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Improved and more environmentally friendly charcoal production system using a low-cost retort–kiln (Eco-charcoal)

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ABSTRACT

Research into a low-cost retort–kiln, used to produce charcoal from sustainably managed forests in a more environmentally friendly way (Eco-Charcoal), has been completed and pilot units have been built in India and East Africa. The unit is called ICPS (Improved Charcoal Production System). Importantly, it has a much higher efficiency rating than traditional earth-mound kilns, which have until now been the main means of domestic charcoal production in developing nations. The efficiency of traditional charcoal production methods is about 10%–22% (calculated on using oven-dry wood with 0% water content) while the efficiency of the ICPS is approximately 30%–42%. As compared with traditional carbonisation processes, the ICPS reduces emissions to the atmosphere by up to 75%. The ICPS works in two different phases. During the first phase the ICPS works like a traditional kiln; however, waste wood is burned in a separate fire box to dry the wood. During the second phase of operation the harmful volatiles are burned in a hot 'fire chamber' meaning all resulting emissions are cleaner, minus these already reduced volatiles. The heat gained by flaring the wood gazes, is used and recycled to accelerate the carbonisation process. Unlike traditional methods the ICPS can complete a carbonisation cycle within 12 h.

1. Introduction

Charcoal is a popular household fuel in many parts of the developing world. Countries like Kenya have a yearly consumption of about 2.4 million tons of charcoal [1], while Zambia uses about 1 million tons [2]. Together producing 3.4 million tons of charcoal, this means that, using a recovery rating or efficiency (yield) of approximately 18%, 18.7 million tons of wood is needed to produce the amount of charcoal that Kenya and Zambia require.

Just one ton of smouldering wood pollutes roughly 700 000 m^3 of air. If we multiply this figure with the 15.3 million tons of wood which disappears during charcoal production, in the region of 10 710 000 000 000 m^3 (10.7 billion m^3) of air is polluted per year in these two countries alone.

This charcoal is mostly produced using the earth-mound kiln, an ancient technology dating from the middle ages. During the four–seven days necessary for charcoal production using this earth-mound kiln, the heat loss through radiation and unpredictable fires lower its efficiency rating. Instead of this older method, a so-called 'retort technology' may be used. Retort–kilns have a much higher efficiency rating of 35%–40% in comparison with earth-mound kilns; they also reduce air pollution by up to approximately 75%, as the smoke produced is partly burned off during the carbonisation process [3]. Another benefit is that the operating time for the retort–kiln is much shorter – about 12 h (plus about 12 h for cooling).

Retort technology is the standard method of production for industrial charcoal in western countries, but due to high investment costs it is not viable for traditional charcoal makers in the so-called south countries. Now, a more appropriate, efficient and affordable design has been developed to transfer and adapt this retort technology in rural or semi-industrial areas. The low-cost retort–kiln is called ICPS (Improved Charcoal Production System or "adam-retort") and can be built by a team of two trained workers within a week for about 300€. The investment recoup period for the investment is about 5 months. The unit was developed in Burundi, East Africa and in India. A successful introduction of the ICPS took place in Kenya in October 2005 [4,5,12]. Retort technology means that the charcoal is locked in a closed container where smoke and wood gases are only able to leave through one controlled opening.

2. Technology and characteristics

2.1. Emissions

In grams per kilogram of dry matter burned, emissions from a normal charcoal production process are approximately 10 times

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Table 1
Annually burned biomass, methane and carbon dioxide emission from biomass burning in intertropical Africa [9].

Type of combustion	Annually burned biomass 10^9 tons dm	Emission factor CO_2 g/kg	Emission factor CH_4 g/kg	CO_2 emission 10^9 t yr^{-1}	CH_4 emission methane 10^6 t yr^{-1}
Savanna fires	2.52 (2–3)	1370	1.65 (1.3–2)	3.45	4.14 (2.6–6)
Forest fires	0.13 (0.1–0.15)	957	6.94 (6–8)	0.12	0.90 (0.6–1.2)
Firewood burning	0.12 (0.1–0.12)	957	5.42 (5–6)	0.11	0.65 (0.5–0.8)
Charcoal making	0.11 (0.1–0.12)	641	21.00 (15–27)	0.07	2.31 (1.5–3.2)
Total for Africa	2.88 (2.3–3.3)			3.75	8.00 (5–11)

more than compared standard wood burning. [6]. This difference is linked to the combustion process, which is characterized by a longer smouldering of the wood. The emissions of traditional charcoal kilns and the pyrolysis of wood cause an excess methane (CH_4) and carbon dioxide (CO_2) and the concentration over average ambient air is about 12%. The corresponding emission factor (21 g CH_4/kg dm) is 4–20 times higher than that observed in the other types of combustion. Other emissions are a combination of chemically active species such as CO, odd nitrogen (NO_x), N_2O, non-methane hydrocarbons (NMGCs), methyl chloride and others. As a result, traditional charcoal making appears to be a significant source of methane. Methane is 21× times more effective and dangerous on the green house effect than CO_2. Taking into account the biomass burned annually in the different processes, the global amount of methane emitted by biomass burning from the African continent (5–11×106 t yr^{-1}) is similar to the emissions from animals or natural wetlands, and represents about 30% of total emissions in Africa [7]. As mentioned in the introduction a retort–kiln could significantly reduce these harmful emissions.

2.2. Fire box

Lack of burning (flaring) of smoke and wood gases produced during pyrolysis in traditional kilns, generates pollution. One of the main differences of this low-cost retort system is that during the second phase of operation the smoke and the wood gases are channelled by the hot zone of the fire box and are then cleanly burned. The heat and energy gained during this process are recycled and used to accelerate the carbonisation process. The wood and partly carbonised wood (torrified wood) are more quickly carbonised and there is a shorter carbonisation period of 10–12 h, compared to the traditional (older) carbonisation method which takes 4–7 days [8].

Wood contains a lot of water which has to be completely evaporated before carbonisation can begin. On average there is about 15%–20% of water content in sun-dried wood. That means 100 kg of wood loaded into the wood chamber of the retort contains 15 kg–20 kg of water. The 3 m^3 volume of the wood chamber can be loaded with about ~750 kg of wood which contains about ~112 kg–~150 kg of water. In the traditional carbonisation process the high quality wood to be carbonised will be partly burned for this purpose to evaporate the water. However the ICPS uses a different concept: that of a 'fire box.' Waste wood and agricultural waste can be burnt in the fire box in order to heat the wood chamber where carbonisation is also initiated. About 50 kg of waste wood is burned per batch of operation.

2.3. Insulation

Traditional kilns do not have good insulation. Wet soil covers the hot wood and charcoal, causing heat loss to occur during the long period of operation.

The ICPS is built with double walls of bricks or even stabilized earth blocks; the double wall provides a natural insulation, and the average temperature of the outer wood chamber wall is roughly only 50 °C. The top of the wood chamber is covered by a thin metal sheet and 4 insulating lids. The lids offer better insulation for wood drying and for pyrolysis. For quick cooling (preferably at night) the lids can be removed and the wood chamber can cool within 12 h (Table 1 and Fig. 1).

2.4. Two phases of operation

Another characteristic of the ICPS is its two-phase operation. During the first phase of operation, which takes about 4 h, the hot volatiles from the fire box directly are channelled to the wood chamber and the wood is dried. Once the smoke from the chimney, which is mainly steam, becomes more yellow in colour, this is an indication that the second phase, the retort operation, can begin. The smoke and wood gases are redirected towards the fire box by a simple device, the wood gases are flared and the heat generated is recycled.

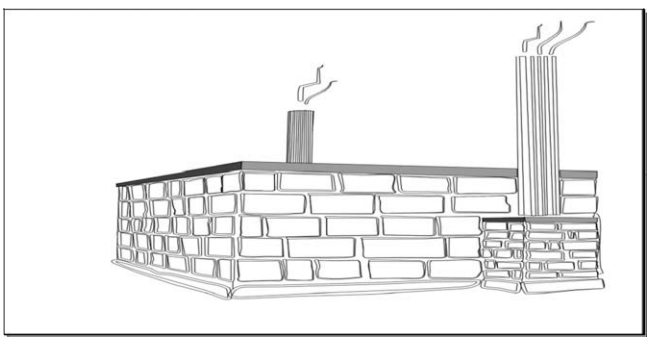

Fig. 1. View of the "low-cost retort unit" (ICPS) or "adam-retort".

Photo 1. ICPS built in the Rift Valley, Kenya.

Photo 2. ICPS built in Germany.

3. Conclusions

With lower incomes in the developing nations and the increase in price of petrol products, the majority of the population cannot afford cooking fuels like kerosene and gas (LPG). The use of these fuels also creates a need for investment in gas- and kerosene-cookers. Some traditional cooking methods, as well as social preferences demand the use of charcoal, e.g., for tandoori bread ovens (India) or for barbecue meat (Burundi) or tachines (Maroc). A wood fire needs to be regularly attended too, for example, whereas a charcoal fire needs less attention.

As charcoal will continue to be used, it is seems better that it is at least produced using a more environmentally friendly method-like the low-cost retort–kiln system (Photos 1 and 2). Another point is that sustainable forests and energy wood plantations can make much more economical use of their wood if it is carbonised with this retort method, which doubles charcoal output. Charcoal has become expensive and in Bujumbura/Burundi a large bag of charcoal costs about 10.000 FBU or about 8€ (June 2006).

Figures on charcoal consumption demonstrate the importance of introducing and disseminating information about a small- or medium-scale retort production method which could spare about two-thirds of the trees currently used [5]. Moreover that the African Development Bank (ADB) estimated in 2005: "*the fact that biomass remains the main sources of energy in Africa and the need of biomass will double in most sub-Saharan countries in the next 10 years*".

The ICPS should be the subject of further research in comparison with traditional systems, especially in the area of air pollution reduction. Another issue to consider is how to effectively disseminate this new technology to rural and semi-industrial areas, as well as how to correlate the selection of locally available materials with the longevity of the system. Another possibility is the integration of a modified chimney which can recover oils and tars during the first phase of operations. These by-products can be used for wood vinegar production [10]. With some minor modification high quality "white charcoal" can also be produced [11].

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