

Original Research Article

Study on The Valorization of Used Waste Oils As Fuel For The Firing of Clay Bricks in An Artisanal Kiln

Formatted: Font: Bold, Highlight

Formatted: Font: Bold, Highlight

Formatted: Font: Bold, Highlight

Formatted: Font: Bold, Highlight

Formatted: Font: Bold, Highlight

Formatted: Font: Bold, Highlight

Formatted: Font: Bold, Highlight

Formatted: Font: Bold, Highlight

Formatted: Font: Bold, Highlight

Formatted: Highlight

Formatted: Font: Bold, Highlight

ABSTRACT

Used engine oil is a main source of oil contamination of waterways and can result in pollution of drinking water sources. Insoluble, persistent, slowly degradable, it can contain toxic chemicals and heavy metals. Animals and birds from the polluted oil soil can be stuck. The present study aims to contribute to solving the environmental problem and energy saving purpose by recovering waste from the recycling of used oil to improve the firing of clay bricks. The waste from recycling used oil is collected and mixed with wood charcoal. This mixture is used as fuel in the artisanal kiln to fire the bricks. The temperature rises in the kiln, the cooling time and the quality of baked Clay Bricks are analyzed. The maximum temperature observed inside the kiln is 900°C in 36 hours of kiln operation when wood charcoal is used as fuel with a firing time of five (5) days and 1020°C in 80 hours when wood charcoal and "Chinese coal" (waste from the recycling of used oil) are used as fuel with a firing time of ten (10) days. This explains the longer cooling time than with wood charcoal alone as fuel. The firing of the bricks is perfect with both fuels, whereas, with wood charcoal alone as fuel, 15% of the bricks are unbaked. The bricks also have a very clean appearance. They have an average shrinkage of 1%, which is lower than the normative value of 3%, the average compressive strength is 16.5MPa which is higher than the normative value of 12.5MPa, and the water absorption is 40% which is lower than the normative value of 60%. This combination of fuels reduces the use of wood charcoal, which in turn reduces deforestation and prevents air pollution and soil degradation through the dumping of waste oil in the environment.

Keywords: Artisanal kiln, used oil, charcoal, combustion, recycling used oil waste.

1. INTRODUCTION

The degree of household and similar waste production is one of the indications of the development of an individual or society. A less fortunate person produces less household waste than a wealthy person. A developed town generates more waste than a less developed town. The diversity of waste follows the same pattern. The management of this diverse waste is one of the environmental problems that developing countries must find sustainable solutions. This involves improving collection processes, treatment, recycling and burial in order to reduce waste volume and make cities cleaner [1].

Great growth in various income-generating activities is observed nowadays in Lome City as in many African capitals. This phenomenon is leading to a rapid increase in the acquisition of

motorized means of transport, resulting in a large discharge of used oil. Used oils such as engine lubrication oil, hydraulic fluids, and gear oils used in worksite vehicles, cars, motors, bikes, or lawnmowers can pollute the environment if they are not recycled or disposed of properly [2]. Dan-asabeet et al. [3] studied the environmental impact of used automobile engine oil on some soil properties and review of remediation techniques. From the result, it is worthy to note that the effect of used automobile oil on soil cannot be overemphasized, owing to the fact that the soil is the primary host of man, living organisms, plants and a key part in the general ecosystem. The effects of used engine automobile oil had more effect on soil organic carbon and moisture content. There was also a change in the pH level of the soils which were mostly alkaline becoming acidic as a result of heavy metals and polycyclic aromatic hydrocarbon (PAHs) in the soil. For particle size, the percentage of sand was observed to have increased with significant reduction in the percentage of silt and clay relative to the control. Used engine automobile oil causes environmental degradation by producing a film in water that blocks sunlight, thus stopping the photosynthesis and preventing oxygen replenishment leading to the death of the soil. It also contains some toxic materials that can reach humans through the food chain. The oil polluted soil also has high reduction of water penetration and thus causes extinction of some species of organisms that dwell inside the soil. Various methods that included biological, chemical and physical were reviewed as remediation techniques to the polluted soils [3].

The biological (microbial) remediation is a method of remediating oil polluted soil using microorganisms such as *Bacillus subtilis* as hydrocarbon degrader [3]. Nwaogu et al. [4] conducted research on *Bacillus subtilis* as a microbial soil reclamation of diesel polluted soil and found that the microorganism has higher potential to use diesel as a source of carbon with about 77.6% increase over 27 days period. Bioremediation is a function of biodegradation that involves complete mineralization of organic contaminants into carbon dioxide, water, inorganic compounds etc. It is also viewed as the transformation of complex organic contaminants to other simple organic compounds by microorganisms. Genetically engineered microorganisms (GEMs) have also received a great deal of attention in bioremediation. Bacteria such as *Pseudomonas putida*, *P. putida* KT2442, *Comamonas testosteroni* VP44 and *Pseudomonas* sp. LB400 have been used in bioremediation. The engineered bacteria have shown higher degradation ability. However, ecological and environmental concerns and regulatory constraints are major obstacles in using GEM in the field (Das et al., [5]

The chemical remediation is a process of reclaiming the soil using chemical degreasers and detergents [3]. Karpenko et al. [6] conducted a review research covering the main agents used for in situ and ex situ chemical oxidation of organic contaminants particularly oil products, in soil and water environments. Among them there are hydrogen peroxide, permanganate salts, ozone and sodium persulfate. The fields of application, as well as benefits and disadvantages of the mentioned agents use were described.

The organic waste remediation is a process of remediating the soil (by providing nutrients and hydrocarbon degrading bacteria) using organic waste such as brewery spent grain (BSG), banana skin (BP), spent mushroom compost (SMC) and cassava peels [3]. Abioye et al. [7] researched on BSG, BS and SMC as organic waste amendments subtract of used engine oil polluted soil and showed that BSG provided a better amendment with about 55% soil degradation in 15% used lubricating oil soil sample and a higher 92% soil degradation in 5% used lubricating oil soil sample. Akpe et al. [8] worked on cassava peels as a remediating waste in crude oil polluted soil and showed that banana peels contains good amount of biodegradation enhancing elements/nutrients viz-a-viz nitrogen (2.37%), potassium (7.31 meq/100g), phosphorus (0.78 mg/kg) and organic carbon (2.37%). The result showed that cassava peel which is an agro waste enhance biodegradation in oil polluted soils and that the lower the percentage of crude oil in the polluted soil, the higher the percentage degraded.

Physical reclamation does not involve change in physico-chemical properties of the polluted soil but extraction, disposal and storage of the polluted soil [3]. The method involves both ex-situ and in-situ methods (Safemanmin, 2016) [9]. Al-Hamaiedh et al. [9] used electrochemical method (ELCM) for treatment of lubricated soil and showed that the geotechnical properties of the soil was greatly improved and thus the technique offers treatment of huge amount of soil providing high efficiency and ecological safety.

The increasing incorporation of waste materials in the manufacture of clay bricks has gained significant proportions for reasons of sustainability [10], environmental protection [11] and the need for easy supply of essential products [12]. The depletion of fossil fuels [13] is also leading to their conservation and efficient use [14].

Fired clay bricks are generally used as wall construction material in buildings. They are often fired in a kiln at a temperature of 1000°C [15]. Thus, a huge amount of fuel is needed to fire the clay bricks. Coal is the most common fuel used in firing clay bricks in kilns [16]. However, the cost of coal is high and the use of coal as fuel contributes to deforestation. Therefore, the use of coal as a fuel increases the cost of bricks and building construction on the one hand and deforestation on the other. In order to reduce the cost of fired clay bricks and to slow down deforestation, alternative, low-cost fuels should be explored [17].

The energy saving of the automated brick making industry helps to protect the environment from the multidimensional damage caused by traditional brick making systems. A green banking is marked as a component of global initiatives to save the environment and climate. Chen J et al. [18] studied the effect of green banking practices on banks' environmental performance and green financing of private commercial banks in Bangladesh. This study provide valuable implications for academics, banking institutions, bankers, managers and government officials in Bangladesh through the promotion of green banking and provision of green funding to boost banks' environmental performances and, consequently, the country's sustainable economic development. Darain KM et al. [19] highlights through their research, existing technologies of brick manufacturing as well as their emission which exceeds the tolerable limit and puts a threat to the environment. Treatise is also portrayed regarding techniques which could help minimizing the drawback of existing brick kiln technologies. Vertical Shaft Brick kiln might be an alternative solution for the small investors in Bangladesh which is energy efficient and can minimize the air pollution to achieve a sustainable environment.

The study of LakhoNA et al. [20] focused on the effect of alternate fuels on compressive strength, water absorption and density of fired clay bricks. They found that compressive strength of bricks fired using rapeseed husk and combination of sugarcane-bagasse, rice husk and used clothes fuels decreased to 11% and 7%, respectively, compared to coal. However, the values of water absorption and density of bricks fired with rapeseed husk fuels were almost same as exhibited by those baked with coal. This study shows also that a saving of 25%, and 18% could be achieved when the bricks were fired using rapeseed husk and combination of sugarcane-bagasse, rice husk and used clothes fuels, respectively, compared to those fired with coal. An experimental study of the firing of red brick using liquefied petroleum gas fuel was performed in a fixed kiln by [21]. Improvement alternatives to the traditional firing techniques were analyzed, including the design of a thermally efficient kiln and the use of gas burners to reduce the pollution generated by using trash or other industrial or agricultural wastes as fuels. The results show an increase in the thermal efficiency, based on the use of 600 liters of fuel to fire a load of 17500 bricks.

Abu Sinaina AM et al. [22] conducted a study to manufacture model building green bricks with different cheap solid additives, petro-coke, animal dung, and saw-dust as an internal fuel. Model samples were manufactured, dried smoothly, and then fired through a suitable predetermined firing technique at range of temperature, 750, 800, 850, 900 and 1000°C. The experimental measurement was performed on these samples at Brick and Road Research Institute (BRR) University of Khartoum, Sudan in order to evaluate internal and external fuel consumption in red brick production and mitigation measures of environmental

contamination. The main bricks properties used for assessment are loss-on-ignition, density and crushing strength that related to the lowest specific fuel consumption and cost. Numerous measurements on samples have compared relative to internal and external energy and fuel consumption. The petro-coke sample was found to be the best, with the lowest fuel consumption, higher crushing strength and very good density of clay bricks as well as with the minimum firing cost. The results reveal the firing temperature is significantly affected densities properties of the clay bricks additive material above 900°C, while the crushing strengths and loss-on-ignition are increasing steadily to 1000°C.

This work aims to solve the problem of environmental pollution caused by the discharge of waste from recycling used oil. This waste is valorized by using it to improve the combustion of charcoal used to fire bricks in an artisanal kiln. For this purpose, the physical and mineralogical properties of the waste from the recycling of used oils are determined. This waste is used as a fuel and mixed with charcoal to fire bricks in an artisanal kiln. The temperature evolution in the kiln and the firing quality of the bricks were examined.

2. MATERIAL AND METHODS

2.1 Materials

The execution of this research required a number of materials of various kinds and a perfect methodology.

These included:

- waste from the recycling of used oil obtained from the recycling unit
- charcoal;
- the artisanal kiln built at the « Centre de la Construction et du Logement (CCL) » of Lome city (Togo);
- the temperature measurement equipment;
- clay bricks;
- the equipment for determining the mechanical characteristics of the fired bricks.

Formatted: Highlight

Formatted: Bulleted + Level: 1 + Aligned at: 0.25" + Indent at: 0.5"

2.2 APPROACH: FIRING TESTS

2.2.1 Fuels

Motor oils are used to lubricate internal combustion engines. They are mineral oils made up of petroleum derivatives and technical additives.

Particularly polluting for the soil and water, "black oil" is a hazardous waste. After their use in the engines of private or industrial vehicles, used oils must be reprocessed. Their volume represents more than 220,000 tons per year, depending on the country. They are composed of heavy metals, organic acids, hydrocarbons and toxic elements that require specific reprocessing by approved companies [23]. The literature indicates that one liter of used oil can pollute an area of 1,000 m² of water and thus reduce the oxygenation of underwater, fauna and flora for several years [24].

Motor oils can be recycled, i.e. re-refined using various processes. Two solutions exist for recycling these waste oils:

- energy recovery by incineration to produce energy,
- regeneration to produce a new lube [25].

Formatted: No underline, Highlight

Formatted: No underline

Formatted: Bulleted + Level: 1 + Aligned at: 0.25" + Indent at: 0.5"

Thus, the oil is first separated from the impurities, then the water and finally the additives. The water can be reprocessed. The oil is converted into diesel fuel. The remaining residue contains the additives, mainly graphite, i.e. carbon, plus some oil derivatives.

The waste used in the CCL is referred to as “Chinese Coal” (Fig. 1.). This study focuses on the recovery of this coal. It consists of carbon (C) and petroleum derivatives.

Similarly, the composition of the waste oil also takes into account (i) graphite: i.e., a natural, black, friable carbon mineral with the chemical formula (C), (ii) petroleum derivatives. The petroleum derivatives from which motor oils are made are derived from refining crude oil under atmospheric pressure.

The atmospheric residue undergoes vacuum distillation to give short-chain hydrocarbons containing a carbon number if possible in the range of C8 to C10.

In motor oils, the petroleum derivatives encountered are hydrocarbons, organic compounds containing carbon (C) and hydrogen (H). The number of carbon atoms ranges from 8 to 10 (C8 to C10) [26].

The waste from the recycling of used oil is collected and mixed with wood charcoal (Fig. 2.). The efficiency of a fuel is characterized by its Calorific Value. The Calorific Value (CV) of a fuel is equal to the energy released by the complete combustion of 1 kg of fuel. It is expressed in KJ/Kg.



Fig. 1. Chinese Coal



Fig. 2. Wood charcoal

2.2.2 Artisanal kiln

The experimental kiln (Fig. 3) is an open artisanal kiln with a natural updraft, whose structure is made up of:

- a hearth, in which the fuel burns to produce the heat necessary for firing the clay bricks.
- a hearth in contact with the combustion chamber, which retains the heat and in which the clay bricks are located;
- a flue through which the hot gases escape, the chimney.

Above the hearth is the floor or hearth plate, on which the clay bricks are stacked. It is pierced by holes called flues which allow the flames from the hearth to pass upwards.

This kiln is made of baked bricks obtained from clay from Kouvé, a town located about 65 km North-East of Lome (Togo).

The schematic of the artisanal kiln is shown in fig. 4.

Formatted: No underline, Highlight

Formatted: No underline

Formatted: Bulleted + Level: 1 + Aligned at: 0.25" + Indent at: 0.5"



Fig. 3. Artisanal kiln

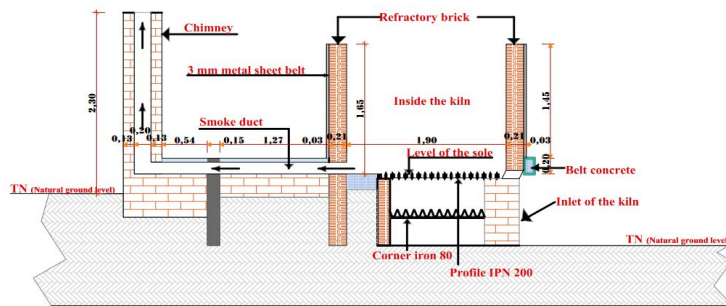


Fig. 4. Schematic of the artisanal kiln

2.2.3 Baked clay bricks

Fig. 5 and Fig. 6 show respectively, clay preparation and bricks production, and natural drying of clay bricks. The clay bricks to be fired have dimensions of 6 cm x 9 cm x 20 cm obtained from Kouve. The production is done according to the NF P 12-121-1 or NFEN 771-1:2011 standard [27].



Fig. 5. Clay preparation and brick production

Formatted: No underline, Highlight

Formatted: No underline



Fig. 6. Natural drying of bricks

2.2.4 Temperature measuring device

For temperature measurements, a digital thermocouple thermometer shown in fig. 7. is used as well as J thermocouples with a temperature range of -210 to 1200°C.



Fig. 7. Digital thermocouple thermometer: PROSTER PST095

2.2.5 Firing process

The clay brick firing process is carried out using wood charcoal as fuel and then a combination of wood charcoal and Chinese coal. The dry bricks are placed in the kiln in a very precise way, so as to allow the horizontal and vertical passage of hot air.

For the first experiment, the clay bricks were fired with wood charcoal alone as fuel, the quantity of bricks fired being two thousand (2000). With the help of a dosing box, 280kg of wood charcoal are loaded into the kiln alternately with the clay bricks. The firing operation lasts seven (7) days: the maximum temperature of 900°C is reached after 36 hours, i.e. two (2) days of kiln operation. Complete cooling of the kiln is observed after three (3) days when the temperature inside the kiln is equal to 32°C i.e., the ambient temperature. After removal of the fired clay bricks from the kiln, it was found that 15% of them were unburnt.

For a complete firing, the combustion equation is as follows:



The carbon input is mainly from the charcoal.

Concerning the second experiment, the cooking takes place by combining the two fuels namely Chinese charcoal and ordinary charcoal. 120 kg of charcoal and 405 kg of Chinese charcoal are used for the same quantity of bricks to be fired, i.e. two thousand (2000). The firing process takes ten (10) days. The maximum temperature of 1020°C is reached after three (3) days and cooling lasts seven (7) days.

The following equations explain the combustion phenomenon. For charcoal we have to consider equation (1) and for Chinese charcoal we have:



Formatted: No underline, Highlight

Formatted: No underline

Formatted: No underline, Highlight

Formatted: No underline

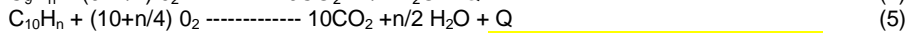
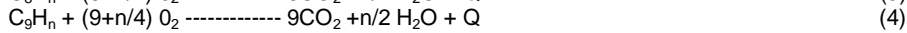
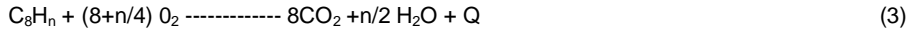
Formatted: Highlight

Comment [AA1]: In the text, do not use the first person "we".

Comment [AA2]: In the text, do not use the first person "we".

Formatted: Highlight

But since waste oils contain C8, C9 and C10 hydrocarbons the combustion equations to consider are:



where n is the number of carbon atoms and Q represents the heat released due to waste fuel combustion.

2.2.6. Quality of fired clay bricks

Formatted: No underline, Highlight

This is done through the analysis of the values of the significant characteristics, namely shrinkage, water absorption, compressive strength, obtained on the fired bricks [28].

Formatted: No underline

2.2.6.1. Shrinkage test

Formatted: Font: Bold, Not Italic, Highlight

As well as during drying, fired clay bricks are subject to shrinkage during firing. It is due to the transformation of the clay particles. To carry out the shrinkage test, a ruler is used to measure to within 1mm each of the dimensions on the four corresponding edges and the flatness of the faces on the basis of the procedure contained in standards NF P 31-305, NF P 31-306 and NF P 13-305.

Formatted: Font: Bold, Not Italic

2.2.6.2. Water absorption test

Formatted: Font: Bold, Not Italic, Highlight

The water absorption test by capillarity is a control test established by the French standard NF P 13-305 for clay bricks. The procedure is as described in this standard.

The experimental equipment consists of an container in which seven (7) test specimens are immersed. The container must be at 20°C ±2°C and 65% ±5% relative humidity. However, the experiment was conducted at an ambient temperature of 30°C and 75% of relative humidity. Four kiln trays model 68/14D.35 of PROLABO with a capacity of 393 litres was used. The formula conventionally expresses the water absorption coefficient of each clay brick:

Formatted: Font: Bold, Not Italic

$$C = \frac{100 \cdot m}{S\sqrt{t}} \quad (6)$$

in which :

m is mass of water absorbed by the product, expressed in g;

S: surface area of immersed face, expressed in cm²,

t: time, in minutes, elapsed since the start of immersion.

2.2.6.3. Compressive strength test

Formatted: Font: Bold, Not Italic, Highlight

The purpose of determining the compressive strength of fired bricks is to check whether the firing has been perfect to the extent that products capable of withstanding stress and weathering have been obtained.

As experimental equipment, apart from the test specimens, there is the PERRIER type 368 hydraulic press with a measurement range of 60kN to 1500kN, and a pressure of 40MPa with a piston stroke of 0 to 30 millimeters to carry out the compression test, commonly known as the crushing test. The procedure is the one described in the French standard NF P 13-305 on clay bricks intended to remain exposed.

Formatted: Font: Bold

3. RESULTS AND DISCUSSION


3.1 Characteristics of fired clay bricks

Formatted: Highlight

Tables 1 and 2 show the technical data on the performance of fired clay bricks when wood charcoal, and the combination of wood charcoal and Chinese coal are used as fuel.


From the results obtained from the characteristics as shown in the tables above, it is found that the firing was perfect, the bricks have a stress well above the normative limits and therefore have a good mechanical strength.

Table 1. Fired clay brick behaviour with wood charcoal fuel

Order No.	Product	Characteristics	Before firing	After firing	Withdrawal
	Brick				
		Thickness (cm)	6.00	5.80	0.20
		Width (cm)	9.20	9.00	0.20
		Length (cm)	20.1	19.80	0.30
		Weight (kg)	1.92	1.91	0.01
		Compressive strength (MPa)	3.07	10.30	

Formatted: Font: Bold, Highlight

Table 2. Behaviour of fired clay bricks with wood charcoal and Chinese coal as fuel

Order No.	Product	Characteristics	Before firing	After firing	Withdrawal
	Brick				
		Thickness (cm)	6.00	5.75	0.25
		Width (cm)	9.20	9.10	0.10
		Length (cm)	20.10	19.9	0.20
		Weight (kg)	1.92	1.89	0.03
		Compressive strength (MPa)	3.07	16.50	

Formatted: Font: Bold, Highlight

Table 3. Characteristics of fired clay bricks

Comment [AA3]: The table should be referenced (in the text).

Order No.	Description	Characteristics	Values Experimental	Normative value
		*Withdrawal		
		- length	1.00 %	< 3.00 %
		- Width	1.00 %	< 3.00 %
		- Thickness	2.50 mm	< 3.00 mm
1	Fired	Water absorption	C = 40.00	C ≤ 60.00
	clay	Compressive strength	16.50 MPa	≥ 12.50 MPa
	brick			

Formatted: Font: Bold, Highlight

The firing process was conducted in such a way as to obtain fired clay bricks with functional and also satisfactory technical characteristics. Furthermore, the usual normative firing temperatures for these baked clay bricks are between 850°C and 900°C, but with wood charcoal as fuel the maximum temperature is 900°C and with the combination of wood charcoal and Chinese coal the maximum temperature of 1020°C is recorded. The total firing time varies from 12 to 48 hours, depending on the clay brick and the type of kiln used. In the case of this study, it ranges from 120 hours for charcoal fuel to 240 hours for charcoal and Chinese coal fuel.

Table 3 shows the average values of the tests carried out on the fired clay bricks at the firing temperature of 1020°C. It is noted that the water absorption coefficient obtained is within the limits set by the standard for fired clay bricks NF P 13-305. Similar result is observed for the average compressive strength values.

From the results obtained from the characteristics as shown in tables 1 to 3, it is found that the firing was perfect, the bricks have a stress well above the normative limits and therefore have a good mechanical strength.

3.2 Efficiency of Fuels

The efficiency of the fuel depends on its calorific value [29]. The calorific value of carbon is 15MJ/Kg. Wood charcoal contains a lot of carbon. The calorific value of waste oil is 90% of that of fuel oil, which is 43MJ/Kg.

Studies carried out at the CCL in Cavavelli have shown that Chinese charcoal is made up of P1= 78% carbon and P2 =22% of waste oil.

Taking P1 as the percentage of carbon, P2 as the percentage of waste oil, and taking PC1 as the calorific value of coal and PC2 as the calorific value of waste oil with PC1= 15MJ/Kg, PC2 is evaluated as:

$$PC2 = 0.9 \times 43 \text{ MJ/Kg or } PC2 = 38.7 \text{ MJ/Kg}$$

Then the calorific value of Chinese coal is expressed as :

$$PC = P1 \times PC1 + P2 \times PC2 \text{ i.e. } PC = 0.22 \times 38.7 + 0.78 \times 15 = 20.21 \text{ MJ/Kg}$$

Hence, PC is approximately equal to 20.21 MJ/kg. This result shows that the calorific value of Chinese charcoal is higher than that of charcoal due to the presence of petroleum derivatives, whereas charcoal consists of carbon only.

3.3 Temperature Distribution

Formatted: Highlight

Fig. 8 and Fig. 9 present, respectively, the evolution of the average internal and external temperature of the kiln and the chimney during operation with wood charcoal as fuel and

combination of wood charcoal and Chinese coal as fuel. The analysis of these figures shows that the internal and external temperature of the kiln and the chimney increases with time, reaches the peak and then decreases towards the initial temperature of the kiln. The temperature increase corresponds to the heating phase of the kiln due to the intensification of the combustion of charcoal and Chinese charcoal mixed with wood charcoal. The cooling phase of the kiln is characterised by a decrease in the kiln and chimney temperature. The external temperatures are lower than the internal temperatures because the external walls of the kiln and the chimney are naturally convected with the ambient air. The temperature in the chimney is lower in the combustion chamber because the exhaust hot gases from the chimney cool down due to the heat convection taking place in the chimney with the outlet port leading to the ambient air with lower temperature. The maximum temperature of 900°C is reached in 36 hours and total cooling to 32°C after 120 hours with charcoal as fuel. Brick firing is observed with 15% incineration.

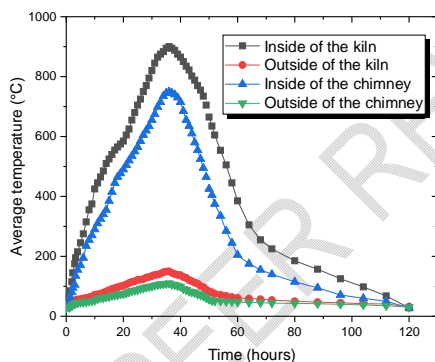


Fig. 8. Evolution of the average temperature during operation of the loaded kiln using the combination of charcoal and "Chinese coal" as fuel.

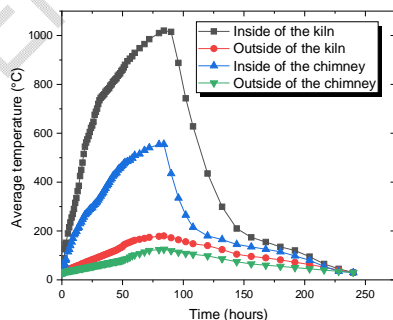


Fig. 9. Evolution of the average temperature during the operation of the loaded kiln using wood charcoal as fuel

The maximum temperature of 1020°C is reached in 84 hours and total cooling to 32°C after 240 hours with the combination of wood charcoal and “Chinese coal” as fuel. Perfect firing of the clay bricks is observed. The standards provide for a firing temperature range between 850°C and 1450°C depending on the type of kiln and the clay brick [30]. The profiles during heating and cooling correspond perfectly to those proposed by GLINKOV [30].

4. CONCLUSION

To prevent oil polluted soil and save the energy used for the firing of clay bricks, this study investigated the effect of firing, using wood charcoal and the combination of wood charcoal and waste from used oils as fuel for the firing of clay bricks in an artisanal kiln. The main findings drawn from the experimental tests can be listed as following:

- -the maximum temperature observed inside the kiln is 900°C in 36 hours of kiln operation when wood charcoal is used as fuel with firing time of five (5) days;
- -for the use of the combination of wood charcoal and “Chinese coal”, the pick of internal temperature of the kiln is around 1020°C in 80 hours of kiln operation with a firing time of ten (10) days
- -the cooling time of the kiln is longer when the combination of wood charcoal and waste from recycling of used oil (“Chinese coal”) is used as fuel for firing the clay bricks;
- -The firing of the clay bricks is better with the use of the combination of wood charcoal and “Chinese coal” as fuels
- -When the fuel employed is the combination of wood charcoal and the waste from recycling used oil, the baked clay bricks have a better clean appearance.
- -The baked clay bricks resulting from the firing with the combination of wood charcoal and “Chinese coal” as fuel, have an average shrinkage of 1% which is lower than the normative value of 3% the average compressive strength is 16.5MPa which is higher than the normative value of 12.5MPa and the water absorption is 40% which is lower than the normative value of 60%.
- -the valorization of waste from recycling used oil contributes to the reduction of the use of wood charcoal, which in turn reduces deforestation and prevents air pollution and soil degradation.

The use of waste from the recycling of waste oils as fuel is an experimental study that is being carried out for the first time to our knowledge. It should open the way for a vast research project in other fields. The study must be conducted further to increase the efficiency of the fuel obtained by the combination of charcoal and “Chinese charcoal” with other admixtures.

REFERENCES

1. Ferronato N, Torretta V. Waste Mismanagement in Developing Countries: A Review of Global Issues. *Int. J. Environ. Res. Public Health*. 2019; 16, 1060; <http://dx.doi:10.3390/ijerph16061060>
2. ChandPR, KumarPB. Oil and Lubricant Hazard Effects on Human Health, *JASET - International Journal of Innovative Science, Engineering & Technology*. 2017; 4(4), 2348 – 7968
3. Dan-asabe B, Nwokeocha H. Environmental impact of used automobile engine oil on some soil properties and review of remediation techniques. Conference: Nigerian Corrosion Association (NICA), NAF International Conference Center, Abuja. November 2019.

Formatted: Bulleted + Level: 1 + Aligned at: 0.25" + Indent at: 0.5"

Comment [AA4]: These references should be rearranged according to this example [Boateng R, Mbrokoh AS, Boateng L, Senyo PK, Ansong E. Determinants of elearning adoption among students of developing countries. *Int. J. Inf. Learn. Technol.* 2016;33(4):248–262.]

4. NwaogwuLA, OnyezeGOC and NwabuezeRN. Degradation of diesel oil in apolluted soil suing *Basillus subtilis*. *African Journal of Biotechnology*.2012; 7(12), 1939 – 1943.
5. DasN and ChandranP. Microbial degradation of petroleum hydrocarbon contaminants: an overview. *Biotechnology Research International*. 2010; 1–13.
6. Karpenko O, Karpenko E, Lubenets V, Novikov V. Chemical oxidants for remediation of contaminated soil and water. A Review. *Chemistry and Chemical Technology*. 2009 3(1), 41-45
DOI:10.23939/chcht03.01.041
7. AbioyeOP, AgamuthaPand Abdul-Azizi AR. Biodegradation of used motor oil in soil using organic waste amendments. *Biotechnology Research International*. 2012; 1 – 8.
8. AkpeAR, EkundayoAO, Aigere SPand OkwuGI. Baterial degradation of petroleum hydrocarbon oil polluted soil amended with cassava peels. *American Journal of Research Communication*. 3(7)97–118.
9. Safemanmin. Safe Management of Mining Waste and Waste Facilities
<http://www.prosodol.gr/sites/prosodol.gr/files/Description%20of%20soil%20reclamation%20and%20remediation%20methods.pdf>, accessed 20th July, 2016.
10. KinuthiaJM, OtiJE. Designed non-fired clay mixes for sustainable and low carbón use. *Applied Clay Science*.2012; 59-60,131-139.
<http://dx.doi.org/10.1016/j.jclay.2012.02.021>
11. ArsenovicM, RadojevicZ, JaksicZ, Pezo L. Mathematical approach to application of industrial wastes in clay brick production - Part I: Testing and analysis. *Ceramics International*. 2015; 41, 4890-98.
<http://dx.doi.org/10.1016/j.ceramint.2014.12.050>
12. MenezesRR, FerreiraH, NevesGA, LiraH, FerreiraHC. Use of granite sawing wastes in the production of ceramic bricks and tiles. *Journal of European Ceramics Society*. 2005;25(7), 1149-1158.
<http://dx.doi.Org/10.1016/j.jeurceramsoc.2004.04.020>
13. Al-HadhramiLM, AhmadA. Assessment of thermal performance of different types of masonry bricks used in Saudi Arabia. *Applied Thermal Engineering*. 2009; 29(5-6), 1123-1130.
<http://dx.doi:10.1016/j.applthermaleng.2008.06.003>
14. QuijornaN, CozaA, AndresaA, ClieesemanC. Recycling of Waelz slag and waste foundry sand in red clay bricks. *Resource Conservation and Recycling*. 2012;65, 1-10.
<http://dx.doi.Org/10.1016/j.resconrec.2012.05.004>
15. KaramanS, GunalH, GokalpZ. Variation of Clay Brick Colors and Mechanical Strength as Affected by Different Firing Temperatures. *Scientific Research and Essays*. 2012; 7, 4208-4212.
16. GhauriMA, AnwarMA, AkhtarN, HaiderR, Tawab A. Status of Coal Biotechnology in Pakistan. *Advanced Materials Research*. (2009); 71-73, 513-516.
<http://dx.doi.org/10.4028/www.scientific.net/AMR.71-73.513>.
17. BhuttoAW, BazmiAA, ZahediG. Greener ENERGY: Issues and Challenges for Pakistan-Biomass Energy Prospective. *Renewable and Sustainable Energy Reviews*. 2011; 15, 3207-3219.
<http://dx.doi.org/10.1016/j.rser.2011.04.015>
18. Chen J, Siddik AB, Zheng G-W, Masukujjaman M and Bekhzod S. The effect of green banking practices on banks' environmental performance and green financing: an empirical study. *Energies*. 2022 ; 15, 1292.
<https://doi.org/10.3390/en15041292>

19. Darain KM, Rahman ABMS, Ahsan A., Islamd ABMS and Yusuf B. Brick manufacturing practice in Bangladesh: a review of energy efficacy and air pollution scenarios. *Journal of Hydrology and Environment Research*. 2013; 1(1), 60-69.
20. LakhoNA, ZardariMA. Structural Properties of Baked Clay Bricks Fired with Alternate Fuels. *Engineering*. 2016; 8, 676-683.
<http://dx.doi.org/10.4236/eng.2016.810061>
21. Martinez-Gonzalez GM, Jiménez -Islas H. Experimental study of the firing of red clay bricks using liquefied petroleum gas. *Journal of Scientific & Industrial Research*. 2014; 73,661-666
22. Abu Sinaina AM, Abdelbagi AM and HamdanAdem AM. Influence of industrial and agricultural additives to clay mitigates fuel consumption on red bricks manufacturing. *International Journal of Innovative Research in Science Engineering and Technology*. 2016; 5(5), 8717-8723.
[DOI:10.15680/IJIRSET.2016.0505275](https://doi.org/10.15680/IJIRSET.2016.0505275)
23. Transportation Research Board and National Research Council. *Oil in the Sea III: Inputs, Fates, and Effects*. Washington, DC: The National Academies Press. 2003.
<https://doi.org/10.17226/10388>.
24. Abu-Elella R, Ossman ME, Farouq R, Abd-Elfatah M. Used Motor Oil Treatment: Turning Waste Oil Into Valuable Products. *International Journal of Chemical and Biochemical Sciences*. 2015; 757-67
25. BridjanianH, SattarinM. Modern recovery methods in used oil re-refining. *Petroleum & Coal*. 2006; 48 (1), 40-43.
26. Sogorb MÁ, Mangas I, Vilanova E. Petroleum Distillates. *Encyclopedia of Toxicology (Third Edition)*. 2014; 828-833.
<https://doi.org/10.1016/B978-0-12-386454-3.00528-5>.
27. Knizek I. Clay Building Materials in Togo, Technical Report, CCL Cacavelli, Lome Togo.1967;1-25.
28. Padayodi E. Contribution to the elaboration of building materials based on natural products: thermomechanical and physicochemical characterization of clays and natural cellulosic fibres. Doctoral thesis from the University of Franche-Comté. 2001; 18-31.
29. Beaumont O. Wood combustion. *Biomass, Actuality*. 1985; 7, 15-24
30. Glinkov MA. Basis of the general theory of furnace operation, Masson and Cie, Paris. 1971; 1-15.