm in diameter, 86 cm in height. The drum is placed on a cement foundation surrounded by a cylinder made of 4 pieces of corrugated galvanised iron sheets, fixed by means of 4 loops of 3 mm galvanised wire. The space between the drum and the corrugated plate cylinder, 20

cm wide, is filled with porous gravel for insulation, Figure 1. The drum has two holes, centralised in the bottom and in the cover. The holes are 12 cm in diameter to allow respectively for air inlet and smoke outlet. A double cylinder chimney made of corrugated iron sheets is mounted around the drum cover hole. This arrangement makes is possible to insulate the top of the furnace by covering it with about 15 cm layer of porous rocky gravel.

Furnace inside parts. The bottom hole in the furnace is covered with a perforated upturned funnel-like device for even diffusion of the inlet air in the charcoal chamber. An upturned funnel-like grill is placed over the air diffusion device. The space between the perforated device and the grill is used as a char coal compartment. Two ¾ inch galvanised iron pipes are caste in the cement foundation for fresh air inlet beneath the drum bottom hole. Another ¾ pipe is bend up to the centre of the drum for firing the produced gasses before emission to the atmosphere. The three pipes can be plugged either totally or partly by placing smaller pipe pieces at their inlets in order to control the fresh air and the heated air inlets.

METHODS

Furnace operation. Five kg, about 17 L of charcoal are piled on the bottom of the furnace between the perforated device and the grill. The charcoal is ignited using a slop of kerosene. As soon as major part of the charcoal makes red-hot it is spread around in the bottom. Whole pieces of raw bones, about 80 kg, together with additional 1 kg of charcoal, are piled around the grill up to the top of the furnace. After 1-2 hours of firing, when the furnace starts smoking heavily, the furnace is covered, the chimney is mounted and the top gravel is placed. The reducing cylinders are put in the air inlet pipes to reduce the ventilation. Depending on the wind direction and strength eventually only one air inlet is sufficient. Hereafter, the furnace is left undisturbed. Emission of evil-smelling smoke is prevented or significantly reduces by removing the cylinder vent reducer for the central air injector. During overnight charring is brought to an end and the furnace cools from about 500 ºC down to less than 100 ºC. Only at this or later point the furnace is uncovered for removal of charred bone pieces. The cycle takes 24 hours or so.

Temperature monitoring. The temperature was monitored using probe electronic digital thermometers, TESTO 950, at three different points in the furnace:

1. The bottom edge, 2 cm inside the drum at a level of 18 cm from bottom.
2. The top edge; 2 cm inside the drum at a level of 68 cm from bottom.
3. The Top centre; beneath the chimney at a level of 68 cm from bottom.

Bone char crashing. The charred bones are sorted out. Brownish as well as white pieces are of no use. The black and blackish-grey pieces are crashed using a manually driven iron roller, 35 cm in diameter, 75 cm in width. Concrete cement is caste in the iron cylinder in order to obtain required weigh. The roller is driven on a special platform for collection of crashed bone char.

Grain selection. The crashed bone char is transferred to a triple tray sieve system. The trays are hanged for manual swinging. Too coarse and too fine grains are rejected. The bone char of 0.2 – 0.5 grain size is collected from the medium tray.

Bone char quality. The quality of the bone char was tested by measuring the residual fluoride concentration in a bottle test. 2 g of bone char were added to 600 mL of distilled water containing 20 mg/L fluoride. Each bottle is shacked by turning upside

down 10 times during 15 seconds, and then left undisturbed for 8 hours. This cycle is repeated 6 times. After a total contact time of 48 hours the residual fluoride concentration is measured, using a Metrohm electrode and TISAB addition. The supernatant water is furthermore used for organoleptic evaluation of platability and measurement of pH and the colour using a Hach portable kit DR/2000.

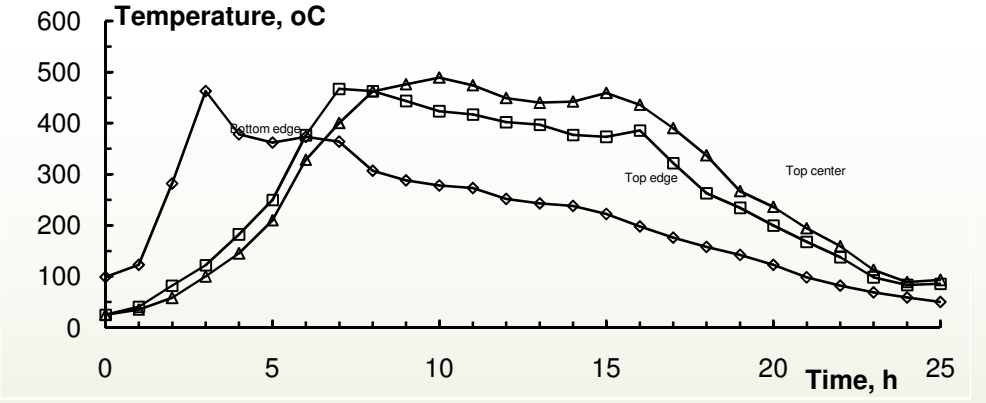

FIGURE 2. Monitoring of the temperature during a charing cycle in the furnace.

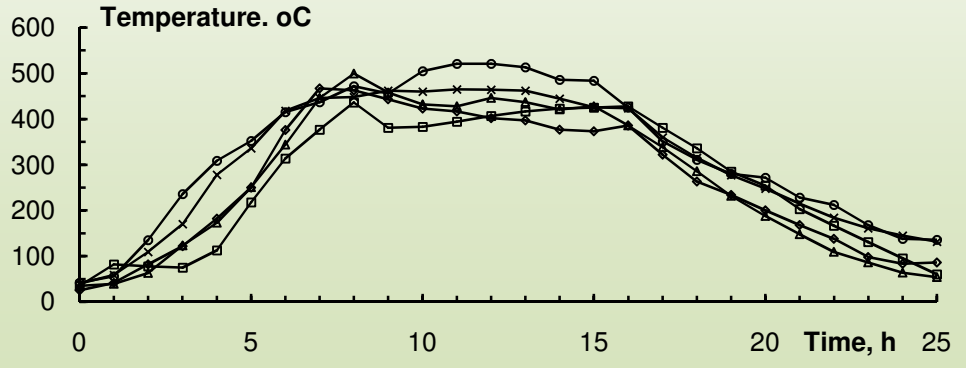

FIGURE 3. Repeatability of the heating procedure in 5 batches of bone charring.

RESULTS

Consumption and yield. The furnace consumed 6 kg of charcoal per batch and about 80 ± 20 kg of raw bones. Experience has shown that yield of charred bone is about 60 %, out of which 2/3 can be sorted out as grained medium, i.e. about 30 kg bone char per batch.

Temperature profiles. Figure 2 illustrates temperature versus time in a selected charring cycle. It is seen that the temperature reaches 400 –500 and remains at this level for a period of about 9 hours. Figure 3 illustrates the repeatability of the heating procedure. The curve pattern from one batch to another is almost the same; 7 hours of temperature increase, 9 hours of stationary charring period at 400-500 ºC and 9 hours of cooling down.

DISCUSSION

The Defluoridation Technology Project has carried out several investigations on technologies, which may be used for preparation of bone char. There seems to be no

doubt that charcoal packed column is far the cheapest and most user-friendly technique that can serve rural communities, if bone char has to be prepared locally.
Another important advantage of the technique is its scalability. It has been demonstrated that the furnace can be made in smaller scale, suitable even for the individual households. Furthermore, the furnace could be built in much larger scale, for centralised production of bone char to be distributed on commercial basis to rural areas.

Finely it has to be mentioned that same technique, after some modification, is probably most useful for charring or calcination of other media, like f. ex. magnesia, activated alumina, clay and the like. The key parameters in such modification would be the charcoal/media ratio, the air vent and flow and the mode of furnace packing.

Both the construction and the operation and maintenance can be carried out by villagers. However, like in rural brick making in kilns, good workmanship and some experience are required in order to run the process with a minimum of smell problems and the maximum of yield of good quality bone char.

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