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Article

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CONSIDERING SAWDUST AS A POTENTIAL RAW MATERIAL FOR CLIMATE CHANGE MITIGATION IN INDOOR ENVIRONMENT

The object of the study is sawdust as a potential raw material for climate change mitigation in the indoor environment. The method of the mixture was used to determine the specific heat capacity of the sawdust sample, while its thermal conductivity was determined using the Lee disc method. The results of the study showed that the specific heat capacity of the sawdust is 54.9271 $J \cdot g^{-1} \cdot K^{-1}$ and that of thermal conductivity is 0.12 W/m·K. The implication of the results is that Sawdust needs about 54.9271 $J \cdot g^{-1} \cdot K^{-1}$ to raise its unit mass by 1 °C and a comparably very low thermal conductivity of 0.12 W/m·K. Sawdust can be used as a composite material for roofing, and ceilings to drastically reduce the rate at which the heat energy from the sun is transferred into the indoor environment and consequently reduce the effects of climate change on the indoor environment. Sawdust that is not properly managed or disposed can pose serious problems to aquatic and terrestrial ecosystems, fuel fire outbreaks and health problems such as severe allergic reactions. Therefore, discovering other reuse options for sawdust will reduce the problems it poses to the environment.

Keywords: *sawdust, thermal properties, composite material, climate change mitigation, indoor environment.*

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1. Introduction

Climate change is a global phenomenon that is largely driven by human activities. The attendant effects of this global phenomenon are severe weather patterns, increased Earth's surface temperature and heat waves, which invariably result in discomforts and health related problems to humans. World Health Organization (WHO) reported the various ways climate change impacts our lives, and these include shortage of potable water, poor air quality, dwindling state of quality food supply, devastating effects on long term progress in human health and also foreclosing more devastating effects from malnutrition and diseases by 2030 and 2040 [1]. United States Global Change Research Program (USGCRP) reported that heat waves, downpours, sea level rise, insect outbreaks, recurrent wildfires, severe drought, poor agricultural produce, and erosion of sea shores terrains which are all linked to climate change pose growing challenges to human lives in all regions of the world [2]. The discomforts and health issues arising from the rise in global surface temperature and heat waves, especially in the tropics and summer seasons in some parts of the globe is a cause for concern. Climate change affects both indoor and outdoor environments. People in developed countries typically spend over 90 % of their time indoors [3]. Any study, which considers the level at which climate change impacts on the physical, mental and social well-being of people in an indoor environment and mitigation strategies is very important.

Interestingly, this study focuses on how to mitigate some of the problems humans are facing due to climate change in the indoor environment. To deal with this environmental problem, it must be approached in two ways – mitigation of direct effects of climate change and a reduction in drivers of climate change. One important strategy for cushioning the impact of climate change on the indoor environment is the incorporation of some locally available materials with high specific heat capacity and very low thermal conductivity in the production of building materials, especially roofing sheets and ceilings. One of such materials is sawdust. However, despite this potential, sawdust is found littered around wood industries and in bushes, constituting a potential danger during fire out-break. Assessments of the thermal properties (specific heat capacity and thermal conductivity) of the sawdust using the method of mixture for determination of the specific heat capacity and the Lee disc method for the determination of thermal conductivity of the sawdust will reveal its suitability in the mitigation of climate change on indoor environment. Air conditioners are used in many business and residential buildings, especially in the urban areas where there is availability of power supply to create comforts, unlike the rural areas. Incorporating sawdust in roofing and ceiling materials to reduce the rate of heat flow into buildings will not only reduce the amount of energy consumed in the urban areas but will also cut cost of installing thermal coolants and enhance the comforts of the people in the rural areas where there is no power supply.

Sawdust is referred to as a «waste product of wood working operations such as sawing, milling, planning, routing, drilling and sanding» [4, 5]. Sawdust is defined as «a by-product of certain animals, birds and insects that live in wood, such as the woodpecker and carpenter ant» [6]. Saw dust can be generated in two ways – by shattering wood cells and by chipping out whole cells during wood processing. «Sawmills in Nigeria generated over 1,000,000 m^3 of wood waste in 2010 while about 5000 m^3 of waste was generated in plywood mills» [7]. «Nigeria generates about 1.8 million tons of sawdust annually and 5.2 million tons of wood wastes» [8]. Sawdust can cause health problems if not properly handled. Airborne sawdust and sawdust accumulations present a number of health and safety hazards. Wood dust becomes a potential health problem. Certain woods and their dust contain toxins that can produce severe allergic reactions. «The impact of improper disposal of waste wood on the environment affects both the aquatic and terrestrial ecosystems» [8]. Sawdust is prone to explosion if one part is lighted with fire, it is capable of spreading rapidly to the rest of it [9]. Therefore, discovering other reuse options for sawdust will reduce the problems it poses to the environment. A study has shown that «saw dust in concrete as partial replacement of fine aggregate provides additional environmental as well as technical benefits for all construction related industries» [4]. Sawdust is said to be the main constituent of particleboard and also found useful in mulching and as fuel [10]. Sawdust was used in ice houses before the introduction of refrigeration to keep the ice frozen, especially during the summer [11]. Ice houses were made of thick wood timbers, with double walls, space filled with straw and sawdust, and an insulated roof, which enabled the ice to remain frozen throughout the summer months [12]. Sawdust is used in manufacturing charcoal briquettes and is also used to clean up liquid spills [13]. The commonness of sawdust in our environment makes it a viable and very cheap material for the treatment of wastewater [14]. Sawdust has been shown to have a good structure suitable for water purification processes [15]. Waste sawdust has also been recognized as an absorbent for the removal of dyes, toxic salts, heavy metals, and waste oils from water [16]. According to International Agency for Research on Cancer (IARC) «Wood dust is composed mainly of cellulose (approximately 40–50 %), polyoses, lignin, and a large and variable number of substances of lower relative molecular mass which may significantly affect the properties of the wood» [17]. The percentage of these compounds depends solely on the type of tree under consideration [17]. «Low density and high thermal insulation value of waste wood aggregate such as sawdust makes it a good alternative ingredient for the production of lightweight concrete, thermal insulation and composites in construction» [13]. Hardwoods have higher thermal conductivity than softwood due to differences in their chemical compositions [18]. It has been demonstrated that a marked reduction in thermal conductivity of porous samples when they contain a high proportion of sawdust [19].

«Thermal conductivity of a material is a measure of its ability to conduct heat». Thermal conductivity is usually denoted by *k* or lambda (Δ). A study on the «effect of recycled cellulose fibers on the properties of lightweight cement composite matrix», the result showed an increase in thermal insulation properties of concrete as the fiber content increases [20]. A study conducted by authors of [21] showed that incorporation of 10 % of sawdust with clay composite «decreases the thermal conductivity of composites by 30 % and improves the thermal resistance of earthen building envelopes by 31 %, while reducing their density». The «effect of additives on the thermal conductivity of clay» has shown that «clay samples with sawdust as additives gave the least value of thermal conductivity of (0.06 W/m·K) than the clay with ashes» [22]. Wood samples with a higher fiber density had higher values of thermal parameters [23].

Thermal conductivity of sawdust board formed by sawdust and resin (polyester) and the result showed that sawdust board pressed 10 tons are K=0.059 W/m·K (0 % sawdust) when 50 % sawdust and 50 % resin was pressed 90 tons, its thermal conductivity became lower to k=0.022W/m·°C, an indication that the thermal conductivity decreased with density [24]. Sawdust also exhibits a high thermal resistivity value, which could serve as a potential source of heat resistance in device applications [25].

Thus, *the aim of this study* is to consider sawdust as a potential raw material for climate change mitigation in the indoor environment.

2. Materials and Methods

2.1. Materials. The materials employed in this study include a Bunsen burner, steam can, rubber pipes, tripod stand, strings, digital weight balance, stopwatch, laboratory thermometers, calorimeter, and Lee disc apparatus.

2.2. Methods. The method of mixture was used to determine the specific heat capacity of the sawdust sample, while its thermal conductivity was determined using the Lee disc method.

3. Results and Discussion

Fig. 1 is the cooling correction graph.

Equation (1) was employed in the determination of the specific heat capacity (S.H.C) of the sawdust sample.

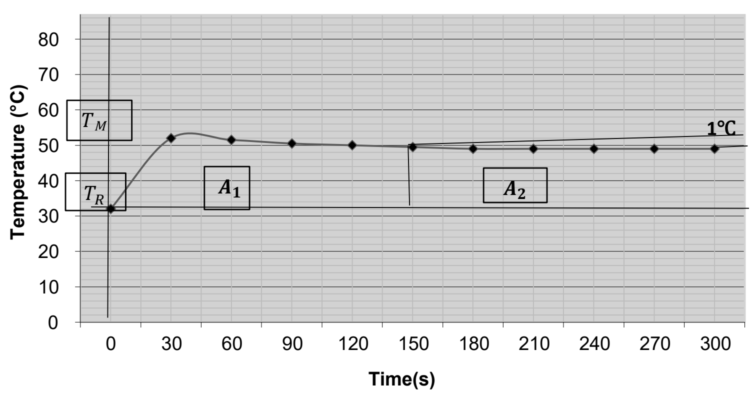

Fig. 1. Cooling correction graph

From Fig. 1, the cooling correction (q) is calculated as follows:

$$q=\frac{A_1\cdot 1\ ^\circ C}{A_2}=\frac{92\cdot 1\ ^\circ C}{88}=0.8889\ ^\circ C, \quad (1)$$

$$c_{sd} = \frac{m_h c_w \left(T_2 - (T_3 + q)\right) - (c_c + m_o c_w)\left((T_3 + q) - T_1\right)}{m_{sd}\left((T_3 + q) - T_1\right)}, \qquad (2)$$

where m_c – mass of calorimeter; m_{sd} – mass of sawdust; m_o – mass of ordinary water; m_h – mass of hot water; c_c – specific heat capacity of calorimeter; c_s – specific heat capacity of sawdust; c_w – specific heat capacity of water; T_1 – initial temperature of calorimeter + sawdust sample + ordinary water; T_2 – temperature of the hot water; T_3 – final temperature of the mixture; q – cooling correction.

The S.H.C of the sample (sawdust) is calculated as follows: m_c=36.50 g, m_{sd}=2.5 g, m_o=22.45 g, m_h=113.45 g, T_1=25 °C, T_2=87 °C, T_3=65 °C, q=0.8788 from the graph, c_w=4200 $J \cdot g^{-1} \cdot K^{-1}$, c_c=400 $J \cdot g^{-1} \cdot K^{-1}$. From equation (2):

$$c_{sd} = \frac{113.45 \cdot 4.2\left(87 - (65 + 0.8788)\right) - (0.4 + 22.45 \cdot 4.2)\left((65 + 0.8788) - 25\right)}{2.5\left((65 + 0.8788) - 25\right)} = 54.9271\ \mathrm{J \cdot g^{-1} \cdot K^{-1}}.$$

Similarly, the thermal conductivity of the sawdust sample is calculated as follows.

Fig. 2 is the temperature fluctuation with time graph for the determination of thermal conductivity of the sawdust sample. In Fig. 2, the gradient of the graph is:

$$\frac{dT}{dt} = \frac{d\theta}{dt} = 0.0061\ \mathrm{s^{-1}}.$$

The thermal conductivity of the sawdust is given by the equation:

$$k = MC\left(\frac{dT}{dt}\right) \Big/ A\frac{(T_1 - T_2)}{L}, \qquad (3)$$

where $A = \pi D^2/4$ – cross-sectional area of the sawdust sample; l is the thickness of the sawdust sample; $T_1 - T_2$ is the difference between the temperature of the cylinder A and slab C; dT/dt – the rate of change of temperature of the brass slab C.

Mass of steel slab c=1.6 kg, S.H.C of 468 $\mathrm{J \cdot g^{-1}} \cdot K^{-1}$, diameter of the sample d=0.07 m, thickness of the sample l=0.005 m, T_1=86 °C, T_2=37 °C.

From equation (3), let's obtain the value of the thermal conductivity of the sawdust:

$$k = \frac{1.6 \cdot 468 \cdot 0.0061}{\frac{3.14(0.07)^2}{4}\left(\frac{49}{0.005}\right)} = 0.12\ \mathrm{W/m \cdot K}.$$

Specific heat capacities of some roofing materials had been established, such as iron sheet (462 $\mathrm{J \cdot g^{-1}} \cdot K^{-1}$), aluminum sheet (887 $\mathrm{J \cdot g^{-1}} \cdot K^{-1}$) and zinc sheet (389 $\mathrm{J \cdot g^{-1}} \cdot K^{-1}$).

Also, marble (832 $\mathrm{J \cdot g^{-1}} \cdot K^{-1}$), glass (792 $\mathrm{J \cdot g^{-1}} \cdot K^{-1}$), brick (841 $\mathrm{J \cdot g^{-1}} \cdot K^{-1}$), rubber (2005 $\mathrm{J \cdot g^{-1}} \cdot K^{-1}$), concrete (879 $\mathrm{J \cdot g^{-1}} \cdot K^{-1}$) which are also used in roofing and buildings.

Comparing the results of this study with the above-mentioned materials, the sawdust sample has the highest S.H.C, making it a very poor conductor of heat.

Also comparing the thermal conductivity of some roofing sheets such as iron (73 W/m·K), asbestos (0.05 W/m·K), zinc (116 W/m·K), brick (0.6 W/m·K), concrete (2.26 W/m·K), aluminum (160 W/m·K) with that of sawdust (0.12 W/m·K).

Sawdust and asbestos have the lowest thermal conductivity but research has shown that asbestos is carcinogenic, and therefore not environmentally unfriendly for roofing.

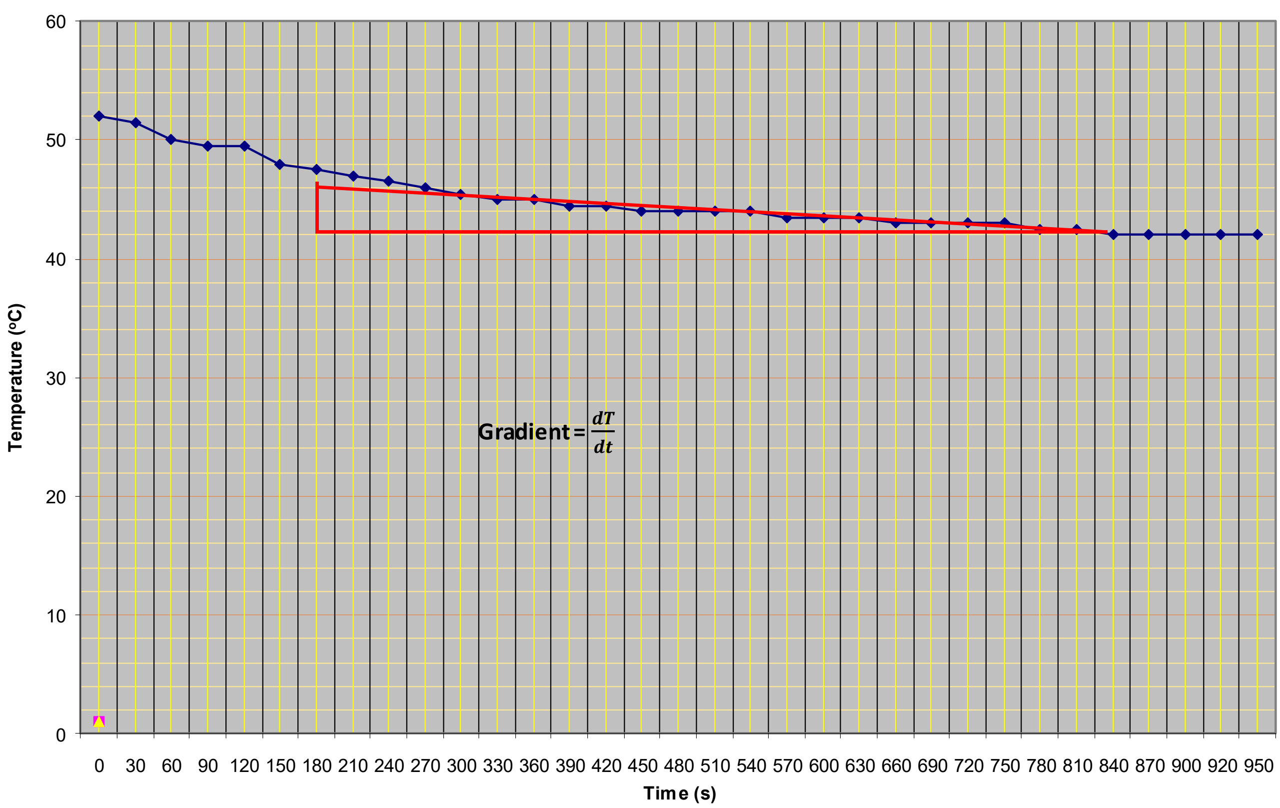

Fig. 2. Temperature fluctuation with time (t)

We mostly approach materials differently, holding ourselves to the highest standards for material selection, sourcing, and development. Sawdust, a by-product of saw Mills is readily available around us, which is also biodegradable compared to other synthetic materials used as roofing sheets and could be employed in the manufacturing of roofing sheets, electrical or thermal insulation, and other engineering applications. Sawdust as an additive in with other materials with low thermal conductivity will be very useful in the manufacturing of electrical and thermal insulators. The thermal properties in roofing sheets materials respond to heat either in length or transferring heat to the room [26]. But sawdust can be combined with other environmentally friendly materials and binders with low thermal conductivity to produce a composite material that can be used in constructing buildings to lower its indoor temperature and thereby reduce the amount of energy required by air conditioners for cooling. For instance, the results of a study conducted on the analysis of «thermodynamic behaviors of a residential building using Energy-Plus software showed that clay-sawdust composites can reduce the energy consumption of conventional and traditional residential buildings by 21 % and 5.3 % respectively» [21].

The limitation of this study is that sawdust alone cannot be transformed into finished materials for roofing sheets, and electrical and thermal insulators without the use of binders. These binders must have either the same specific heat capacity and thermal conductivity as that of sawdust or a higher specific heat capacity and lower thermal conductivity than that of sawdust in order not to alter but improve the thermal insulating properties of the sawdust. This study being a practical study is time-consuming and it is a disadvantage.

Finally, there is a need for further study in terms of a combination of sawdust with other materials that have the potential to improve the thermal insulating properties of sawdust for engineering applications.

4. Conclusions

The paper shows that materials with high specific heat capacity and low thermal conductivity have less ability to conduct heat compared to those with low specific heat capacity and high thermal conductivity. The experimental results of the specific heat capacity and thermal conductivity of the sawdust are 0.12 W/m·K and 54.9271 $J \cdot g^{-1} \cdot K^{-1}$ respectively. The implication of the results is that sawdust needs about 54.9271 $J \cdot g^{-1} \cdot K^{-1}$ to raise its unit mass by 1 °C. Materials with thermal conductivity below 0.25W/m·K are good for thermal insulation. The thermal conductivity of this sample (sawdust) is (0.12 W/m·K) below the established value of 0.25 W/m·K. This means that sawdust has very low thermal conductivity and this makes it suitable for use as a composite material for roofing, and ceilings to drastically reduce the rate at which the heat energy from the sun is transferred into the indoor environment and consequently reduce the effects of climate change on the indoor environment.

Conflict of interest

The authors declare that they have no conflict of interest in relation to this research, whether financial, personal, authorship, or otherwise, that could affect the research and its results presented in this paper.

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Data availability

Data will be made available on request.

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