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Assessment of Compressive Strength of Concrete Produces by Varying Water Cement Ratio Maiduguri, Nigeria

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Abstract: *The present study has evaluated the effects of varying water-cement ratio on workability and compressive strength of locally generated aggregates for high strength concrete. Development of mix design method plays a key role that involves the process of determining experimentally the most suitable concrete mixes in order to achieve maximum strength. Tested samples include 60 while w/c was varied at 0.55, 0.6, 0.65 and 0.7. Workability of fresh concrete was evaluated through slump test. Hardened concrete cubes were subjected to compression tests respectively, after 7, 14, 21 and 28 days curing periods. The compressive strength at 28 day for 0.55 produced 22.6N/mm^2, 0.6 produced 23.2 N/ mm^2, 0.65 produced 23.8 N/mm^2 and 0.7 produced 18.4 N/mm^2 respectively. The study observed that 0.65 has the highest strength of 23.8N/mm^2 at 28 days for mix ratio 1:2:4. It was concluded that the strength of concrete of a given water-cement ratio, depend on the size and texture of aggregates, method of compaction, differences in types and sources of cementing materials, entrained-air content, and the length of curing time..*

Keywords: *Water cement-ratio, Compressive strength, Concrete, Mix design. Maiduguri*

INTRODUCTION

Concrete an engineering material consisting of cementing substance, aggregates, water and controlled amount of entrained air. It is initially a plastic, workable mixture which can be moulded into a wide variety of shapes when wet. The strength is developed from the hydration due to the reaction between cement and water. Concrete has very good compressive strength and resistance to fire (Ede and Aina, 2015), but the tensile strength is just about 10% of the compressive strength and have been responsible for many recent researches aimed at improving the general strengths of concrete (Zongjin, 2011; Ede and Aina, 2015). As there has not been a better alternative over the years modern structures in developed and developing nations are mostly built in concrete (Gideon et al., 2015).Concrete is considerably stronger in compression than in tension, for structures required to carry only compressive loads such as massive gravity dams and heavy foundations, reinforcement is not required and the concrete is consequently called plain concrete. When the structure is to be subjected to tensile stresses, steel bars are embedded in the concrete (Nyiutsa and Aondowase, 2013). There are many types of concrete available, created by varying the proportions of the main ingredients. By varying the proportions of materials, or by substitution for the cemetitious and aggregate phases, the finished product can be tailored to its application with varying strength, density, or chemical and thermal resistance properties. The *mix design* depends on the type of structure being built, how the concrete will be mixed and delivered, and how it will be placed to form this structure (Olugbenga, 2014).

Currently there are no special tests developed to determine the suitability of mixing water except comparative tests. Generally, comparative tests require that, if the quality of water is not known, the strength of the concrete made with water in question should be compared with the strength of concrete made with water of known suitability. Both concretes should be made with cement proposed to be used in the construction works. In concrete mix design, the ratio of the amount of water to the amount of cement used (both by weight) is called the water to cement ratio (w/c). Water-cement ratio is usually depends on properties of mixture of sands, gravels and cements. Concrete becomes stronger with time as long as there is moisture and a favorable temperature available. Therefore, the strength at any particular age is both a function of the original water cementitious material ratio and the degree to which the cementitious materials have hydrated. The importance of prompt and thorough curing is easily recognized. Concrete with a higher w/c ratio is also more susceptible to cracking and shrinkage. Shrinkage leads to micro-cracks, which are zones of weakness. Once the fresh concrete is placed, excess water is squeezed out of the paste by the weight of the aggregate and the cement paste itself. When there is a large excess of water, that water bleeds out onto the surface. The micro channels and passages that were created inside the concrete to allow that water to flow become weak zones and micro-cracks.

Since most buildings in Nigeria are owned by common individuals who cannot afford to engage the qualified professionals for the construction of their buildings, most building (conservatively about 70%) in Nigeria are constructed by the roadside craftsmen. These roadside craftsmenconstruct building ranging from one to three/four storeys. These incompetent roadside craftsmen do not carry out any concrete mix design tests for construction work . The concrete production, placement and other activities involved in concreting used for the construction of most buildings in Nigeria are done by the roadside bricklayers/masons without the supervision by the qualified professionals. This explains why the incessant collapse of buildings is more common in building construction works owned by individuals that are constructed by the roadside craftsmen(Adewole et al., 2015). The water to cement ratio largely determines the strength and durability of the concrete when it is cured properly. The simplest way to think about the w/c ratio is to think that the greater the amount of water in a concrete mix, the more dilute the cement paste will be. This not only affects the compressive strength, it also affects the tensile and flexural strengths, the porosity, the shrinkage and the color (Jo, B.W et al, 2007). The objective of research was to develop high strength concrete by varying the w/c ratio using local material under local environment of Maiduguri.

MATERIALS AND METHODS

The materials used are ordinary Portland cement, sharp sand, natural coarse aggregate and water. The mix proportions were prepared according to BS 1881. The concrete were mixed thoroughly to obtain a homogeneous mix. Slump test was carried out to assess the workability of fresh reference concrete according to BS 1881. For each mix of concrete, a sample of freshly mixed concrete is placed and compacted by rod in a frustum of cone mold. For concrete to be workable it is expected that the slump value should be equal to vertical distance between the original and displaced position of the center of the top surface of the concrete after raising a mold (Fig. 1). If this is not obtain the concrete is said to have shared, indicating that concrete workability is not appropriate (Fig. 2). Concrete cubes were produced using concrete mold size of (150mm x150mm x 150mm) from a mix proportion of 1:2:4 (cement-sand-gravel) and water-cement ratio

of 0.55, 0.6, 0.65 and 0.7 fifteen sample each of concrete cubes were produced (Fig. 3).The samples were cured for 7,14,21and 28days before crushing.

Fig. 1: Slump test showing true slump at 0.55 w/c ratio

Fig. 2: Slump test showing slump share at 0.70 w/c ratio

Fig 3 : Concrete cubes in curing tank

RESULT AND DISCUSSIONS

Table 1: average density of concrete with their corresponding water-cement ratio

Mix ratio	W/C Ratio	Average density (Kg/m^3)
1: 2: 4	0.55	5065
1: 2: 4	0.60	5066
1: 2: 4	0.65	5244
1: 2: 4	0.70	4815

Table 2: Slump value at vary water-cement ratio

Mix Ratio	Water-cement ratio	Slump (mm)	Slump (%)
1: 2: 4	0.55	30	10
1: 2: 4	0.60	40	13
1: 2: 4	0.65	60	20
1: 2: 4	0.70	Share	_

Table 1 showed an increase in water-cement ratio increased the density of concrete. This shows that water is an essential property for increasing density of concrete. Slump was obtained at 0.55 water-cement ratio (Table 2) and as the w/c ratio increased the concrete was observed to produce share slump (Fig. 2). This is because the particles become too saturated with water and slump cannot be obtained, indicating concrete workability cannot be achieved above 0.70 w/c ratio.

Table 3: Average compressive strength of concrete at various water-cement ratio

Mix Ratio	Water-cement	Average compressive strength (N/mm^2)			
	Ratio	7 days	14 days	21 days	28 days
1:2:4	0.55	10.6	10.6	11.15	11.6
1:2:4	0.60	10.8	11.8	11.9	13.05
1:2:4	0.65	11.7	18.4	18.4	20
1:2:4	0.70	10.7	9.8	10.1	11.3

Table 3 illustrates the average 28-day density of concrete specimens for all concrete mix. The results indicate that the density of concrete increase as the water-cement ratio and days of curing increase the strength of density of concrete increase. Thus, it was observed that at water-cement ratio of 0.65 yielded the maximum strength. The present study differs from (Hosseini et al, 2011, Yaqub and Bukhari, 2006) work that established 0.55 of water-cement ratio having the maximum strength of concrete. The difference observed could either be as a result of aggregate material used, types of cement or variation and changes in weather conditions. Decreased was observed as the water-cement ratio exceeded 0.65. This could be as a result of concrete becoming too saturated. The result also shows that the strength increase as the days of curing increased. Therefore the maximum strength was achieved at water-cement ratio of 0.65 corresponding to 28 days of curing (Fig. 1).

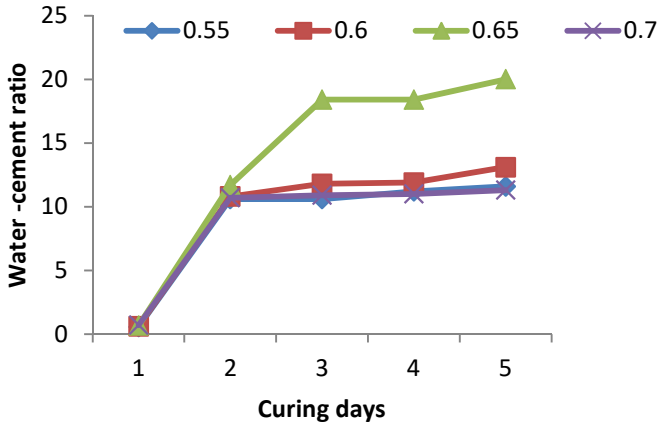

Fig. 2: Compressive strength of concrete at vary water –cement ratio

CONCLUSION

Evaluation of suitable water-cement ratio for concrete design mix was carried out in the laboratory. It was observed that low and high water-cement ratio affect both density and strength of concrete. At mix ratio of 0.70 the concrete is not workable. The highest compressive strength of 20 KN/ mm^2 was obtained at 0.65 water-cement ratio. Therefore the water-cement ratio of 0.65 could be more suitable for concrete mix in Maiduguri.

RECOMMENDATIONS

The following recommendations are:

1. It is very important to adhere to water-cement ratio in concrete mix design.
2. Water-cement ratio of 0.65 could be suitable for concrete mix in Maiduguri for suitable and good strength of concrete.

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Effect of Organic Materials on Evapotranspiration and Coefficient of Sorghum Using Drainage Lysimeter in Semi-Arid Region of Borno State

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Abstract: *The research was carried out to determine the influence of organic materials on crop evapotranspiration of sorghum in semi-arid region of Nigeria. In order to ascertain the influence; a drainage type lysimeter of 0.6m height, and 0.3 diameter with cross-sectional area of 0.85m^2 were used. The organic materials used were; Moringa Olifera leaves, Groundnut Haulm and Maize leaves, were grown and incorporated into the soil at tonnage of 0.45kg/m^2. The organic materials (treatments) were laid in Randomized Complete Block Design (RCBD). For consistency water application, an irrigation interval of 4days was maintained. Furthermore, the highest maize crop evapotranspiration was 19.2, 88.1, 127.32 and 86.10mm/day at all stages of growth and was found with Moringa Olifera leave respectively. Therefore, the study indicates that Moringa recorded the highest influence on the crop evapotranspiration on growth parameters and yield attributes (3663.8kg/ha) of Sorghum crop. Nevertheless, the statistical analysis (T-test) showed that there is no significant difference between the mean of the ETc predicted using the model and that observed from the field using lysimeter, however comparison between the predicted ETc and observed from the lysimeter using Nash- Sutcliffe efficiency (NSE) exhibited a high degree of agreement between the model output and the field observed data with R^2 = 0.9779, NSE values of 0.98, 0.68, 0.78and 0.66, RSR values of 0.11, 0.64, 0.59 and 0.58 for initial, development , middle and late stages respectively; in addition the RMSE for the same growth stages were found to be 0.86, 1.9, 1.6 and 0.92, this implies that the applicability of Hargreaves model is a good representation of calculating maize evapotranspiration for semi-arid region with sandy soil.*

Keywords: *Sorghum; Drainage; Evapotranspiration; Lysimeter; Organic Matter; Nash- Sutcliffe efficiency (NSE)*

1.0 Introduction

Agricultural water users need plan an of annual water budget in semi-arid and arid region lands and in areas where water usage is regulated due to ecological protection programmes, limited resources and competitive demand (Meysam, 2015). Irrigation plays an important role in food production globally. Irrigation is the supply of water to agricultural crops by artificial means,

designed to permit farming in arid region and to offset the effect of drought in semi-arid region and even in areas where total seasonal rainfall is adequate or average (Vaughan *et al.,* 2007). The Rainfall pattern in Maiduguri semi-arid region of Nigeria is characterized by limited and undependable rainfall and the rate of moisture loss into the atmosphere through the process of evapotranspiration is relatively high (Abebe, 2012). Sorghum is the fourth most important world cereal and the second most important cereal after maize in sub-Saharan Africa (Nukenine *et al.*, 2010). Sorghum is grown mainly as a rain fed crop in the semi-arid areas. In these areas, sorghum production is being limited by water stress due to low and variable rainfall between season and within season, and hence sorghum yields vary considerably between years and show a close dependence on also in some highland areas (Yitebitu, 2004). The area of sorghum production is 1.62 million. Moreover, the determination of evaporation in a region with different simple or complex equations required a wide range of meteorological data. This again proved the difficulty of choosing the most appropriate method.However, elevation of organic material level in the soil can promote increased crop yield, stored moisture and enhancing evapotranspiration especially in sandier soil by management of cation exchange avoiding major losses by leaching (Yanfei *et al*., 2006). In addition, organic material is an important way to provide nutrient to plant and may promote greater absorption efficiency resulting in productivity gain (Sendiyama. *et al* 2009). Moringa Olifera is a tropical crop, grown for its nutritional and medicinal purposes. Furthermore Groundnut haulm has most of the qualities of mulching materials, but is not commonly used in the semi-arid region of Africa (Maduka 2011). Most crops grow best in soil with organic matter content between 2 and 5 percent (Pennsylvania. 2009).Therefore, the current study is under taken to determine the most effective organic materials to be used for improved crop evapotranspiration for growth and yield of sorghum crop and to validate the applicability of ETc model develop by Hargreaves-Samani to the study area.

2.0 Materials and Methods

2.1Experimental Site Description

The experiment was conducted at the Ramat Polytechnic Teaching and Research farm Maiduguri during the dry season between Februarys to April, 2018. Maiduguri i.e. on latitude 1 1.4°N and longitude 13.05°E it has the altitude of 354m above sea level Bashir., 2015).The average annual rainfall is around 640mm and the temperature is high ranging between 20-40^{o}C (Dalorima, 2002). The area is highly susceptible to drought with relative humidity of 13% and 65% in dry and rainy season respectively (Bashir. 2014). Also the area is vulnerable to desertification (Dibal, 2002).

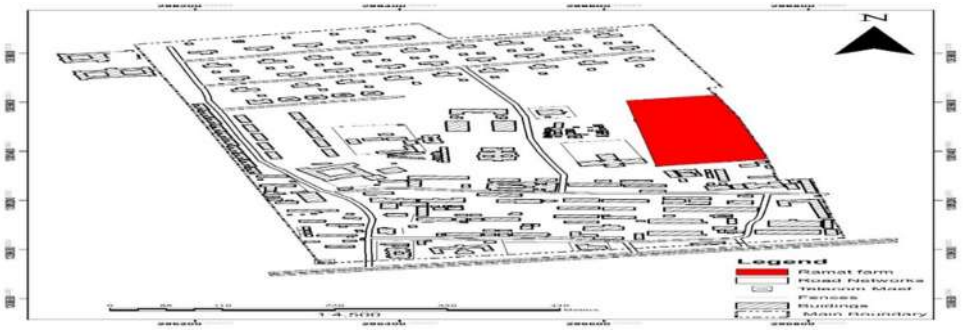

Table 1: Soil Characteristics of the Experimental Site (0-30 cm)

Soil type (USDA soil classification)	**Sand loamy**

Clay (%)	8.0
Silt (%)	11.8
Sand (%)	80.2
P^h	6.8
Field capacity (vol. %)	16.2
Wilting point (vol. %)	3.2
Available water content (vol. %)	13.0
Bulk Density (g/cm^3	1.70
Organic matter (%)	3.99

2.2 Experimental design

The field experiment was conducted at the Teaching and Research Farm of the Ramat Polytechnic Maiduguri. The experimental site was15m x 15m. The selected area was divided into 3 plots of 14m x 4m each with a foot path of 1.5m in between the plots. Subsequently, the entire land area was fumigated manually to prevent the crops from pest attack. Drainage type lysimeter of 0.6m height, and 0.3 diameter with cross-sectional area of $0.85m^2$ was used for this study. A plastic container (5 liters) was placed at 1m away from the lysimeter to serve as drainage collector. However, 0.02m (2cm) diameter plastic pipe was used to link between the lysimeter and the drain collector. The Installation was accomplished by used of backhoe, forklift, hand shovels, and hand tools. An order of returning excavated soil for the lysimeter. "Last out first in and first out last in" was used to maintain same natural soil structure or arrangement as suggested by Shukla et al., (2007). Furthermore, the lysimeter were set into the soil pebbles and wire mesh was placed at the bottom of the lysimeter to a depth of 5cm in order to facilitate easy drainage and help in preventing blockage of the drain. The organic materials used for this study were Moringa Olifera leaves, Groundnut Haulm and Maize Leaves were grown and incorporated into the soil at $0.45kg/m^2$ tonnage to a depth of 8inch beneath the soil in the lysimeter for the all experimental unit, the cropwas irrigated as per the design of the treatments. Measured quantity of water was applied. Soil moisture was measured before each irrigation. Since the experiment was carried out in dry season no rainfall part was considered and only change in soil moisture during the period under consideration were subtracted from the applied water to obtain crop evapotranspiration (ET_c).

2.3 Agronomic practices

An improved variety of sorghum developed by (ICRISAT) was obtained from Borno State Agricultural Development Programmed (BOSADP) Maiduguri was planted on the 31st of December, 2021 and to avoid alteration of the treatments, water was applied using a sprinkling irrigation method i.e. using hand watering-can as have suggested by (Howell, 2001). The standard lysimeter spacing of (1m) was used and the sorghum was planted six seed per hole in each lysimeter plots at the depth of 7cm using hoe. It was letter thinned to two seedling per hole on each experiment unit after germination. (De Rouw and Rajot. 2004).Recommended NPK fertilizer50kg of K_2O per hectare for most cereals crop was applied. The first dosage of fertilizer was applied after the first week of planting at a depth of 5-8cm, while the second dosage was also applied four weeks after planting as recommended by (Onyibe et al. 1997). Weeding was carried out manually throughout the growing period to avoid competition for space, water light and nutrients between the crops (James et al., 2000). The first weeding was done two weeks after planting and the second was carried out 5 weeks after planting.

2.4 Estimation of crop Evapotranspiration (ETc) using lysimeter

The determination of sorghum crop evapotranspiration using lysimeter was achieved using Equation (1) below as suggested by (Sharma 1995). However, the moisture available in the soil at the root zone of the crops in each lysimeter was estimated using speedy moisture meter. Nevertheless, the difference between water applied and water drained was determined using measuring cylinder.

$$ET_c = R_w + I_w - QD \pm \Delta S \quad (1)$$

Where: ET= Evapotranspiration (mm/day), Rw= Rainfall Water (mm) Iw= Irrigation Water (m^3) QD=Quantity of water drained Δs=Surface & Subsurface changes in storage difficulties Involved

2.5 Estimation of Crop Coefficient

Sorghum crop coefficient was determined at growth stages of the crop using empirical relation recommended by (Allen *et al*., 1994) shown in equation (2).

$$K_c = \frac{ET_c}{ET_o} \quad (2)$$

Where, Kc is crop coefficient (-),ETc is crop evapotranspiration in (mm/day) was estimated as stated in equation 1,ET_o is reference evapotranspiration in (mm/day) was estimated using pan method as mentioned in shown in equation 3

$$ET_o = K_{pan} \times E_{pan} \quad (3)$$

2.6 Determination of Leaf Area Index (LAI)

Sorghum crop leaf area index at all stages of growth was determined using Babiker (1999) formular

$$kc = \frac{\max\ leaf \times \text{max width} \times \text{no.of leaves}}{\text{plant} \times 0.75 \times \text{no.of plants}\ /m^2} \quad (4)$$

Where, 0.75 is the Correction factor for crop

2.7 Determination of the crop yield

The panicle length of the fully matured grain was measured using meter rule and the mean was recorded for each treatment in (cm). Number of panicle per plant was counted and the mean values were recorded. The panicle from each lysimeter in the experiment units were threshed, seeds were counted, and the average seed number per head was recorded.

2.8 Hargreaves-Samani Crop evapotranspiration (ETc) models

The model considered for validation is Hargreaves-Samani equation for estimating crop ET which doesn't require wind speed data Presented in FAO - 56 by Allen et al. (1998) Adopted by Abhinaya *et al* (2015). For the validation studies, some meteorological parameters such as daily values of mean minimum and maximum temperature, sunshine, mean daily relative humidity, and evaporation using evaporation pan was collected and considered. These weather parameters

were obtained from Ramat Polytechnic and Maiduguri international airport weather stations (NIMET) and were substituted into models as presented in equation 5 below

$$ET_c = \frac{\mathbf{0.0135}\boldsymbol{Rs}\,(\boldsymbol{T}+\mathbf{17.8})}{2} \quad (5)$$

Where; Rs=0.758RaS$^{0.50}$, and S=0.125(100-Rh), Rh = daily mean relative humidity (%), Tmean is the daily mean air temperature (◦C), and Rs is mean daily sunshine radiation (mm day^{-1})

2.8.1 Model performance evaluation

The validity agreement between the observed and predicted sorghum crop evapotranspiration was quantitatively evaluated using the Nash- Sutcliffe efficiency (NSE), the ratio of the root mean square error to the standard deviation of measured data (RSR), and root mean square error (RMSE). The evaluation were rated 'Very Good' ($0 \leq RSR \leq 0.50$ and $0.75 < NSE \leq 1.00$), 'Good' ($0.50 < RSR < 0.60$ and $0.65 < NSE < 0.75$), 'Satisfactory' ($0.60 < RSR < 0.70$ and $0.50 < NSE < 0.65$), or 'Unsatisfactory' ($RSR > 0.70$ and $NSE \leq 0.50$), according to the criteria suggested by Moriasi *et al.* (2007).

$$\boldsymbol{RSR} = \frac{\sqrt{\frac{\mathbf{1}}{\boldsymbol{n}}\sum_{\boldsymbol{i=1}}^{\boldsymbol{n}}(\boldsymbol{ET_{cobs-}}\,\boldsymbol{ET_{cal}})\text{^}\mathbf{2}}}{\sqrt{\frac{\mathbf{1}}{\boldsymbol{n}}\sum_{\boldsymbol{i=1}}^{\boldsymbol{n}}(\boldsymbol{ET_{cobs-}}\,\boldsymbol{ET_{mean}})\text{^}\mathbf{2}}} \quad (6)$$

$$\boldsymbol{RMNS} = \sqrt{\frac{\mathbf{1}}{\boldsymbol{n}}\sum_{\boldsymbol{i=1}}^{\boldsymbol{n}}(\boldsymbol{ET_{cobs-}}\,\boldsymbol{ET_{cal}})\text{^}2} \quad (7)$$

$$\boldsymbol{N\,S} = \sqrt{\frac{\mathbf{1}}{\boldsymbol{n}}\sum_{\boldsymbol{i=1}}^{\boldsymbol{n}}(\boldsymbol{ET_{cobs-}}\,\boldsymbol{ET_{cal}})\text{^}\mathbf{2}} \quad (8)$$

Where; ETc cal = calculated ETc by model, ET cobs = observed ET_C by lysimeter and ETc Mean=average daily ETobs over the season

2.9 Data Analysis

All the data collected on the growth and yield parameters of the millet were subjected to Analysis of Variance (ANOVA) using Statistic 8.0 package. The difference between treatments means were separated using least significant difference (LSD).

3.0 RESULT AND DISCUSSIONS

3.1 Influence of Organic Materials on Crop Evapotranspiration (ETc)

The experimental results obtained on influence of organic materials on crop evapotranspiration ET_c, Crop coefficient K_c, leaf area index LAI, Yield and yield attributes of millet are presented in internationally recognized growth stages Initial (10 DAS), development (35 DAS), middle (60 DAS) and late season (80DAS) stages and DAS means (day after sowing) as illustrated in Table 2, 3, 4, 5&6 below.

Table 2 Influence of organic materials on evapotranspiration (ETc) of sorghum crop at different growth stages (mm)

Treatments	Initial	Development	Middle	Late
Maize leave	16.3[b]	62.2[c]	137.6[b]	97.7[a]
Moringa leave	18.2[a]	97.8[a]	148.0[a]	76.6[b]
Groundnut haulm	18.0[a]	79.0[b]	133.3[c]	68.1b[c]
Control	17.6[b]	82.3[b]	137.7[b]	71.6[c]
SE±	2.537	4.04	3.331	5.140

Means within a treatment column followed by similar letter(s) are not significantly different at 5% probability level

The organic materials used had significantly ($P<0.05$) influenced the evapotranspiration of millet (Table 2). The highest evapotranspiration values of 18.2mm, 97.8mm, and 148.0mm at initial, development and middle stages of growth respectively occurred due to the use of Moringa Olifera leaves as an organic material. It was closely followed by Maize leave (97.7mm) at late stage. Also there were significant differences among the organic materials used. Thus, groundnut haulm has the least value (68.1mm) at late stage. Whereas, crop evapotranspiration is less in control lysimeter than all the treatment used. These results are similar to finding of (Irmak, 2009), who reported that the weekly ET_c values for millet ranged from 25.2 to 61.9 mm. Higher ET_c values were recorded from initial and development stages as compared to the values in the initial and end of the crop life cycle.

3.2 Influence of Organic Material on Stage –Wise Crop Coefficient (Kc) of sorghum.

The results obtained on the influence of organic materials on crop coefficients of sorghum are presented in Table 3 below.

Table 3: Influence of organic material on stage –wise crop coefficient (Kc) of the sorghum crop at different growth stages.

Treatments	Initial	Development	Middle	Late
Maize leave	0.35[c]	0.79[d]	1.27[a]	0.33[b]
Moringa leave	0.40[a]	1.16[a]	1.38[a]	0.93[a]
Groundnut haulm	0.39[ab]	0.95[c]	1.30[a]	0.69[ab]
Control	0.35[c]	1.06[b]	1.31[a]	0.66[ab]
SE±	0.180	0.093	0.204	0.368

Means within a treatment column followed by similar letter(s) are not significantly different at 5% probability level

Crop co-efficient values for different growth stages of millet crop were significantly ($p<0.05$) influenced by the treatments used Table 3. The highest millet crop coefficient (Kc) values (0.40, 1.16, 1.38 and 0.93) at all the stages growth were occurred as a result of moringa leaves use as an organic material. It was closely followed by groundnut haulm with Kc values range from (0.39, 0.95, 1.30 and 0.69) correspondingly. While, least (Kc) values were recorded from the maize leaves and control plot. The changed in Kc could be attributed to the seasonal variation of leaf area, the results were tallied with the findings of Zhang *et al* (2005). For more detail see figure 1

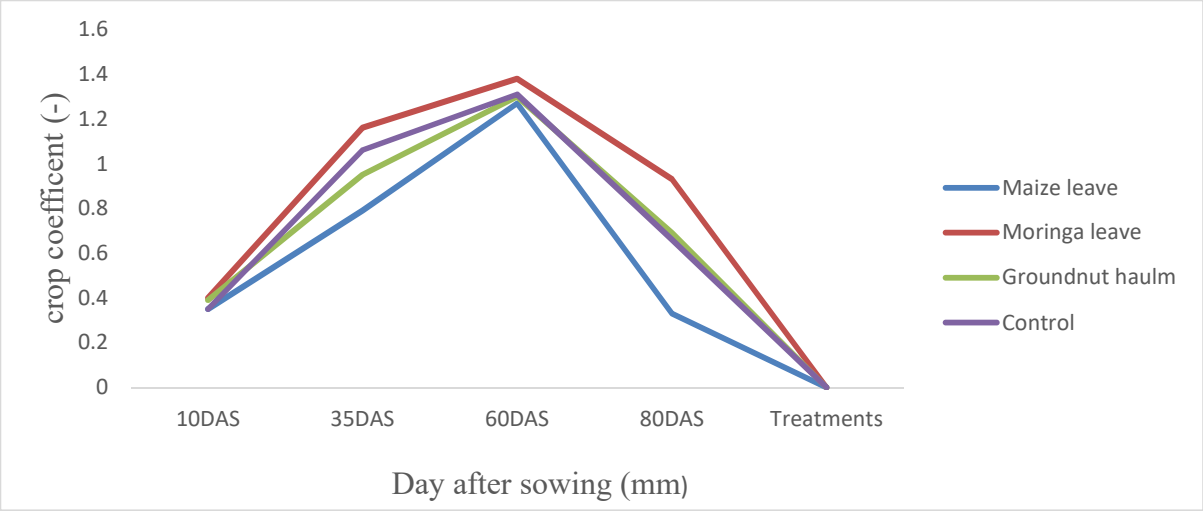

Figure: 1 showing the graph of Kc versus DAS

3.3 Influence of Organic Material on Crop Leaf Area Index (LAI) of Sorghum

Results obtained on influence of organic materials on leaf area index of sorghum crop are illustrated in Table 4 below.

Table 4: Influence of organic materials on leaf area index of sorghum crop at different growth stages (m^2)

Treatments	Initial	Development	Middle	Late
Maize leave	0.03^{b}	0.25^{c}	2.40^{b}	1.87^{ab}
Moringa leave	0.04^{a}	0.34^{a}	3.20^{a}	1.50^{b}
Groundnut haulm	0.03^{ab}	0.22^{d}	3.00^{a}	1.93^{a}
Control	0.02^{c}	0.28^{b}	2.50^{b}	1.50^{b}
SE±	0.342	0.126	0.2514	0.321

Means within a treatment column followed by similar letter(s) are not significantly different at 5% probability level

The leaf area index (LAI)) of a sorghum crop were significantly ($P > 0.05$) affected by the treatment used throughout the period of experiment Table 4. Rapid increase in LAI was observed highest with moringa olifera leaves during initial, development and mid- stage of the crop growth with corresponding values of 0.04, 0.34, and 3.20, closely followed by groundnut haulm at mid-stage with LAI of 3.0. Similarly at late stage the highest LAI (1.93 and 1.87) was recorded both in groundnut haulm and maize leave respectively. This could be attributed to leaf droppings at crop full maturity affects the leaf area index. Similar observation was reported by Fasinmirin *et al*. (2015).

3.4. Influence of Organic Material on Yield Parameters and Yield of Sorghum

The experimented results of the yield and its attribute of sorghum crop as influenced by the organic material used as treatments were illustrated in Table 5

Table 5: Influence of organic material on yield attributes and yields of sorghum crop

Treatment	Panicle length (cm	Panicle diameter (cm)	Number of panicle per plant	No seed per panicle	Panicle weight (Kg)	Yield (kg/ha)
Maize leave	21.17[a]	10.2[ab]	3[b]	2228.7[bc]	0.3690[bc]	2969.5[b]
Moringa leave	21.23[a]	11.2[a]	5[a]	2636.0[a]	0.4190[a]	3663.8[a]
G. haulm	20.33[ab]	10.3[ab]	4[ab]	2390.0[ab]	0.3553[b]	3468.0[ab]
Control	19.00[b]	10.3[ab]	2[c]	1979.0[c]	0.2360[c]	2308.3[bc]
SE±	2.029	1.351	1.793	349.13	0.0850	364.72

Means within treatment and a column followed by similar letter(s) are not significantly different at 5% probability level.

The treatments used were significantly ($P<0.05$) influenced the yield and yield parameters of sorghum crop as shown in Table 5. Moringa leaves and maize leaves gave highest number of panicle lengths per plant (21.17and 21.23) respectively. It were followed by groundnut haulm (20.333) and control having the least (19.0). Also, the highest panicle diameter and number of panicle per plant were obtained from moringa leaves were 11.2cm and 5cm respectively. Conversely, followed by groundnut haulm with (10.3cm and 4), while the least was recorded from maize leaves and control. The findings were agreed as stated in (Wahome *et al*, 2010). Also the maximum grain yield of 36637.8 kg/ha with total seed per panicle of (2636.0) was obtained from moringa Olifera. It was closely followed by the groundnut haulm and maize leaves with corresponding yield and number of seed per panicle of (3468.0kg/ha, 2969.5kg/ha) and (2390.0 and 2228.7), respectively. The least yield of 2308.3 kg/ha was recorded in control plot and was achieved with (1979.0) number seed per plant respectively. According to FAO (2010) reported that the number of seed per plant are the most important characters that affect seed yield in most cereal crops.

Table: 6 Performance evaluation comparison between ET observed from (lysimeter) versus predicted from Hargreaves–Samani (ABC model) for sorghum crop at different growth stages.

Growth stages	ETobs (mm)	ETcal (mm)	ΔET	ET mean (mm/day)	RMSE	NSE	RSR	Performance Rating
Initial	17	18.9	-1.9	1.8	0.86	0.99	0.12	VG
Development	82	70.2	11.8	3.0	1.2	0.65	0.60	G
Middle	138.1	135.3	2.8	5.5	0.93	0.69	0.54	G
Late	72.5	78.2	-5.7	3.7	0.38	0.68	0.59	G

RMSE – root mean square error; NSE – Nash-Sutcliffe efficiency; RSR – ratio of the root mean square error to the standard deviation of measured data; S – satisfactory; VG – very good; G – good, and ΔET difference in ETc.

The comparison as presented in Table 6, showed a good agreement between the ETc calculate from ABC model and ETc observed from the lysimeter for the sorghum crop, the model output and the experimental result plotted on the graph Fig 4.1, have yielded the slope and intercept of 10.971x and 3278respectively and with R^2 of 0.977, exhibited a high degree of agreement between the model output and the field observed data. the NSE values of 0.99, 0.65, 0.69 and 0.68 and RSR values of 0.12, 0.60, 0.54 and 0.59 for initial, development , middle and late growth respectively. In addition the RMSE for the same growth stages was found to be (0.86, 1.2, 0.93, and 0.38) and also indicated that model performed 'Very Good' in estimating the seasonal evapotranspiration of millet. However, the agreement between the calculated and measured values as presented in Table 4.9.1 varied from the agreement rated 'very good' for the initial stage, 'good' for development stage, middle stage, and the late stage. Similarly, the observed and predicted millet crop evapotranspiration were analyzed using T-test as shown Table 6 below indicating that there is no significant difference between the predicted and measured crop evapotranspiration at ($P<0.05$), implies that, the applicability of ABC model is a good representation of calculating evapotranspiration to semi-arid region with sandy loam in the study area.

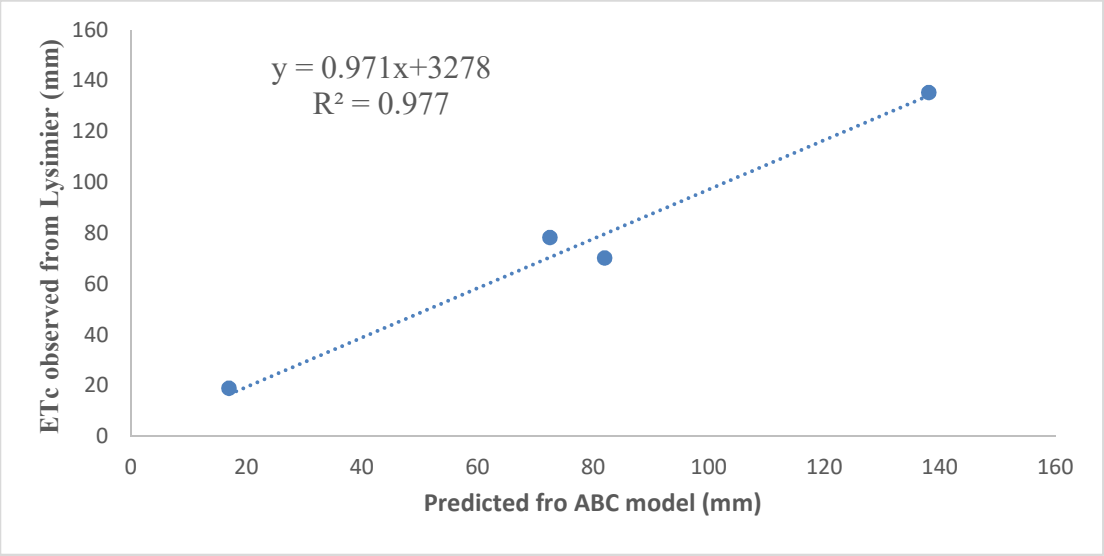

Figure: 2 showing relationship between the predicted and observed ETc

Table 7: Summary of T-Test for comparing ETc by Lysimeter and ABC model at growth stages

Z	*ETc Predicted values (mm)*	*ETc Observed values Millet (mm)*
Mean	75.65	77.4
Variance	2271.63	2459.273333
Observations	4	4
Pooled Variance	2365.452	
Hypothesized Mean Difference	0	

Df	6
t Stat	-0.050
P(T<=t) one-tail	0.480
t Critical one-tail	1.943
P(T<=t) two-tail	0.461
t Critical two-tail	2.446

T Stat < T critical

As presented in table 7 there is no significant difference between the ETc observed from the lysimeter and ETc predicted from fapohunda model. Therefore, ETc predicted from the model and the ETc observed from the field produce the same result. This indicate that the ABC model is a good representation of calculating evapotranspiration to semi-arid region with sandy loam in the study area.

Conclusion and recommendation

The research analyzed the influence of organic materials on crop evapotranspiration of sorghum crop, to determine its influence on the crops. The study employed statistical technics including analysis of variance (ANOVA) and Nash- Sutcliffe efficiency (NSE) and concluded as follows:

1. Analysis of variance (ANOVA) showed a significant difference between the treatments used (organic materials). Moringa Olifera has the highest influence on ET_C, Kc, LAI at all stages of growths and significantly influenced the yield of the grain with (3663.8kg/ha) than of all other treatment experimented
2. comparison between the predicted ETc and observed from the lysimeter using Nash-Sutcliffe efficiency (NSE) exhibited a high degree of agreement between the model output and the field observed data with an $R^2 = 0.9779$.
3. The results of comparison the study implies that the applicability of Hargreaves model is a good representation of calculating sorghum crop evapotranspiration to semi-arid region with sandy soil.
4. The statistical analysis (T-test) showed that there is no significant difference between the means of the ETc predicted using the model and that observed from the field using lysimeter
5. Similar experiment are needed to be conducted at different agro-ecological condition in order to confirm the findings

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Effect of Furrow Irrigation Variables on Growth Performance and Yield of Millet in Borno State

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Abstract: *Efficient application and distribution of water by furrow irrigation is dependent on furrow parameters such as inflow, soil texture, field slope, soil infiltration, plant coverage, roughness coefficient, field shape and irrigation management. The study was carried out to determine the effects of furrow irrigation variables on millet crop growth and yield in semi-arid region of Maiduguri, Borno state of Nigeria. The experiment was conducted between December to March 2021 during dry seasons at the Teaching and Research Farm of Agricultural Engineering Department, Ramat Polytechnic Maiduguri. The furrow irrigation variables used were furrow lengths and stream sizes each at three level namely; FL10m, FL20m, FL30m and SS0.5 l/s, SS1.0 l/s, and SS1.5 l/s respectively. The variable (treatments) were laid in Randomized Complete Block Design (RCBD). The growth and yield parameters of the millet experimented measured were included; plant height, stem diameter, panicle length, panicle dry weight, thousand seed yield and days to 50% maturity level of girth and silking were also recorded on week after sowing basis in the studies. Data from the experiment was subjected to Analysis of variance (ANOVA). The results showed that there were no significant differences among the treatment means of the growth parameter at ($p<0.05$) probability level. The highest Plant height at all weeks after sowing was observed in FL2 with corresponded plant height values (39.5cm, 68.18, 109.86, 149.5 and 206.3) respectively. whereas the variables (SS1.0 l/s and FL20m) were produced the highest number of growth parameter and yield parameter. Likewise, highest grain yield of 3.9563 t/hac and 4.3463 t/hac were recorded between FL2 and SS2 respectively.*

Keywords: *Millet, Furrow, Stream size, Furrow length and Performances Parameter*

1.0 INTRODUCTION

Furrow irrigation is one of the extensively used means of irrigating crops in many developing countries. It is especially recommended for growing row crops on medium to heavy textured soils and is preferred over other surface irrigation methods due to its simplicity and low capital cost (Dibal *et al* 2015). Furrow irrigation requires precisely graded fields with furrows or small ditches formed between crop rows for the water to flow by gravity from one side of the field to the other Eshetu (2007). Its efficient application and distribution of water by furrow irrigation is dependent on furrow parameters such as inflow, soil texture, field slope, soil infiltration, plant coverage, roughness coefficient, field shape and irrigation management (Holzapfel, 2010). The optimal design of furrow irrigation methods can be an important way to maximize net returns and to use water most efficiently. Well-designed methods can increase the water application

efficiency to levels of 60-80 % compared with typical efficiencies of 20-40% reported by Clyma, *et al.* (2001). Poor performance of furrow irrigation system suggests a need for better system design and management. Improved designs of furrow irrigation systems would result in more effective and efficient use of water resources Rice et al (2001). Determining flow rate is a critical step in designing furrow irrigation systems for maximum net return. Earlier methods were developed to optimally design furrow systems for maximization of net returns from farm, assuming infiltration characteristics do not change during the season and not considering deep percolation losses (Zehirun,.*et al* 2001). Mekonen (2006) investigated 0.3, 0.4 and 0.5 lit/s flow rates against 24, 35 and 50 m furrow length design at Batu Degaga and found that average application efficiency of 28.9, 33.6 and 40.46% for furrow lengths of 24, 35 and 50 m, respectively. Regarding flow rates, the average values of application efficiency became 32.9, 32.8 and 36.9% for the flow rates of 0.3, 0.4 and 0.5 lit/s, respectively. Therefore, the present study was undertaken in order to analyse influence of some furrow irrigation variables (inflow discharge and furrow length,) on growth and yield millet, as well as furrow performance parameters. Irrigation efficiency is a crucial aspect for irrigated agriculture and a key factor due to the competition for water resources (Hsiao *et al*., 2007). Furrow irrigation variables are the most sensitive engineering problem most affecting farmers in the region. Basic requirement is to adequately select furrow irrigation variables (furrow length, and stream flow), with the view to improve irrigation scheduling, and improve water management of the field which will also potentially reduce over-irrigation and deep percolation of applied water. Therefore, the current study is undertaken to determine the influence of some furrow irrigation variables with the view to ascertain its performance on irrigation performance parameters, growth and yield of millet crop in Maiduguri.

2.0 MATERIALS AND METHODS

2.1 Experimental Site

The field experiment was conducted at the Teaching and Research Farm of the Ramat Polytechnic, Maiduguri. The site lies between latitude $11^0$5 N and longitude $13^0$09E (Kyari, *et al* 2014). The area is about 335m above sea level and lies within the lake Chad Basin formation, which is an area formed as a result of down –warping during the Pleistocene period (Waziri, 2007). The average annual rainfall is around 640mm and the temperature is high ranging between 20-40^{o}C (Dalorima, 2002). The area is highly susceptible to drought with relative humidity of 13% and 65% in dry and rainy season respectively (Bashir 2014). Also the area is vulnerable to desertification (Dibal, 2002). However, the soil texture in the farm is predominantly sandy loam with an aggregates proportion as shown in table 1 below.

Table: 1 Soil characteristics at the experimental site (0-40 cm)

Soil type (USDA soil classification)	Sand loamy
Clay (%)	8.0
Silt (%)	11.8
Sand (%)	80.2
P^h	7.8
Field capacity (vol. %)	17.2
Wilting point (vol. %)	4.2

Available water content (vol. %)	13.0
Bulk Density (g/cm^3	1.70
Organic matter (%)	3.99

Source : Agrcultural Research Farm Rampoly (2019)

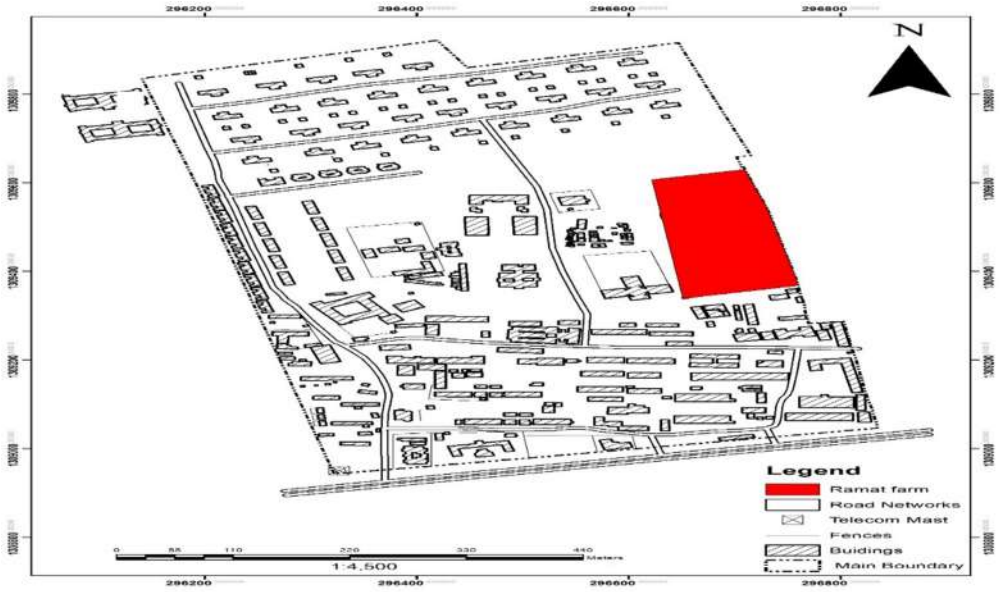

Fig: 1 Map showing the experimental site

2.2 Treatment and Experimental Design

The experimental factor considered in this work were furrow Length and stream size at three level each, and replicated three times to make total of 27 treatments. The stream size were 1.5l/s, 1.0 l/s sand 0.5l/s, while the furrow length were 30m, 20m and 10m that were laid in a Randomized Complete Block Design (RCBD).

2.3 FIELD EXPERIMENTATION

2.3.1 Furrow Geometry

2.3.2 Furrow Stream Flow Measurement

The stream flow in each furrow was measured by volumetric method as suggested by Zerihun *et al*. (2010). A drum having capacity of 100 litres was filled completely with water flowing out of the pipe at the head end of the furrows and time taken by the water flow to fill the drum was noted with the help of a stop watch. The capacity of drum divided by the time gave the stream flow.

2.3.3 Furrow Cross Section Area

Trapezoidal shaped furrows were made by using a tractor drawn ridges. The depth of furrow was measured by installing a hook gauge at every 5m distance along the furrow length and the average depth was found to be 0.25 m. Top width and bottom widths were also measured at the same distances. With a side slope of 1.5:1, the top width was measured as 0.6 m against the bottom width of 0.15 m.

2.3.4 Furrow-Bed Slope

The bed or bottom slope of furrow was maintained as 0.2 per cent with the help of dumpy level and levelling staff.

2.3.5 Measurement of Infiltration in Experimental field

In the experiment, furrow infiltration was determined by volume balance method. The furrow was completely filled with water up to the top width and immediately, the water depths at different distances along the furrow length were measured. At the end, the furrow was blocked so that no water is allowed to escape as runoff. Then at different time intervals, the flow depths were measured at the same distances as was measured when the furrow was completely filled with water at the beginning. The difference of the two depths gave the depth of water infiltrated.

Table 2: Geometric details of experimental plot

Expereiment plot area	**752.5 m^2 =35×21.5**
Furrow length	At 3 level = 30m, 20m and 10m
Furrow stream size	At 3 llevel=1.5m, 1.0m and 0.5m
Furrow width	0.35m
Furrow topwidth	0.6m
Furrow bottonwidth	0.15m
Furrow depth	0.25m
Side slope	2:1
Bed slope percentage	0.2%
Row to row spacing	0.60 m
Plant to plant spacing	0.45m

3.0 Result and discussions

The experimented results on effects of furrow length and stream size as affected the growth, yield attributes and yield of millet were presented at 2-10 week after sowing basis (WAS) as presented below.

3.1 Effects of furrow length and stream sizes on millet plant height

The result obtained on the effects of furrow length and stream sizes on the millet plant height were illustrated in Table 1.

Table 1: Effects of furrow lengths and stream sizes on the millet plant height

Treatments	**WEEK AFTER SOWING**				
Furrow length (m)	**2**	**4**	**6**	**8**	**10**
FL1(10)	37.6[b]	64.8[b]	101.33[b]	145.3[b]	190.4[b]
FL2(20)	39.5[a]	68.18[a]	109.86[a]	149.5[a]	206.3[a]
FL3(30)	35.4[c]	49.88[b]	81.69[b]	139.5[c]	176.4[c]
Significance	Ns	*	*	*	
SE±	0.150	0.137	0.0553	0.032	0.1452
Stream sizes (L/s)					
SS1 (0 .5)	38.6[a]	65.8[a]	113.33[a]	150.3[a]	197.4[b]
SS2 (1.0)	38.5[a]	64.18[b]	112.86[a]	150.5[a]	199.3[a]

SS3 (1.5)	37.4[b]	46.88[c]	88.69[b]	129.52[b]	170.4[c]
Significance	Ns	*	*	*	
SE±	0.5050	0.1687	0.1553	0.0932	0.012
Interaction					
FL x SS	*	*	*	*	*

Means within a column followed by similar letter(s) are not significantly different at 5% probability

As illustrated in table 1 the furrow lengths and stream sizes used as treatment were significantly ($p<0.05$) affected the Plant height of millet as presented in (Table 4.1). The highest Plant height at all weeks after sowing was observed in FL2 with corresponded plant height values (39.5cm, 68.18, 109.86, 149.5 and 206.3) respectively. It was closely followed by FL2 at same weeks after sowing and the least plant height at 2WAS and 4WAS was recorded in FL3 treatment. Likewise, the stream sizes variation had significantly affected the millet plant height. The highest plant heights at all WAS were recorded both from SS1 and SS2 used as treatment, while the least plant height values of 7.4 cm, 46.88 cm, 88.69 cm, 129.52cm and 170.4cm for 2WAS, 3WAS, 4WAS and 5WAS respectively found with SS3. Likewise, the interactions between the furrow lengths and different stream sizes were not significant The finding was similar with one reported by Yazar *et al*., (2012) stated that stream size in furrow irrigation plays a vital role in vegetative growth of plant and causing improvement plant height.

3.2: Effects of furrow lengths and stream sizes on millet stem diameter

The result obtained on the effects furrow length and stream size used as treatments on steam diameter of millet crop were illustrated in Table 2

Table 2: Effects of furrow lengths and stream sizes on millet stem diameter

Treatments	**WEEKS AFTER SOWING**				
furrow length (m)	**2**	**4**	**6**	**8**	**10**
FL1(10)	2.3[b]	2.6[c]	3.1[c]	4.0[b]	8.1[a]
FL2(20)	2.4[b]	2.8[b]	3.5[b]	3.9[c]	7.6[b]
FL3(30)	3.7[a]	3.9[a]	3.7[a]	4.1[a]	6.3[c]
Significance	Ns	*	*	*	
SE±	0.150	0.236	0.054	0.082	0.215
Stream sizes (L/s)					
SS1 (0 .5)	2.8[c]	2.9[b]	3.3[b]	4.1[b]	7.9[a]
SS2 (1.0)	2.9[b]	2.5[b]	3.2[b]	4.3[a]	7.5[b]
SS3 (1.5)	4.0[a]	3.1[a]	3.9[a]	4.0[b]	6.2[c]
Significance	Ns	*	*	*	
SE±	0.050	0.187	0.153	0.032	0.142
Interaction					
FL x SS	*	*	*	*	

Means within a column followed by similar letter(s) are not significantly different at 5% probability level

The treatment used were significantly ($p<0.05$) affected the stem diameter of the millet crop as presented in (table 2). The highest stem diameter at 2WAS and 4WAS of (3.7 cm and 3.9 cm) was recorded with FL3, closely followed by FL2 and FL1 same WAS with corresponding stem diameter of (2.4 cm, 2.3 cm 2.8 cm, and 2.6 cm) respectively. Similarly, stream sizes variation for both SS1 and SS2 were not significantly affected the stem diameter of the millet crop, but the diameter values differ with those recorded from SS3. The finding was similar to those

reported in Ikwu, (2011) and the interactions between the furrow lengths and different stream sizes were not significant

3.3: Effects of furrow length and stream Sizes on leaf area index of millet

Results obtained on effects of furrow length and stream sizes on leaf area index (LAI) of millet and crop were shown in Table 3

Table 3: Effects of furrow length and stream sizes on (LAI) of millet

Treatments	WEEKS AFTER SOWING				
Furrow length (m)	**2**	**4**	**6**	**8**	**10**
FL1(10)	0.31[b]	0.62[c]	1.98[c]	2.5[a]	3.4[b]
FL2(20)	0.43[a]	0.80[a]	2.10[a]	2.4[b]	3.7[a]
FL3(30)	0.04[c]	0.79[b]	2.00[b]	2.2[c]	3.0[c]
Significance	Ns	*	*	*	*
SE±	0.12	0.34	0.07	0.14	0.33
Stream sizes (L/s)					
SS1 (0 .5)	0.12[c]	0.59[a]	1.99[c]	2.4[c]	3.0[a]
SS2 (1.0)	0.47[b]	0.42[b]	2.16[a]	2.7[b]	2.8[b]
SS3 (1.5)	0.66[a]	0.59[a]	2.01[b]	3.0[a]	2.9[c]
Significance	Ns	*	*	*	
SE±	0.03	0.16	0.161	0.021	0.133
Interaction					
FL x SS	*	*	*	*	*

Means within a column followed by similar letter(s) are not significantly different at 5% probability level

The treatments used were significantly ($p<0.05$) affected the leaf area index (LAI)) of a millet crop as presented in (table 3). Steady increase in LAI was observed at all weeks after sowing, with furrow lengths variation but the highest LAI was induced by FL2 at all weeks after sowing with corresponding leaf area index of (0.43, 0.80, 2.10, 2.4 and 3.7) respectively. It was closely followed by FL1 at same WAS with leaf area index values of (0.31, 0.62, 1.98, 2.5 and 3.4) respectively, while the least was observed with FL3 treatment, the interactions between the furrow lengths and different stream sizes were not significant. Similar observation was reported by Fasinmirin *et al*., (2009).

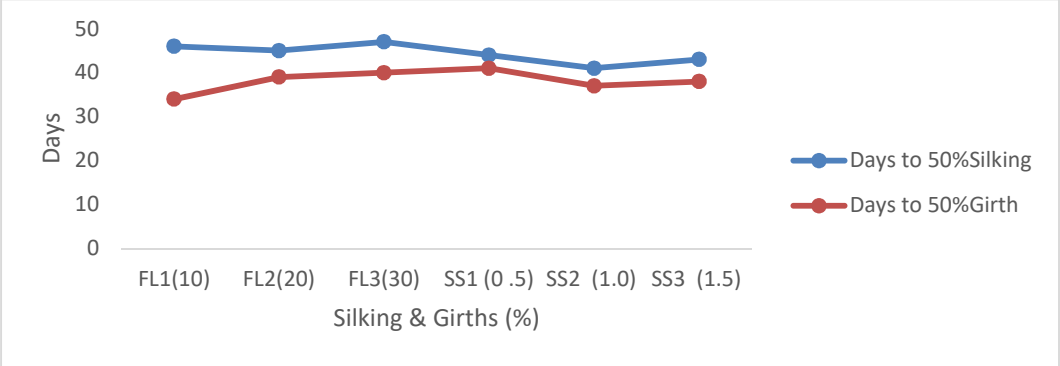

Fig 2: Shows the effects of furrow lengths and stream sizes on days to 50% silking and girth

As shown in the fig 2, the earlier days to 50% silking and girth of 45 and 39 days after sowing of the millet was recorded in FL2, it was closely followed by FL2 with corresponding silking and girth of 46 and 34 days after sowing respectively. While the longest days to 50% maturity was observed in FL1. Conversely, the different stream sizes used as a treatment has remarkably induced the days to 50% silking and girth of the millet, but the earlier 41days to silking and 37 days girth was recorded in SS2, closely followed by SS3 with corresponded (43 and 38 days after sowing) while the lately days to silking and girth was observed in SS1, apparently the interactions between the furrow lengths and different stream sizes were not significant The result was similar to the finding of (Yusufari, 2013)

3.4: Effects of furrow lengths and stream sizes on millet yield and yield parameter

The experimented results of the yield and its attribute as affected by the furrow length and stream size used as treatments were illustrated in Table 4.8

Table 4: Effects of furrow lengths and stream size on yield attributes and yield of millet

Treatments	Panicle Length (cm)	Panicle Dry weight (kg)	NSPC	1000 Seed weight (g)	Yield t/h
Furrow length (m)					
FL1(10)	22.4^{c}	0.34^{c}	528^{c}	21.93^{c}	2967.4^{c}
FL2(20)	27.8^{a}	0.45^{b}	736^{a}	26.40^{a}	3956.3^{a}
FL3(30)	25.7^{b}	0.64^{a}	636^{b}	25.73^{b}	3697.2^{b}
Significance	Ns	*	*	*	*
SE±	0.12	0.34	0.07	0.14	0455
Stream sizes (L/s)					
SS1 (0 .5)	25.4^{c}	0.33^{c}	518^{c}	20.23^{c}	2882.2^{c}
SS2 (1.0)	29.8^{a}	0.59^{a}	596^{a}	29.10^{a}	4346.3^{a}
SS3 (1.5)	26.8^{b}	0.44^{b}	587^{b}	27.73^{b}	3812.2^{b}
Significance	Ns	*	*	*	*
SE±	0.03	0.16	0.161	0.021	0.144
Interaction					
FL x SS	*	*	*	*	*

Means within a column followed by similar letter(s) are not significantly different at 5% probability level

All the furrow lengths variation experimented had significantly ($P<0.05$) affected the panicle length of the millet as presented in (Table 4). The maximum cobs length of (27.8) was obtained from treatment FL3, it was closely followed by FL3 with panicle length of (25.8), while least cobs length of (21.833) was obtained with the FL1. Similarly furrow lengths (FL2) used as treatment had significantly affected the dry panicle weight, number of seed per plant, thousand

seed yield and yield with corresponding values (0.45kg, 736, 26.40 g and 39563 t/ha) respectively. It was closely followed by other furrow length. But the least yield in torn per hectare was recorded in the FL1. Also, the different stream sizes used had significantly affected the yield and yield attribute of the millet crop as presented in the (Table 4.8). The maximum panicle dry weight per (0.59kg), was recorded with SS2 treatment, it was closely followed by SS3 with panicle dry weight values of (0.44kg), while the minimum value (0.33kg) was counted with SS1. The grain weight per plant increased with the increasing of irrigation water discharge levels. Also the highest number of plant per seed of 596 and587 was remarkable observed in SS2 and SS3 while, SS1 still exhibit least. Likewise, highest yield in tone per hectare of (4346.3t/h and 3812.t/ha) were still recorded with SS2 and SS3 than all other treatment used and the least of 2882.8 t/ha was recorded from SS1. The finding was in line with those obtained from Hanson et al. (2007).

4.0 CONCLUSION AND RECOMMENDATIONS

4.1 CONCLUSION

The research was carried out to determine the effect of furrow irrigation variables on furrow performance parameter was conducted at the Agricultural Engineering Research and Teaching farm of Ramat Polytechnic Maiduguri during the dry season from 12 January to 12 April 2018. The result of the studies was analyzed using statistic 8.0 as follows.

I. Based on the findings of results, it can be suggested that furrow irrigation variable at 30m and 20m with different stream sizes of 1.5l/s and 1.0 could be a good variables strategy to improve crops productivity and the yield attribute of the millet in the study area.

II. The finding attested the adoption of furrow length and stream size between 20m-30 m could be a good variable strategy to improve furrow irrigation performance parameters in the study region.

4.2 Recommendations

(i) Since this experiment is season study in a single environment, further studies over seasons are required in order to develop reliable values.

(ii) Further research need to be carried out at different soil type, millet varieties and farm practice.

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Design Modification and Construction of Ice Block Making Machine

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Abstract: *Refrigeration is an artificial withdrawal of heat production in a substance within a spaced temperature lower than that which will exist under the natural influence of the surrounding. The invention of a refrigerator has allowed modern families to purchase, store, and freeze, prepare and preserve food products in in a fresh state for human consumption. This work aims to construct a refrigerator using locally available materials neglecting import cost. The refrigerant (R-12) dichloroflouromethane or Freon 21 is a halomethane or hydrochlorofluorocarbon with the formula $CHCl_2F$. It is a colorless and odorless gas. It is produced by fluorination of chloroform using a catalyst such as antimony trifluoride: $CHCl_3 + HF \rightarrow CHCl_2F + HCl$ .It shall be used for charging the system. For the reason of instability of power in the country, a stabilizer is recommended to keep the efficiency of the system. The (C.O.P) coefficient of performance of the refrigerating system is to be maximized. The refrigerating system would be affordable with low cost depending on the construction; the cost analysis incurred during the course of the construction of this refrigerator will be minimized. The purpose is to serve both for domestic and commercial activities such as small water cooling cold storage of food products as well as to display cabinets such as candy dry, meats etc.*

Keywords: *R-12(dichloroflouromethane), COP (coefficient of performance)*

1. INTRODUCTION:

It is a known fact that the demand for preservation of food and perhaps perishable product are of the paramount importance to all household regardless of the part of the country they belong to, most of our food stuffs need to be stored below atmospheric temperature after harvesting. Similarly our diary and some of our pharmaceutical product required low temperature storage. To achieve all these goals, refrigeration are required (Ashrae Standard, 2013).

Refrigeration is now part of our way of life. It would be comfortable for it to be in any other way. It has even become an essential ingredient in improving the quality of life, the cooling chain enable storage, transport and use of food items in ideal hygienic condition reducing loss and water (Ashrae standard, 2009).

The definition of refrigeration is the removal and relocation of heat forms an enclosed space or form a substance and moving it to a place where it is unobjectionable. The primary purpose of refrigeration is covering the temperature of the enclosed space or form a substance and then maintaining that lower temperature (Ashrae, 2006)

The invention of the refrigeration has allowed the modern families to purchase, store, and freeze, prepare and preserve food products in a fresh state for much longer period of time than it was previously possible. Diary product, meat fish, poultry and vegetable can be kept refrigerated in the same space within the kitchen (Although raw meat should be kept separate from other food stuff for reasons of hygiene). The refrigerator allows families to consume more fresh fruits and vegetable during meals without having to own a garden or an orchard. Exotic food stuff from far off countries that have been imported by means of refrigeration can be enjoyed in the home because of the availability of domestic refrigeration.

In commerce and manufacturing, there are many uses of refrigerator. Refrigeration is used to liquefy gases like oxygen, Nitrogen, propane and methane. In compressed air purification, it is used to condense water vapor from compressed air to reduce its moisture content, in oil refineries chemical plants and petro-chemical plants; refrigeration is used to reduce certain processes at their required low temperature. Metal workers use refrigeration to temper steel and artery. In transporting temperature, sensitive food stuff and other materials by trucks, trains, air planes and sea going vessels refrigeration is a necessity (Aprea, 2003)

Although refrigerators are prevalent and are accepted as an important electronics gadget needed either domestically, commercially, industrially or otherwise, yet not all who want to afford one are able to. This could be as a result of its cost in a country where most of its population is below the standard of living they rarely think of owing a refrigerator which is as a result of cost or not giving them value for their money. Some refrigerators come to operate at lesser working capacity than expected by their users. Their cooling and freezing rate takes longer periods than expected.

Another problem is the choice of refrigerant or chlorofluorocarbons (CFCS) used as refrigerants in some commercial air conditioning and refrigeration system (Chlorofluoro Carbons are considered to be 100% ozone depleting meaning that they are the standard for efficiency in catalytic breakdown of ozone. In refrigeration system it is R-22 or Freon 21s which is hydrochlorocarbon or HCFCS. Hydrochlorofluorocarbon are considered to be 5% ozone depleting and are less of a danger to earth's vital ozone layer. However, non-ozone layer depleting refrigerants are the most desirable (Andrew, 2003)

2. LITERATURE REVIEW.

The use of ice to refrigerate and preserved food goes back to prehistoric times. Through their ages, the seasonal harvesting of snow and ice was a regular practice of most of the ancient culture, Chinese, Hebrew, Greek, Roman and Parisians stored in caves or dug out line with straw or other insulating materials the Parisians stored ice called Yakchals. Rationing of the ice allowed the preservation of foods. Over the warm periods. This practice worked well down through the century with ice house remaining in the use in to the twentieth century (Ashrae, 2006).

William Cullen demonstrates the first known method of artificial refrigeration at the University of Glasgow in Scotland in 1756. Cullen used a pump to create a partial vacuum over a container or diethyl leather, which when boiled, absorbs heat from the surrounding air, the experiment even created a small amount but had no practical application at that time (Dossat, 1978). In 1920, the British scientist Michael Faraday obtained the first patient for a vapor compression refrigeration system. In 1834, Jacob Perkins built a prototype system and it actually worked

although it did not succeed commercially. (Dossat, 1978). An American physician John Go designed the first system for refrigeration water to produce ice. He also conceived the idea of using his refrigeration system to cool air for comfort in homes and hospitals (i.e. air conditioning). His system compressed air then partially cooled the hot compressed air with water before allowing it to expand while doing part of the work required driving the air compressor. That isentropic expansion cooled the air to a temperature low enough to freeze water and produce ice, or to flow "through a pipe for effecting refrigeration otherwise" as a state his patent granted by the US patent in 1951 (Anderson, 1972).

James Harrison from Scotland began operation of a mechanical ice making machine in 1851 on the banks of the Barwon River at rocky point in Geelong, Victoria. His first commercial making machine followed in 1854 and his patent for an either liquid vapor compression system was granted in 1855. Harrison introduced commercial vapor compression refrigeration to breweries and meat packing houses and by 1861 a dozen of his system was in operation.

Types of refrigeration

For convenience of study, refrigeration application may be group into the following

Domestic refrigeration: Domestic refrigeration is concerned with household refrigerators and home freezers. However, because the number of unit in service is quite large, domestic refrigeration represents a significant portion of the refrigeration industry. The domestic units are usually small size, having is hermetically sealed type. (Andrew 2003).

Commercial Refrigeration

This is concerned with designed installation and maintenance of refrigerated fixtures of the types used by retail stores, restaurant, hotels and institution for storing, displaying, processing and dispensing of perishable commodities of all types. (Andrew, 2003).

Industrial Refrigeration: Industrial refrigeration is often confused with commercial refrigeration because the division between these two areas is not clearly defined. As a general rule, industrial applications are larger than the commercial application and also with an attendant on duty, usually a licensed operating engineer. (Andrew, 2003). Typically application of industrial refrigeration includes ice plants, large packing plants (meat, fish, and frozen foods) breweries and industrial plan etc. Industrial refrigeration includes also those application concerned with the construction industries (Andrew, 2003).

Marine and transport refrigeration: Application falling into this category could be listed partly under industrial refrigeration. However, both these areas of specialization have grown to scientific size to warrant special mention. Marine refrigeration refers to refrigeration about marine vessels and in boats and for vessel transporting perishable goods as well as refrigeration for shops stores on vessels of all kinds.

Transportation refrigeration is concerned with refrigeration equipment as it applied is concerned with refrigeration equipment as it applied to trucks, both long distance transport and local delivery and to refrigerated railway cars (Andrew, 2003).

Method of refrigeration

Method of refrigeration can be classified as non-cyclic and thermoelectric

Thermoelectric refrigeration: Thermoelectric cooling uses the patter effect of create a heat flux between the junctions of different types of materials. This effect is commonly in camping and portable coolers and for cooling electronics components and small instrument (Dossat, 1978).

Magnetic refrigeration: Magnetic refrigeration or a diabetic demagnetization is a cooling technology based on the magneto caloric effect, an intrinsic property of magnetic solids. The refrigerant is often a paramagnetic salt, such as cerium, magnesium, and nitrate. The active magnetic dipoles in this case are those of the electron shells of the paramagnetic atoms (Dossat, 1978).

Heat naturally flow form hot to cold; work is applied to cool a living space or storage volume by pumping heat from a lower temperature heat source into a higher temperature heat sink. Insulation is used to reduce the work and energy required to achieve and maintain a lower temperature in the cooled space. The operating principle of the refrigeration cycle was described mathematically by Carnot in 1824 as a heat engine. (Anderson 1972). The most common types of refrigeration systems use the reverse ranking vapor-compression refrigeration cycle although absorption heat pumps are used in minority of application. Cyclic refrigeration can be classified as

- Vapor cycle and gas cycle
- Vapor cycle refrigeration can further be classified as vapor compression refrigeration
- Vapor absorption refrigeration.

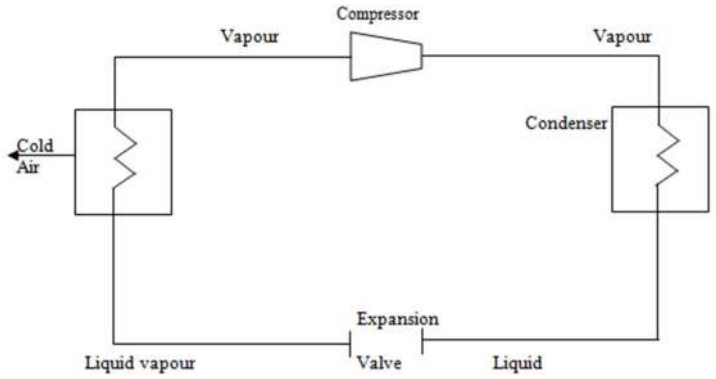

Figure 1 Vapour compression refrigeration

Typical Single Stage

Vapour compression refrigeration figure 1

1 to 2 = compressor of vapor

2 to 3 = vapor super heat removal in condenser

3 to 4 = vapor converted to liquid in condenser

4 to 5 = liquid flashes into liquid + vapor across expansion valve

5 to 1 = liquid vapor converted to all vapor

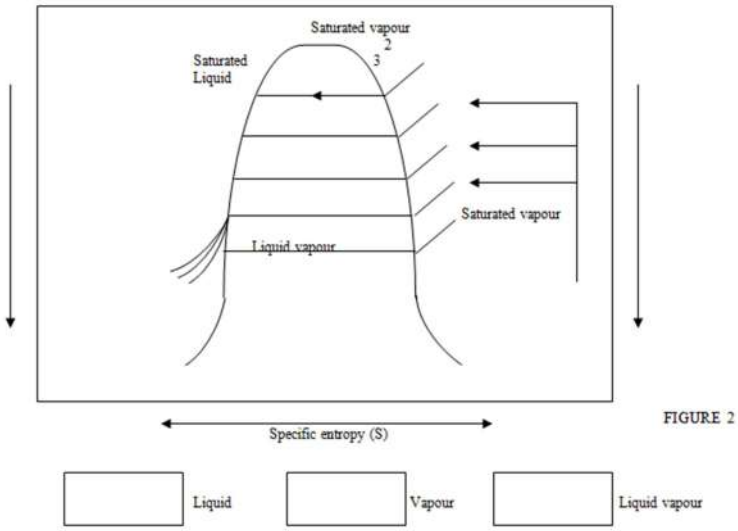

FIGURE 2

Other method of refrigeration include the air cycle machine used in aircraft, the vortex tube used for spot cooling when compressed air is available and thermo-acoustic refrigeration using sound waves in a pressure gas to drive heat transfer and heat exchange

Component of Refrigerator

Refrigerating machine comprise of several components explain below

- Compressor
- Condenser
- Evaporator
- Accumulator
- Capillary tube
- Thermostat
- Refrigerants.

Environmental alternative refrigerant for HCFC-22

The present invention discloses ternary mixtures of fluorine (HFL-101) pentaflouro ethane. Pentaflouro ethane (HFC-125) and difluoromethane. (HFC-32) used as environmentally friendly alternative refrigerants to HCF-22. The mass rations of ODP are zero with no depleting potential

to ozone layer. Its GWP is smaller and close to those of HFC-22. With few changes to system components, it can be used as a potential substitute refrigerant for HCFC-22.

2.1 Review of Related Past works

R.Z.Wang. (2001) work on the adsorption and discovered that various adsorption refrigeration cycles have been investigated, such as continuous heat recovery cycle, cascade multi effect cycle, hybrid heating and cooling cycle. Reasonable experiment shows that with a heat source temperature of 100^0c, the refrigeration can obtain specific refrigeration power for 5.2kg-ice/day per Kg.

Mohammed et al. (2008) corroborated that a lubricating agent is necessary in almost all the refrigeration vapor for compression systems, particularly for correct operation of the compressor. His findings are at the origin of deviation from the theoretical behavior (i.e. based on pure refrigerant) of the components.

3. RESULTS AND DISCUSSION

Design Analysis and Construction

In the designing the refrigerating system, there are major factors upon which the heat transfer capacity of an evaporator and condenser depends on, yet the following are important from the subject point of view and have been taken into consideration.

Materials

In order to have rapid heat transfer in evaporation, the material used for construction should be of good conduction. Since metals are best conductors of heat, therefore they are always used. Here galvanized sheets of metals were used. Also, material which is not being sealed affected by refrigerator must also be sealed.

Temperature Difference: The temperature difference between the refrigerant within the evaporator and product to be cooled plays an important role in the heat transfer capacity of an evaporator.

Thickness of the Material: The thickness of the material affects the heat transfer capacity of evaporator and medium that flow through it. The thickness, the evaporator wall, and the slower the rate of heat transfer.

Contact Surface Area: The amount of contact surface area, in turn, depends basically on the physical size and shape of the evaporator coil.

Cabinet Size for Total Surface Area

L = 465mm
= 0.465mm
Width , W = 417mm = 0.417m
Height, H = 735mm = 0.735m
Area of upper and lower floor
L x W x 2 = 0.465 x 0.417 x 2 = 0.3878m2
Area of both sides
W x H x 2 = 0.417 x 0.735 x 2 = 0.6130m2
Area of front and back
L x H x 2 = 0.465 x 0.735 x 2 = 0.683m2
Total surface area, TSA = 0.387 + 0.6130 + 0.6836 = 1.6844m2

Heat Transfer Capacity Q, of an Evaporator through Composite Way in the System
Heat transfer takes place from the vapor refrigerant to the outside through condensing film. The value of this transfer of heat is giving by:

$$Q = hA(T1 - T2) \quad \text{OR}$$

$$T1 - T2 = Q/hA \qquad (1)$$

Where:
T1 = Temperature of refrigerant vapor condensing film in K.
h = Coefficient of heat transfer in W/m 2K
A = Surface area in m.
Heat transfer taken place from the outside surface to the inside surface of the system. The value of this heat transfer is giving by:

$$Q = \frac{K1A(T2 - T3)}{X1}$$

Or;

$$T2 - T3 = \frac{Q(X1)}{K1A} \qquad (2)$$

Where;
A = Area of surface in m2
K = Thermal conductivity of the material in wink
X = Thickness of galvanized and outside temperature respectively
Heat transfer from boundary layer to the liquid in the condenser is;

$$Q = K \qquad (3)$$

Adding equation (1), (2) and (3)

$$T1 - T4 = Q\left(\frac{1}{hA} + \frac{X1}{K1} + \frac{X2}{K2}\right) \quad \text{OR}$$

$$Q = \frac{T1 - T4}{\frac{1}{Ha} + \frac{X1}{K1} + \frac{X2}{K2}}$$

Temperature Readings
Assuming the temperature of the evaporator to be -15^0C and 26^0C at 200m temperature for the thickness and conductivity of the cabinet material.
Galvanized sheet
Thickness X1 = 7 x 10-4m
Conductivity K = 400W/mK
Insulator foam
Thickness X2 = 40 x 10-3m
Conductivity K2 = 0.04W/mK
Refrigerant Vapor R
Coefficient of heat transfer R

$$Q = \frac{A(T1 - T4)}{\frac{1}{Ha} + \frac{X1}{K1} + \frac{X2}{K2}}$$

$$Q = \frac{1.6(299 - 258)}{\frac{1}{1000} + \frac{7 \times 10\text{-}4}{4000} + \frac{40 \times 10\text{-}3}{0.04}}$$

Q = 77W.

Calculation of coefficient of performance of the system.

Assuming the temperature line of the refrigerating system to be 25^0C and -10^0C for calculating the coefficient of performance (C.O.P)

T1 = -10^0C = 263K

T0 = 25^0C = 298K

$S1 = SF1 + X1\ hfg1$
$T1$

$= 0.1080 + X1\ \frac{(156.32)}{263}$

$= 0.1080 + 0.5944\ X1$ (1)

$S2 = Sf2 + \frac{hfg2}{T}$

$= 0.2239 + \frac{138.03}{298}$

$= 0.2239 + 0.4632$

$= 0.6871$ (2)

Equation (1) and (2)

$0.1080 + 0.5944\ X1 = 0.6871$

$0.5944\ X1 = 0.6871 - 0.1080$

$0.5944\ X1 = 0.5791$

$X1 = \frac{0.5791}{0.5944}$

$X1 = 0.974$

$h1 = hf1 + X1\ hfg1$

$h1 = 26.87 + 0.974\ (156.32)$

$h1 = 179.13Kg$

$h2 = hf2 + hfg2$

$h2 = 59.70 + 138.03$

$h2 = 197.73kg/kgk$

$C.O.P = \frac{Qe}{W}$

$= \frac{\text{Heat absorbed}}{\text{Work done}}$

$= \frac{h1 - hf2}{h2 - hf1}$

$C.O.P = \frac{178.50 - 59.70}{197.73 - 178.50}$

$= \frac{118.8}{19.23}$

$C.O.P = 6.2$

For actual coefficient performance of the refrigerating system

Let T1 = lower temperature

T2 = higher temperature

$C.O.Pref = \frac{T1}{T2 - T1}$

$$= \frac{263}{9298 - 263} = \frac{263}{35} = 7.5$$

C.O.P (actual) = 7.5

$$\text{Relative C.O.P} = \frac{\text{Actual C.O.P}}{\text{Theoretical C.O.P}} = \frac{7.5}{6.2} = 1.2091$$

From the above calculation:

Let X = Dryness fraction
S1 = Entropy at point 1
S2 = Entropy at point 2
hf3 = Enthalpy of refrigerant
h1 = Enthalpy at point 1
h2 = Enthalpy at point 2
hfg2 = Latent heat of refrigerant at condenser
hfg1 = Latent heat of refrigerant at condenser
Sf2 = Liquid entropy leaving the condenser
Sf1 = Liquid entropy entering the evaporator

Name of parts needed for the construction

1. Galvanized sheet (for exterior and interior cabinet)
2. Compressor
3. Evaporator
4. Condenser
5. Foam
6. Capillary tube
7. Door hinge
8. Rivets
9. Refrigerant and refrigerant oil
10. Expansion valve
11. Cabinet gasket

Electrical components

1. Flexible wire cable
2. Fused plug

Construction sequence

The conduction of this refrigerator consists of primarily of three (3) parts namely:

1. Construction of the body
2. Assembling and installing of the mechanical (compressor, condenser and evaporator)
3. Electrical connection.

4 CONCLUSION

Our research design and construction of a refrigerator with visible bar ware compartment mostly to be used at homes, motels, shops and restaurants etc. has much to be desired

especially in the use of local sophisticated equipment and materials of high quality are used in the cases of foreign systems.
The purpose is to serve both for domestic and commercial activities such as small water cooling, cold storage of food products as well as to display cabinets such as candy, dry meats, frozen foods, drinks etc. The cost of foreign ones despite the fact that its materials used is gotten from local retailers. The needs for this protect necessary because it will save Nigeria foreign exchange and improve high foreign reserve of product, on commercial quantity. Although during performance analysis, it was discovered that the performance new refrigerator is bare better than this constructed ones, but this has open up and welcome any means for improvement, just because it retained much ice needed for efficient performance.

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Efficacy of Organic Inhibitor on Corrosion Inhibition of Mild Steel Using Rain Water as Media

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Abstract: *The deterioration of facilities by corrosion is a major problem in our society. Corrosion of metals/alloys, which can be defined as the deterioration or disintegration of materials due to their reaction with the environment, has continued to receive attention in the technological world. In this research, extracts from Leptadenia Hastata leaves was subjected to phytochemical analyses. The low carbon steel samples were subjected to corrosion inhibition test using gravimetric and thermodynamics methods. The corrosion inhibition effects of the leaves extracts on low carbon steel surface in Rain water solution was investigated at different temperatures (303, 313, 323 and 333 K). The results obtained shows that the inhibition efficiency (IE) increase (with at least 1.8%) with increase in the inhibitors concentration from (250 ppm- 1000 ppm) but decreases with increase in temperature from 303-333 K.*

Keywords: *Leptadenia Hastata*, corrosion, inhibitor, efficiency, *adsorption*

1.0 INTRODUCTION

1.1 Background

Corrosion phenomena, control and prevention are unavoidable major scientific issues that must be addressed daily as far as there are increasing needs of metallic materials in all facets of technological development (Loto et al, 2011). Corrosion is the deterioration of materials by chemical interaction with their environment. The consequences of corrosion are many and varied and the effects of these on the safe, reliable and efficient operation of equipment or structures are often more serious than simple loss of a mass of a metal. Failure of various kinds and the need for expensive replacements may occur even though the amount of metal destroyed is quite small. (Umoren, 2009). It has been reported after corrosion cost studies carried out in a number of countries including the United Kingdom, Sweden, Germany, and Finland that the annual cost of corrosion ranged as high as 5% of GDP (Corrosion Control Solutions, 2013). This represents a huge sum of money which should have been channeled into the provision of basic social amenities in these countries. In practice corrosion can never be stopped but can be hindered to a reasonable level. Due to problems from corrosion that are confronting industries; several methods of corrosion control and prevention have been put in place. These include: cathodic protection, lubrication, anodic protection, alloying, coating, inhibition etc. The choice and

application of any of the methods is based on their efficiency, economic factors and the nature of the corrosive environment. (Njoku, 1998).

The use of inhibitors is one of the most practical methods for protection against corrosion in corrosive environments. Inhibitors are chemicals that directly or indirectly coat a film on a metal surface to protect it from its environment. Most inhibitors are adsorbed by the metal surface from a solution or dispersed, but some are applied directly as coatings. Generally, the dissolution of metal can be suppressed by the action of adsorptive inhibitors which may prevent the adsorption of the aggressive ions, and by the formation of a more resistant film on the metallic surface (El Maghraby, 2010). Corrosion inhibition is of great practical importance, being extensively employed in curtailing wastage of engineering materials and minimizing corrosion control costs. Inhibitor applications is quite varied often playing an important role in oil extraction and processing industries, heavy industrial manufacturing, water treatment facility, water-containing hydraulic fluids, water treatment chemicals, engine coolants, ferrous metal cleaners, automatic transmission fluids, automotive component manufacture, cutting fluids etc. to minimize localized corrosions and unexpected sudden failures. (Loto, et al. 2012) Historically, most of the known corrosion inhibitors are synthetic chemicals (Heavy Metal), expensive and very hazardous to environment. Therefore, it is desirable to source for environmentally safe inhibitors (Paul, et al. 2012).

In very recent time, however, there has been the need to look at some other environment friendly substances, especially from natural resources that could be used to control/prevent incessant corrosion problems apart from the synthesized inorganic and other organic chemicals, some of which are toxic to the environment. Many scientific researchers have responded to this need and it has generated increased research studies into the use of plant extracts (Loto, et al. 2011). The use of natural products otherwise tagged-green corrosion inhibitors has been advocated because of the cost, toxic nature and environmentally unfriendliness of some of the inorganic and organic corrosion inhibitors. More so, they are readily available, cheap and a renewable source of materials. Very encouraging results have been obtained in this regard. An attempt at making a contribution to this growing research area has necessitated the Present investigation. Plant parts that have been used include leaves, bark, fruit and the roots. In very many cases, the corrosion inhibitive effect of some of the plants‘extracts has been attributed to the presence of tannin in their chemical constituents. Also associated with the presence of tannin in the extracts is the bitter taste in the bark and/ or leaves of the plants (Loto, et al. 2011). In this work, corrosion inhibition of guava, Leptadenia Hastata leave extract in Rain water solution on low carbon steel was investigated. The leaves of these plant, was chosen on ecological basis (also referred to as green corrosion inhibitor which are environmentally friendly), presence of tannin (have an array of hydroxyl and carboxyl groups through which the molecules can adsorb on corroding metallic surfaces), in their chemical constituents and their abundance. The choice of low carbon steel as the test specimen was due to its wide usage and good mechanical properties which include: ductility, malleability, formability, high tensile strength, impact strength, weldability etc. It is also comparatively cheap and available in abundance. These properties make low carbon steels to be used in many engineering applications and their subjection to acidic environments is also common feature during processing and in some areas of application. Thus it becomes imperative to investigate the corrosion behavior of low carbon steels in acid solution as well as their response to inhibition in such media (Njoku, 1998).

2.0 Materials and methods

2.1 Materials

The materials used for this research include:

Low carbon steel, *Leptadenia Hastata (Yadiya) leaves.*Masking tapes, cotton wool, burette, dropper, hand gloves, thread, plastic container and abrasive papers was used.

2.2 Chemicals, Solvents and Reagents

Rain water was used for preparation of media needed for the corrosion process. Distilled Water, Ethanol and Acetone were the solvents used for extract preparation and Ferric chloride, 1 M NaOH, silica gel, Molish, Mayers and Fehling's reagents were used for phytochemical screening obtained from Emmicon scientific supplies chemical store, Adjacent Mara-Zain Hotel Bama road Maiduguri.

2.3 The equipment used for this research include the following

Bench vice, hack saw, metal scraper: used to cut and prepare the steel bar into required dimension (coupons). Xenemetrix XRF Machine (Model: Genius IF) for determining the elemental composition of the steel bar. Analytical mass balance (Newacalox: Mode 8068, 100×0.001g): for measuring the mass of samples. Desiccator: used for drying and keeping the prepared samples air tight. Soxhlet extractor: for preparation of extracts. Separating funnel and filter paper: for filtration of mixture of ethanol and leave or from their chaff. Conical flask, water bath (Gulfex Medical and Scientific: HH-420).

2.4 Sample Collection

Fresh leaf of *Leptadenia Hastata* will be collected from Ramat Polytechnic school farm, and was taken for identification by a Plant Taxonomist, in the Department of Biological Science Faculty of Science, University of Maiduguri.

2.5 Sample Preparation

The plant leaf material was air-dried in the laboratory at room temperature. The leaf of the plant was ground to fine powder using wooden mortar and pestle and the sample was stored in the research laboratory of Science Laboratory Technology Department of Ramat Polytechnic Maiduguri Borno state for further analysis.

2.6 Preparation and Elemental Content Analysis

2.6.1 Sample Extraction

The ground leaf material (2,000g) was extracted with 85% ethanol using Soxhlet technique. The crude extract was concentrated under reduced temperature. The crude extract was then stored in a desiccator. The chaff was socked in distilled water for three hours and the mixture was filtered, concentrated and stored under pressure and reduced temperature.

2.7 Phytochemical Screening of *leptadenia Hastata*

Phytochemical screening carried out on the ethanol crude extract of the plant *Leptadenia Hastata* according to standard methods is as follows:

2.7.1 Test for Tannins

To extract (0.5g) 10ml of distilled water was added and stirred and the mixture was filtered. The filtered was used for the following test. To 2 ml of the filtrate, drops of 1% ferric chloride solution were added. The occurrence of a blue-black, indicate the presence of tannins. A mixture of equal volume of 10% lead ethanoate was added to 2 ml of the filtrate. The formation of white precipitate indicates the presence of tannins. The filtrate of the extract was boiled with drops of 10% HCl, and a drop of methanol. A red precipitate was taken as indication for the presence of tannins (Sofowora, 1993; Trease and Evans, 2002).

2.7.2 Test for Phloba tannins

The (0.5g) of the extract was boiled with 5ml of distilled water and then filtered. The filtrate was further boiled with 1% aqueous HCl. The appearance of red precipitate indicates the presence of phloba tannins (Trease and Evans, 2002).

2.7.3 Test for glycosides

Lieberman Burchard's test

To the extract (0.5g), 2ml of acetic anhydride was added. The mixture was cooled in ice and then 3ml of concentrated tetraoxosulphate (VI) acid was added carefully. Color development from violet to bluish-green indicates the presence of a steroidal ring. (Silver *et al*., 1998).

Salkowski's Test (test for steroidal nucleus)

To the extract (0.5g), 2ml of chloroform was added. Then, 3ml of tetraoxosulphate (VI) acid was carefully added by the side of the test tube to form a lower layer. Appearance of a reddish-brown colour at the interphase indicates the presence of steroidal ring. (Silver, 1998)

2.7.4 Test for Flavonoids

Ferric Chloride Test

The extract (0.5g) was boiled with 5ml of distilled water and then filtered. To a 2 ml of the filtrate, few drops of 10% ferric chloride solution was added. A green-blue coloration indicates the presence of phenolic hydroxyl group (Trease and Evans, 2002).

2.7.5 Test for Saponins Glycosides

The extract (0.5g) was boiled with 5ml of distilled water and filtered. The filtrate was divided into 2 portions, to the first portion about 3ml of distilled water was added and shaken for about 5 minutes. Frothing which persist on warming is an evidence for the presence of saponins (Sofowora, 1993). To the second portion, 2.5ml of a mixture of equal volume of Fehling's solution A and B was added. The appearance of brick-red precipitate shows an indication for saponins glycosides (Vishnoi, 1979).

2.7.6 Test for Alkaloids

Preliminary Test for Alkaloids

The extract (0.5 g) was stirred with 5 ml of 1% aqueous HCl on water bath then filtered. Three ml (3ml) of the filtrate was taken and divided equally into 3 portions in a test tube. To the first portion, few drops of Dragendoff's reagent was added. The occurrence of orange red precipitate was taken as the indication for the presence of alkaloids. To the second; 1 ml of Mayer's reagent was added and the appearance of buff-coloured precipitate was considered as an indication for the presence of alkaloids; to the third portion, 1 ml or a few drops of Wagner's reagent was added and a dark-brown precipitate indicates the presence of alkaloids (Brain and Tuner, 1975).

2.8 Corrosion Efficiency

Weight loss method and thermodynamic method was used for the evaluation of corrosion inhibition efficiency of the extracts.

2.9 Weight Loss Method

Cylindrical coupons of 10mm diameter and 10mm in length were used in this research as earlier stated. Four solutions of 250, 500, 750 and 1000 ppm of extract concentration was prepared for each extract of leaves of leptadenia hastata in each test media of Rain water respectively, by dissolving 0.025g: 0.05g, 0.075g and 0.1g of each extract in different beaker containing 100ml of Rain water. In addition, one beaker containing 100ml of Rain water was used as control. The

corrosion inhibition and immersion test was carried out in accordance with ASTM G3 1 -72. The coupons removed from the desiccator six each as a group, after individual weighing, was introduced into each beaker ranging from the control to the inhibited Rain water solutions as thread aided suspensions, at ambient temperature. An exposure period of 432hr (18 days) total was observed, at 72hr (3days) interval of measurement respectively. Unit specimen removed from each beaker at this interval was cleaned off corrosion products, dried and reweighed. The change in weight recorded, was used to calculate the rate of corrosion measured in millimeter per year (mmpy) as described by Yawas, (2005):

Corrosion rate (CR) = $\frac{87.6\ x\ W}{P\ x\ A\ x\ T}\ (mmpy)$ ... 3.4

Where:

W = the weight loss in mg, P = the metal density in g/cm^3.

A = the exposed area of the test coupon in cm^2.

T = the exposure time in hrs.

However, the inhibition performance was also calculated as follows (Ibrahim et al., 2011):

Inhibition Efficiency (IE) = $\frac{CR_0 - CR}{CR_0}$ x 100% ... 3.5

The surface degree of coverage (∅) at each inhibitor concentration, defined as the degree of surface of material coverage by the inhibitor was calculated as;

Degree of Surface Coverage (∅) = $\frac{CR_0 - CR}{CR_0}$ ….3.6

Where;

CR_0 = the corrosion rates without inhibitor

CR = the corrosion rates with inhibitor.

2.10 Thermodynamics Techniques

Again, weighed specimens from the desiccator was immersed in 100ml preparatory solution of 0 – 1000 ppm of Rain water, for a constant period of 3hour each, at varying temperature of; 313K, 323K, 333K. The weight loss measurement was carried out as in Weight loss techniques earlier discussed. The adsorption isotherm will be selected based on the adsorption isotherm that best describe mechanism of adsorption. Thermodynamic parameters such as; Change in Free Energy of the reaction in Kjmol^{-1} (ΔG_{ads}), Corrosion Rate (CR) and Activation Energy for corrosion reaction of low carbon steel in KJmol^{-1} (E_a), will be calculated using the Arrhenius equations as (kairi and Kassim, 2013):

log CR = log A - $\frac{E_a}{2.303RT}$ ... 3.7

$K_{ads} = \frac{\emptyset}{C(1-\emptyset)}$ ...3.8

Where:

A = the Arrhenius pre-exponential factor, a constant dependent on metal type and electrolyte,

T = Temperature in Kelvin, $\emptyset$ = the degree of surface coverage,

K_{ads} = Equilibrium constant, C = the concentration of inhibitor

R = the universal Gas Constant ($8.314 jmol^{-1}K^{-1}$)

The enthalpy (heat) (ΔH_{ads}) and entropy ΔG_{ads} of adsorption of the inhibitor will be calculated from rearranged Gibbs-Helmholtz equation as;

$$\frac{\Delta G_{ads}}{T} = \frac{\Delta H_{ad}}{T} + K_{ads} \quad 3.9$$

$$\Delta G_{ads} = \Delta H_{ads} - T\Delta S_{ads} \quad 3.10$$

Where;

ΔH_{ads}= Enthalpy of adsorption reaction

ΔS_{ads} = Entropy of adsorption reaction

Alternative, the enthalpy and entropy can be obtained from transition state equation as:

$$CR = \frac{RT}{Nh}\ exp\ \frac{\Delta S_{ads}}{R}\ exp\ \frac{-\Delta H_{ads}}{RT} \quad 3.11$$

Where;

N = Avogadro's number ($6.022 \times 10^{22} mol^{-1}$)

h = Plank's constant ($6.626 \times 10^{-34} m^2 Kgs^{-1}$)

3.0 RESULTS AND DICUSSION

3.1 PHYTOCHEMICAL ANALYSIS.

The results obtained from the phytochemical analysis are shown in table 1

Table1: Phytochemical Constituents of the Plant

Chemical Constituents	***Leptadenia Hastata* Leaves**
Alkaloids	+ + +
Saponins	+ +
Tannins	+ +
Flavonoids	+

Phlobatannins	+ +
Cardiac glycosides	+

-	Absent	++	Moderately Present
+	Present	+++	Highly Present

The phytochemical analysis of the leaves extract reveals the presence of alkaloid, saponins, tannins, flavonoids, Phlobatannins, and cardiac glycosides**.**From the results of the phytochemical analysis in table 1 tannins, phlobatannins and flavonoids are present in the plant leaves extract, generally the natural compounds found in all the plant leaves extracts will form a film on the surface of the mild steel, which will serve as a hurdle at the surface of the mild steel through the mechanism of adsorption, there by inhibiting the corrosion process of the mild steel coupon.The phytochemical component of plant leaves extract encompass rich naturally synthesized eco-friendly organic compounds which combat with corrosion on mild steel in an aggressive media. According to Iloamaeke *et al*. (2013), these compounds contain nitrogen and oxygen which are the center for chemical adsorption on the mild steel.Alkaloid present in plant extract have a fascinating features about inhibit corrosion, alkaloid prevent metal corrosion by adsorption of their molecules on metals surface to form a protective layer.Saponins has rich oxygen molecules that provides good adsorption sites via the lone pair of electrons residual on the oxygen atoms. Tannins aids in forming the inhibitor protective layers on the metal surface with an adsorption mechanism on the oxide films. Thus from the results and the role of each of phytochemical constituent's in prevention of corrosion as stated above, the leave of *Leptadenia Hastata* is expected to have high inhibitive properties, because *Leptadenia Hastata* extract has Alkaloid, Tannins, Flavonoids, Cardiacgycoside all present.

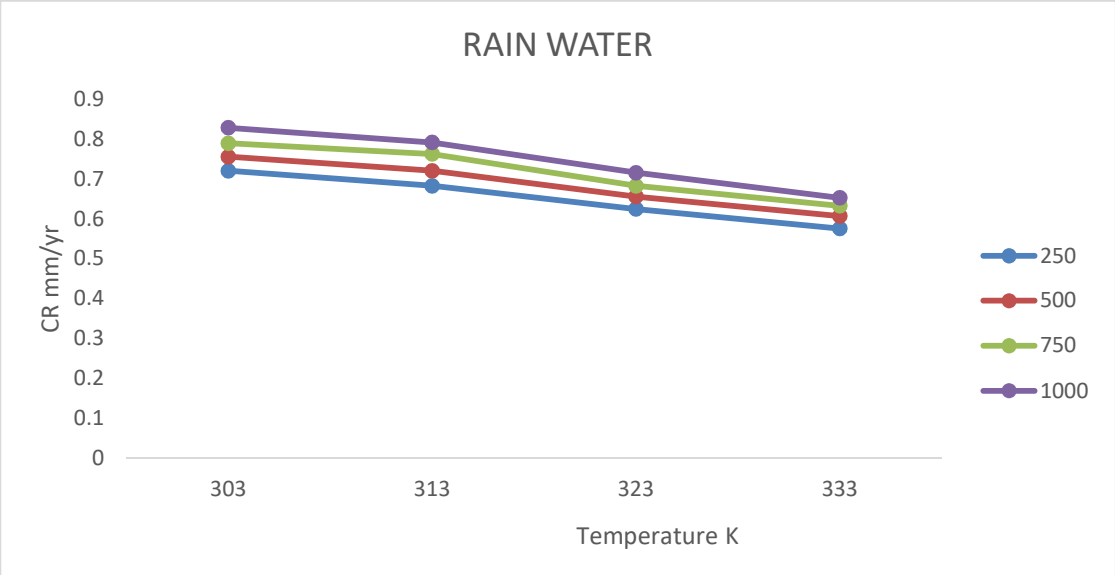

Figure: 1 Variation of Corrosion Rate against Temperatures at different concentration of leaves extracts

Corrosion rate

From the result obtained on the corrosion rate against temperature at different inhibitor concentrations plotted in Figure 1 it is clear that corrosion rate decreases as the temperature increases. As the concentration of inhibitors increased (with 250 % increment), the rate of corrosion decreased which indicates that protective layer is formed at the surface of the coupons which prevents serious damage. This is in agreement with previous work by Zubairu et al (2021).

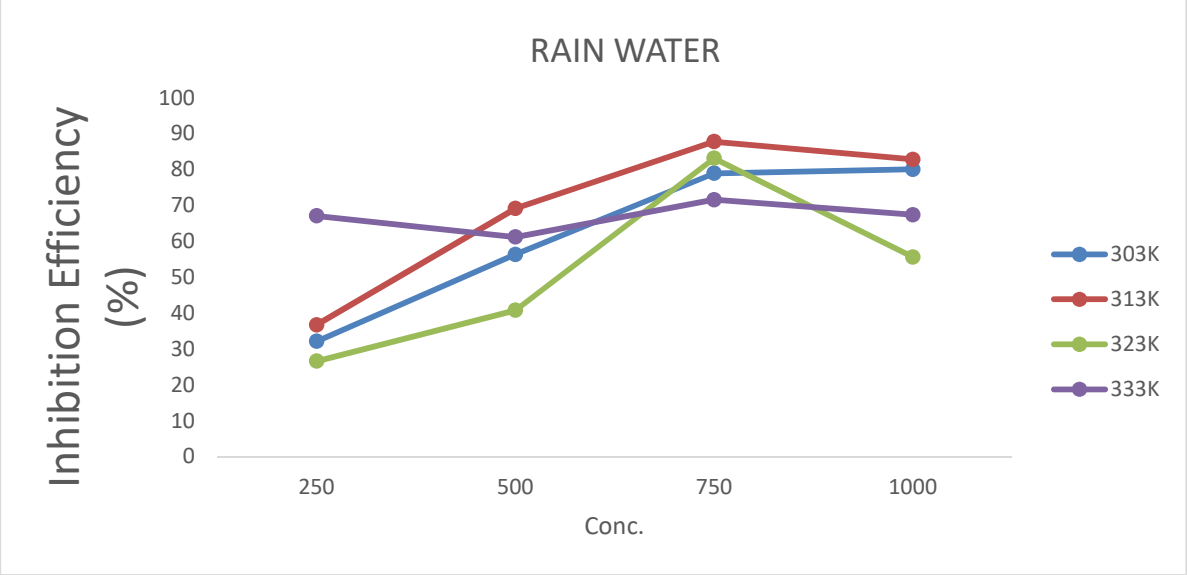

Figure 2: Variation of Inhibition efficiency against concentration of leaves extracts

Inhibition Efficiency

Figure 2 show the performance of *Leptadenia Hastata* on low carbon steel in Rain water at temperatures of 303,313,323 and333K. Highest inhibitor efficiency of 83.16% was obtained at 313K and 750 ppm concentration and lowest inhibitor efficiency of 26.62% was obtained at 323 K and 250 ppm respectively. The increased in efficiency with increase in inhibitor concentration, a trend that supports the mechanism of physical adsorption. Ergun *et al*., (2008) attributed the decreased in inhibition efficiency with rise in temperature to an enhanced effect of temperature on the dissolution process of steel in corrosion media and/or the partial desorption of the inhibitor from the metal surface. A similar trend was also reported in Umoren *et al*., (2008).

5.0 CONCULSION

From this research work natural (green) plant extracts (leaves) has shown a great alternative for inhibition of corrosion in metals. Though, some plants may have low inhibition properties despite they are abundant in the locality reason being that the low amount of the physiochemical constituent need to stop or slow process of the corrosion on the material when exposed to the atmosphere.

Hence a plant that is abundant and has little or no economic value (not eatable) and shows properties that can be useful in prevention of corrosion can also be used in the prevention of corrosion, which is less expensive, create job opportunities and most importantly environmentally friendly.

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Effect of Hot Water Treatment on Post-Harvest Disease and Quality of Sweet Potato

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Abstract: *Nigeria is the largest producer of sweet potato in Africa with annual output of 3.46 million metric tons globally the second largest producer of fruits and vegetables, the losses range from 10 to 30% of the entire production. This is due to numerous causes but the most important reason is infestation of fungi. Many synthetic fungicides are employed for postharvest treatment of tubers through the world. However, fungicide residues often represent a significant threat to human health. The current study was to use warm water treatment on sweet potato. Warm water at 50^0c was used for four treatments in three different dipping time of 0min (control) 10 minutes, 15 minutes and 20minutes. Data are collected based on quality assessment these include weight loss, tuber firmness, rind thickness and appearance. The experiment was single factor and will be laid in (CRD). The result on all parameter showed that 10min dipping time has the potential in prolonging the shelf life of tuber by reducing decay on it and has best ability to maintain the quality of sweet potato in comparison with the other treatment.*

Keywords: *Potato Tuber, Hot Water Treatment, Postharvest, Fungi*

Background of the Study

Sweet potato (*Ipomoe batatas L.*) is an important crop food security in many parts of the developing world. Sweet potato has a short growth cycle (four to five months): yields will in maginsl area, and is drought tolerant. In addition to these agronomic advantage sweet potato is good source of carbohydrate, fiber, vitamin and minerals (Endrias et al., 2016) Sweet potato also certain phytochemicals which are good for human health despite all these nutritional and agronomic benefit, sweet potato is highly perishable after harvesting (Rees *et al*., 2003). The major cause of product losses is weight loss, sprouting and rotting (Ravi *et al.,* 1996). Control of sweet potato postharvest losses has generally been reliant on the manipulate of storage temperature and relative humidity. With the aim of achieving an ideal storage temperature of 15 degree and relative humidity of 80% to 95% (Amral B., *et al.,* 2011) in some cases, sprouting and rotting is controlled by heat treatment.

Sweet potato is a major crop that surfer serious negligence in the past and now occupies a global position as a source of food and industrial raw materials (NjokeJ.E., 2007). Nigerian is the abundance producer of sweet potato in Africa with annual output of 3.46 million metric tons and globally the second largest producer after china. However, this is the only crop among the root

and tuber crops that has a position per capital annual rate of increase in production in sub-Saharan Africa (Olagunju FL *et al.,* 20013).

Sweet potato (ipomoea balatas) is an herbaceous warm wetted creeping plant that belong to the family of convolulacease and genius of Ipomoeas (Mbansa E.O 2010). The family is mad of 45 genera and 1000 species. It grows best at temperature of between 24° to 28° with annual rainfall of 1000mm to 7000mmC.

In Nigeria, more 85% of the sweet potato production is done by farmers who maintain small farms and carry out their operations manually with traditional farm tools such as hoe and machete (Okonkwo J.C *et al.,* 2009). According to (Ugonnaet *et al*., 2013), the main sweet potato growing areas in Nigeria is Jos plateau and this could be attributed to its attitudes which range which range from 1200m to 1400m and summer temperature that rarely exceed 35°c which makes the temperature climate sweet able for potato production. Sweet potato has been identified to be the fourth most important root crop in Nigeria after cassava, yam, and cocoyam (Okonko J.C, 2009),

Postharvest loses are quite often the limiting factor of sufficient production of this particular crop. This may be due to several factors such as improper handling during and after harvest, deficiency in curing and storage infrastructure, lack of proper packing and grading, and also inadequate knowledge in global market requirements and opportunities (Siddique, 2005).

Sweet potato (*Ipomoea batatas L*) is an herbaceous warm watered creeping plant that belong to the family of convolulaceae and genus of Ipomoea (Mbansa, 2010). Sweet potato (*Ipomoea batatas(L*.) *Lam*.), is an important crop food security in many parts of the developing world. Sweet potato has a short growth cycle (four to five months); yields will in marginal area, and is drought tolerant. In addition to these agronomic advantages, sweet potato is good source of carbohydrate, fiber, vitamins and minerals (Woolfe, 1992). Sweet potatoes also contain phytochemicals which are good for human health. Despite all these nutritional and agronomic benefits, sweet potato is highly perishable after harvesting (Reese *et al*., 2003). The major causes of product losses are weight loss, sprouting and rotting (Ravi *et al.,* 1996). Control of sweet potato postharvest losses has generally been reliant on the manipulation of storage temperature and relative humidity, with the aim of achieving an ideal storage temperature of 15 degrees and a relative humidity of 80% to 95% (Picha, 1985a). In some cases, sprouting and rotting is controlled by use of hot water treatment. (Woolfe, 1992, Afek *et al*., 1998). However, these control methods are difficult to achieve for subsistence farmers whose villages are not network. The present study investigated the effectiveness of different hot water treatments in preserving the important qualities of sweet potato in order to reduce the usage of synthetic chemicals. The results could be a reference point for relevant parties to take necessary actions in providing a favorable treatment for potato tuber storage and providing an affordable control of diseases.

Material and Method

Sample Collection

One bag of Freshly harvested sweet potato tuber were purchased from Gamboru Market Maiduguri and transported to Ramat Polytechnic postharvest laboratory early in the morning and are allowed to cool for 1hr, clean and stored according to sizes and quality before subjecting

them to the experimental set up. About 128 were washed to removed dirt sorted and dust free sweet potato tubers

Preparation of Sweet Potato for Experiment

The treatment was laid in completely randomize design (CRD). There were four different treatment of hot water treatment that have been tested on sweet potato and each treatment was subject to 10 min, 15 min and 20 min immersion time, T2 (50^0C for 10 min), T3 (50^0C for 15 min), and T4 (50^0C for 20 min). Untreated (0 min control) sweet potato were immersed in sterile water at room temperature only (T1). All the treated sweet potatoes including 0min control were stored at normal room temperature (27^0C ± 2^0C) for 4 weeks. Three replicate had been set up for each treatment and each treatment has 2 number of sweet potato per replicate. The assessment of postharvest quality on treated sweet potato was conducted at every 1 week (7 days) interval for week.

Conduction of Experiment

32 tubers from each treatment were initially weighted and monitored at a 7 day (1 week) interval for 4 weeks. Weight loss percentage was calculated using this formula or equation

$$\text{Weight loss (\%)} \quad \frac{\text{Initially weight} - \text{final weight}}{\text{Initially weight}} \times 100$$

While the Appearance were evaluated using quality rating scale: visual quality rating:- 1 = excellent, fresh appearance; 2 = very good slightly defects; 3 = good limit of salability, defect; 5 = poor). (1 = no decay, 2 = 1-10% decay/slight; 3 = 11-25% decay/moderate; 4 = 26 – 50% decay/moderately 5 = more than 50% decay (Anna M et al., 2019).

RESULT AND DISCUSSION

Tuber Weight Loss

The result for hot water treatment at 4 weeks showed a significant difference among the treatments (Table 1). The control had 35% weight loss, which was significantly higher compared to other treatments. However, there was no significant difference between 20-minute 15-minute dipping time, which had 25% and 23% of weight loss respectively. Followed by 10-minute dipping time which had the lowest weight loss of 15%. The reduction of weight loss in the treatments compared to the control was attributed to the hot water treatment melting the wax and closing cracks while reducing weight loss, delaying ripening and slowing the degradation rate of peroxidase (Lurie et al., 1997).

Tuber Firmness

The observations (Table 1) on firmness display a significantly higher firmness on the fruits treated for 10-minute with a firmness value of 45.5 N, while the control had a significantly lower firmness value of 20.2 N. However, there was no significant firmness difference between the 15- and 20-minute treated fruits with the values of 30.3 N and 29.1 N, respectively. The results suggest that hot water treatment offers benefits in controlling fruit firmness, but prolonging the

period can cause adverse effects on fruit firmness. However, the results were much better than those in the control group were.

Rind thickness

Water loss from sweet potato tubers during storage results in shrinkage and fruit softening. The results (Table 1) for the rind thickness of sweet potato tuber showed a significantly lower rind size for the control compared to other treatments, with a size of 0.99 mm, but there was no significant difference at $P \leq 0.5$ between 15- and 20-min dipping times, with the rind thicknesses of 1.5 mm and 1,6 mm, respectively. Meanwhile, the 10-minute treatment had a highest rind size of 2.1.

Appearance

The observation on appearance of the fruit is presented in Table 1. Appearances showed significant differences at $P \leq 0.5$ between control and other treatment having 1.0 according to the scale of Anna et al., (2019). However, 0-min and 20-min dipping time had a significantly higher scale value of 4.0 respectively, followed by 15-min dipping time having a scale of 3.0. However, there was a significant difference between the 10-min and other treatments respectively.

Table 1. The main effect of hot water treatment on sweet potato tuber during storage.

Treatment	Weight loss (%)	Firmness (N)	Rind thickness (mm)	Appearance (1-5)
Control	35c	20.2c	0.99c	4c
10MIN	15a	45.5a	2.1a	2a
15MIN	23b	30.3b	1.5b	3b
20MIN	25b	29.1b	1.6b	4c

Means with the same alphabet are not significantly different at LSD ($P \leq 0.5$).
Note. Appearance scale of 1 = excellent, fresh appearance; 2 = very good slightly defects; 3 = good limit of salability, defect; 5 = poor). (1 = no decay, 2 = 1-10% decay/slight; 3 = 11-25% decay/moderate; 4 = 26 – 50% decay/moderately 5 = more than 50% decay

Conclusion

In the present study, sweet potato treated with (10 min) dipping time was able to maintain the weight loss firmness, rind thickness and appearance. It showed that hot water treatment of 10 min dipping time at temperature range of 50^0c has the potential in prolonging the shelf life of sweet potato by reducing decay and has the best ability to maintaining the quality of sweet potato tuber in comparison with the control and other treatments.

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Performance Evaluation and Analysis of an Automatic Disinfectant Passage System Parameters

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Abstract: *Coronavirus disease 2019 (COVID-19) is an infectious illness caused by the severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) that spreads by inhalation of tiny droplets from an infected individual. An automated disinfectant transit system with continual biosecurity programmes was presented to manage and eliminate the danger of introducing viruses and germs. The proposed disinfectant system a stainless-steel double frame and a 100-litre chemical tank. The system was evaluated based on infrared temperature and disinfectant flow. The system was able to monitor the sections where the data was correctly captured and gathered based on these two factors, and it did so in real time. Therefore, the findings demonstrated that the system was capable of accurately recording the temperature and producing disinfectant for the individual who was afflicted. A system that might be utilised to monitor COVID outbreaks or any other associated disease outbreaks effectively and efficiently is thus proposed.*

Keywords: *COVID-19, Automated Disinfectant, and Passage System*

Introduction

Disinfection is the process of inactivating or destroying bacteria on inert surfaces using a chemical agent [1]. Disinfection may not always result in the eradication of all germs, particularly resistant bacterial spores. It is less effective than sterilisation, a harsh physical or chemical procedure that eliminates all forms of life. The world is battling with a global pandemic called coronavirus disease 2019, nicknamed COVID-19[2]. About 188 countries are engulfed by this pandemic, which spreads largely when people are in close contact and one person inhales small droplets produced by an infected person. (symptomatic or not), coughing, sneezing, talking, or singing [3]. The World Health Organisation recommends 1 metre (3 ft) of social distance; the U.S. CDC recommends 2 metres (6 ft)[4]. People can transmit the virus without showing symptoms, but it is unclear how often this happens. One estimate of the number of those infected who are asymptomatic is 40%. People are most infectious when they show symptoms (even mild or non-specific symptoms), but they may be infectious for up to two days before symptoms appear (pre-symptomatic transmission) [5]. They remain infectious for an estimated seven to twelve days in moderate cases and an average of two weeks in severe cases[6]. When the contaminated droplets fall to the floors or surfaces, they can, though less commonly, remain infectious if people touch contaminated surfaces and then their eyes, nose, or mouth with unwashed hands[7]. On surfaces, the amount of active virus decreases over time until it can no longer cause infection, and surfaces are thought not to be the main way the virus spreads [8.9]. It is unknown what amount of virus on surfaces is required to cause infection via this method, but it can be detected for up to four hours on copper, up to one day on cardboard, and up to three days

on plastic (polypropylene) and stainless steel (AISI 304) [10]. Surfaces are easily decontaminated with household disinfectants, which kill the viruses outside the human body or on the hands. Since the virus can be transmitted mostly by people and materials moving from one place to another, there is a need to disinfect those people from entering and leaving common areas [11-13]. Hence the need for an automatic disinfectant passage system [14-17]. Similarly, when using the passage system, one cannot be sure whether it is totally disinfected [18]. Hence the need to evaluate the performance of the passage system and its effect on the disinfectant.

Methods

The automatic disinfectant system can be described as a two-stage system. The disinfectant unit and the drying unit the disinfectant unit consists of the whole body disinfectant, shoe bottom disinfectant, hand sanitizer, chemical tank, and waste management tank. The design proposed was described. It was designed with a width of 1.1m, a length of 2.35m, and a height of 2.20m. The materials used are made of stainless steel (304 Quality Cr-Ni) and aluminium components. It does not contain bacteria. It can be used indoors and outdoors. An automatic pulverisation (fogging) system is available. It is one of the most effective methods for whole-body disinfection. It is economical since water-based disinfectant is used. A non-harmful disinfectant must be used. With the fogging method, penetration is high. Water and disinfectant consumption is low. Shoe bottoms are disinfected with a special disinfection mat. Disinfectant waste is prevented since the mat is sensitive to weight. It has a modular design where there is an electrical installation in accordance with the IP65 class (solid and liquid protection). The drying unit is made up of the ultraviolet light generator, a fan, and the heating elements. The dimensions of the drying unit are as follows: width: 450mm, length: 600mm, and height: 600mm.

Plate 1.1: Results and Discussion

The system consists of various sensors, these includes Infrared Temperature sensor, Water Flow Sensor, distance measurement sensors. The temperature measurement data was compared to the temperatures recorded by the 12 infrared sensors, and the findings were shown. Based on the

data in Table 1, the most accurate temperature measuring range was between 35 and 36 degrees Celsius, with an accuracy of less than 0.1 degree Celsius (1 percent of the total measurement).
Table 2.1: Infrared Temperature sensor data evaluation

Sen 1 (^{0}C)	Sen 2(^{0}C)	Sen 3(^{0}C)	Sen 4(^{0}C)	Sen 5(^{0}C)	Sen 6(^{0}C)	Sen 7(^{0}C)	Sen 8(^{0}C)	Sen 9(^{0}C)	Sen 10(^{0}C)	Sen 11(^{0}C)	Sen 12(^{0}C)
34.5	35.5	34.5	35	36	36	36.2	35.9	36.2	37	36.9	36.0
34.5	35.5	34.5	35	36	36	36.2	35.9	36.2	37	35.9	35.4
34.5	35.5	34.5	35	36	36	36.2	35.9	36.2	37	36.9	36.4
34.5	35.5	34.5	35	37	36	36.2	35.9	36.2	35	36.1	36.6
34.5	35.5	34.5	35	36	36	36.2	35.9	36.2	37	36.9	35.6
34.5	35.5	34.5	35	36	36	36.2	35.9	36.2	35	36.9	35.4
34.5	35.5	34.5	35	36	36	36.2	35.9	36.2	37	36.9	35.8

The disinfection flow sensors were put through their paces to measure flow volume. The data from the disinfectant flow sensor is included in Table 2 as well. The volume recorded by the flow sensor was extremely near to the volume obtained by translating the disinfectant weight measure from a digital balance, indicating that the flow sensor was a highly accurate instrument.

Table 2.2: Disinfectant Flow Rate evaluation

Measured 1(L)	Measured 2 (L)	Measured 3(L)	Measured 4(L)	Measured 5(L)	Average (L)	Spray Time (s)	Flow Volume L/s
2	1.8	2.1	1.7	1.9	1.90	30	0.063
2	1.8	2.1	1.7	1.7	1.86	30	0.062
2.1	1.9	2.1	1.7	1.7	1.91	30	0.064
2.1	1.8	2.1	1.8	1.6	1.86	30	0.063
2.1	1.7	2.1	1.8	1.7	1.87	30	0.062
2.1	1.7	2.1	1.8	1.7	1.90	30	0.064
2.1	1.7	2.1	1.7	1.7	1.86	30	0.063
2.1	1.8	2.1	1.7	1.9	1.91	30	0.062
2	1.9	2.1	1.7	1.7	1.86	30	0.064
2	1.8	2.1	1.7	1.7	1.87	30	0.063
2	1.8	2.1	1.7	1.7	1.90	30	0.062

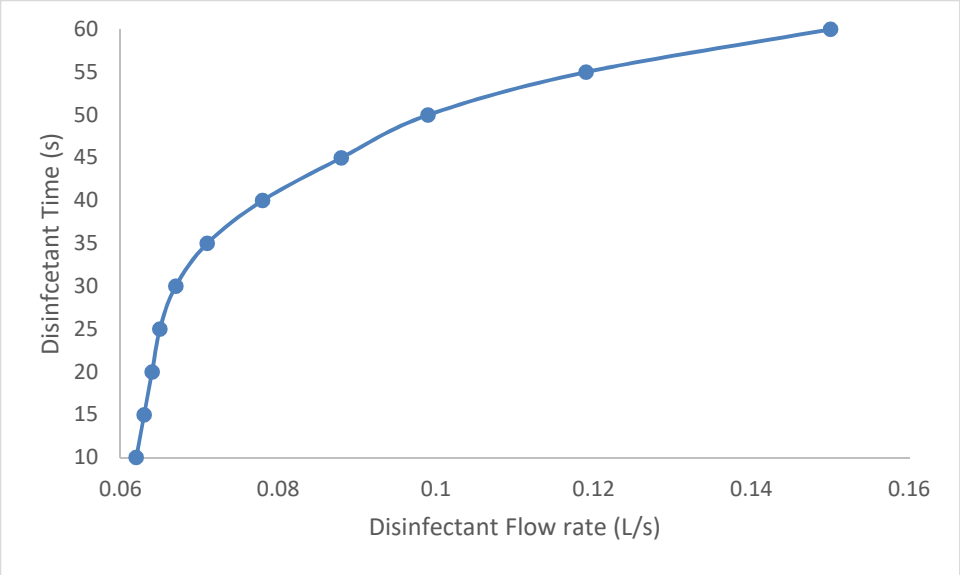

Figure 2: Disinfectant time vs flow rate of the disinfectant

Figure 2 depicts a plot of the disinfectant time vs the flow rate of disinfectant. In the period between 10 seconds and 1 minute, the value of the flow rate climbed significantly, and the relationship became practically flat after the time crossed 50 seconds.

Conclusion

This research developed a disinfection system that could recognise persons exhibiting illness symptoms and disinfect them based on their body's internal temperature. According to the findings of the research, the assessment of the two primary factors should be carried out. These include data from infrared temperature sensors as well as data on flow rate. The data collected by the system for testing and evaluation revealed that the physical parameters, such as temperature and disinfectant flow, which target human passage effectively and accurately, are a system that could be used to monitor COVID or any other related disease outbreak effectively and efficiently.

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Fabrication and Characterization of Composite from Bamboo Fibre and Recycled Polyethylene Terephthalate (PET)

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Abstract: *In this study, Bamboo fibre was extracted via retting process, and subsequently crushing to remove the fibre. These processes enables the removal of fibre surface impurities. The composites samples were produced by a mixing process involving the introduction of the Recycled Polyethylene Terephthalate (PET) while the rolls of the two rolls mill machine (model: 5183) were in counter clockwise motion and soften for a period of 5 minutes at a temperature of 190°C. Upon achieving a band and bank formation of the PET on the front roll, the prepared Bamboo fibre was introduced gradually to the bank, cross mixed and allowed to mix for 3 minutes. The composite obtained from the mixing process was placed into a metal mould of dimensions 120mm x100mm x 3.2mm and was placed on the hydraulic hot press {Compression Moulding Machine (model: 0557)} for shaping at temperature of 160 °C and pressure of 2.5 MPa for 5mins and labeled into samples BF1, BF2, BF3 and BF4 using 10, 20, 30 and 40 % weight fraction of Bamboo fibre, respectively. The experimental characterization of PET-bamboo composite was performed by testing the tensile, flexural, impact and hardness properties of the developed composite. These tests were carried on the samples cut from the developed composite as per the relevant ISO and ASTM standards for composite laminates as shown in Table 2. Three specimens from each sample (BF1, BF2, BF3 and BF4) were tested and the average properties were calculated. The tests on the PET-Bamboo composite with 20 % fibre loading (BF2) was shown to possess higher tensile and flexural strength, thus making it suitable for high strength application. However, sample BF4 with 40 % fibre loading possess higher hardness than other fibre loadings, making it suitable for application where hardness is the major property needed. This work also reveals the strength dependence on the fibre/matrix; while the tensile and flexural strengths of the developed PET-Bamboo composite were observed to be more dependent on the PET matrix alone, while the impact and hardness properties were more dependent on the Bamboo Fibre than the PET matrix.*

Keywords: *Bamboo fibre; natural fibre reinforced polymer composites; life cycle assessment (LCA)*

1. Introduction

As concern about resource conservation has grown, research efforts have increased to develop materials out of rapidly renewable constituents, to assess their life cycle environmental impacts, and to predict their service-life performance. Determining material property suitability, often a concern for polymers and their composites, is essential in evaluating their viability as novel materials to serve as lower environmental impact replacements for conventional materials. However, research in methods to combine environmental impacts from production and material

use is needed. (Olivetti et al., 2018). Composite manufacture and usage comes with attendant negative environmental impact. A life cycle assessment (LCA) of an all-composite airplane, based on a Boeing 787 Dreamliner by Timmis, Hodzic, Koh, Bonner, Soutis, Schäfer, & Dray, L. (2015) was undertaken utilising SimaPro 7.2 in combination with Ecoinvent. The analysis demonstrated CFRP structure results in a low single score environmental impact during usage, but there is higher environmental impact in the manufacturing phase, due to the increased fossil fuel use.

In the mid-1940s PET were essentially used in the production of textile fibres (Gargiulo, 1997). While by 1973 the PET bottle was patented by Nathaniel Wyeth and their used in the production of disposable soft drink bottle was popularised by 1980s. By 1987, more than 700 million pounds of PET were consumed in their production. Virgin pet has been traditionally used as fibre in textile industry and subsequently their used in the manufacture of soft drink bottles. The widespread use of pet results in a very enormous quantity of waste which is environmentally damaging. It is also important to highlight that to tackle the problem recycling of pet product is the best way to economically reduce PET waste (Throne 1987 & Yoda 1998). The major factor affecting the suitability of post consumed PET flake for recycling is the level and nature of contaminants present in the flakes (Al-Sabagh et al., 2016).. To this end, as observed by (Giannotta, Cardi, Tampellini, Occhiello, Garbassi, & Nicolais, 1994) contamination of post-consumed PET is the major cause of deterioration of its physical and chemical properties during re-processing.

Notwithstanding, the contamination that can be associated with the recycled pet considering their used in packaging consumables, they can be employed in other applications that won't interfere with the environment. Therefore any contribution to environmental protection is always helpful however small it may be. In an attempt to contribute to this noble cause of protecting the environment many researchers have investigated the use of recycled matrix and natural fibre as reinforcement in polymeric composite production. The biodegradability, low cost, abundance, and suitable mechanical properties, of the natural fibre make them a suitable alternative to traditional reinforcement fibres such as glass fibre (Boopathi, & Mylsamy. (2012).

Apart from the matrix another important constituent of composite is the fibre as mentioned above. The term "fibre" refers to materials that use to reinforce the natrix to form the composite. Among all reinforcing fibres there are those that are naturally occurring while others are synthetic. But natural fibres have gained great significance as reinforcements in polymer matrix composites. Natural fibre polymer composites (NFPC) are a composite material consisting of a polymer matrix embedded with high-strength natural fibres, like jute, oil palm, sisal, kenaf, and flax (Sabbie, Sarah & Micheal, 2015). .Depending upon the source of origin, natural fibres are classified as plant, animal and mineral fibres. The main advantages of natural fibres are their availability, low cost, low density, high specific properties and good thermal properties. Natural fibres are now considered as a serious alternative to synthetic fibres for use in various engineering design fields (Dinesh Bhonde, Parbat, & Waghe. 2014).

Bamboo fibre as a fibre in polymeric composite stems from the fact that a fibre from bamboo takes advantage of its light weight, flexibility, toughness, high tensile strengths, cheapness than the other fibre materials like carbon and glass fibres. This paper will examines the fabrication Bamboo fibre-Recycled PET matrix and determination of the mechanical properties namely; hardness, tensile, flexural and impact strengths

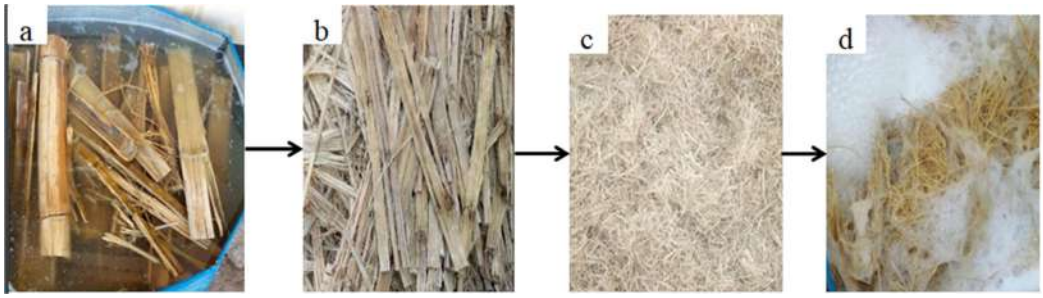
2. Materials and Methods

2.1 Materials

The materials used in this work include the Fibre material, Matrix material and the Mould material.

2.1.1 Fibre

The bamboo fibre shown in figure 1 used in the present investigation was sourced from local market. Bamboo fibre possessed higher ultimate tensile strength compared to other natural fibres, such as sisal Fibre (polymers).



3.1.2. PET

In preparation for recycling, the waste PET bottles collected were cleaned with water to remove impurities and subsequently sun dried to ensure no moisture remains. After which, they were shredded into small sizes. This was done for easier melting.

3.1.3 Equipments

The equipments used in this project are given in Table 3.1.

Table 1 Equipments used in PET-Bamboo fibre composite fabrication.

S/N	Equipment	Manufacturer/Model No.	Location accessed
1	Two Roll Mill	North Bergen, U.S.A (Model: 5183)	NILEST- Zaria*
2	Compression Moulding Machine	Wenzhouzhiguang Ltd, China (Model: 0557)	NILEST- Zaria
3	Universal Material Testing Machine	Norwood Instruments Ltd, (Cat. Nr. 261)	ABU, Zaria**
4	Digital Weighing Balance	Mettler Instruments Ltd (Model no: AE200)	NILEST- Zaria
5	Microhardness Tester	Vicker Hardness Tester (Model no MV 1-PC)	ABU, Zaria

6	Resil Impact Tester	CEAST Resil Family (6957.0000)	NILEST- Zaria

***NILEST-** Nigerian Institute of Leather and Science Technology, Zaria, ****ABU-** Ahmadu Bello University, Zaria

3.1.4. Manufacture of Mold

The mold was constructed according to the shape of the composite to be fabricated. For this work, a square mold of 150 mm x 150 mm x 3 mm dimension was adopted. The mold was produced with the use of a 3 mm heavy gauge iron sheet so that it is not affected by the high temperature during composite manufacture. Hence, the effect of mold bending was eliminated which results in perfect-shaped composite.

3.2 Specimen Preparation

The composites samples were produced by a mixing process involving the introduction of the Recycled Polyethylene Terephthalate (PET) while the rolls of the two rolls mill machine were in counter clockwise motion and soften for a period of 5 minutes at a temperature of 190°C. Upon achieving a band and bank formation of the PET on the front roll, the prepared Bamboo fibre was introduced gradually to the bank; cross mixed and allowed to mix for 3 minutes. The composite was sheeted out and labeled accordingly.

The composite obtained from the mixing process was then placed into a metal mould of dimensions 150 mm x 150 mm x 3 mm and was placed in the hydraulic hot press (Compression Moulding Machine) for shaping at temperature of 160^{o}C and pressure of 2.5 MPa for 5mins. The resulting composite was then cooled in a cool compression moulding machine platen under 2.5 MPa pressure at room temperature for 3mins and labeled accordingly.

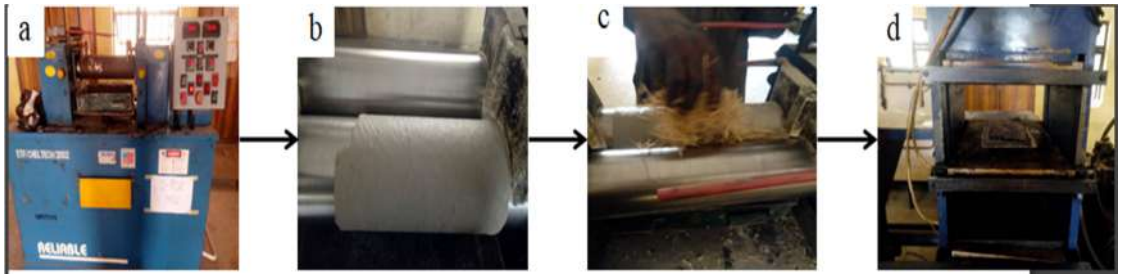


Plate 2 Composite production process; a) Two roll mill machine b) PET compounding c) Mixing PET with Bamboo fibre d) Compression Moulding Machine

3.3 Characterization Process

The PET-Bamboo fibre composite was prepared using randomly oriented fibre and is characterized into samples BF1, BF2, BF3 and BF4 using 10, 20, 30 and 40 % weight fraction of Bamboo fibre, respectively. The experimental characterization of PET-bamboo composite was performed by testing the tensile, flexural, impact and hardness properties of the developed composite. These tests were carried on the samples cut from the developed composite as per the relevant ISO and ASTM standards for composite laminates as shown in Table 2. Three specimens from each sample (BF1, BF2, BF3 and BF4) were tested and the average properties were calculated.

Table 2 Test standards adopted

Type of test	Test Standard
Tensile test	BS EN ISO 527-2:1996
Flexural test	EN ISO 14125:1998
Impact test	ASTM D256
Hardness test	ASTM D785

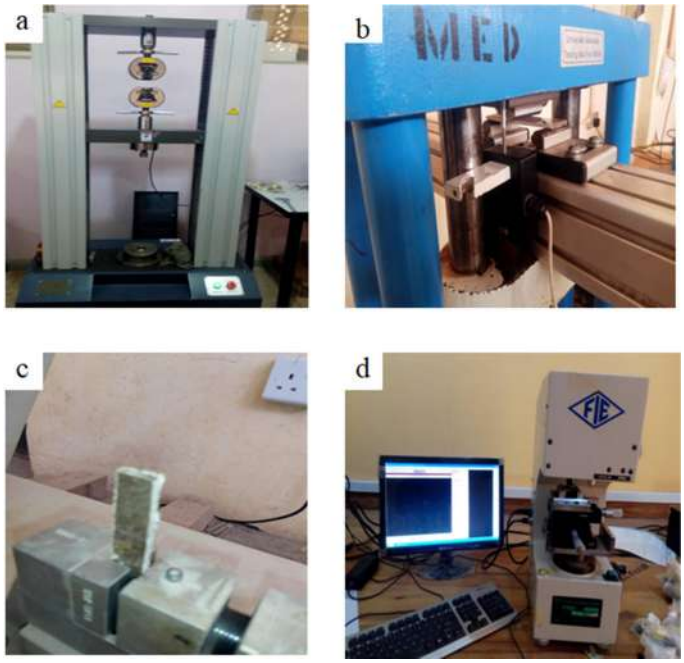


Plate 3 Testing Set-up; a) Tensile test b) Flexural test c) Impact test d) Hardness test

3.3.1 Tensile Strength Test

The tensile strength test was carried out using Universal Testing Machine according to ASTM D-638. A dumbbell shaped samples with gauge dimensions 50 mm x 10 mm x 3 mm were subjected to a tensile force and tensile properties such as the tensile strength, % elongation, and modulus for each sample was determined. These were automatically generated by the machine.

3.3.2 Flexural Strength Test

The flexural strength test on the blends was carried out in accordance with ASTM D-790. The specimen measuring 100 mm x 25 mm x 3 mm was placed on a support span horizontally at 80 mm gauge length and a steady load was applied to the center by the loading nose producing three-point bending until the sample specimen failed. The maximum load (N) and the corresponding deflection (mm) were recorded accordingly as the sample specimen failed. The flexural strength and flexural modulus were calculated using the equations;

Flexural Strength = $3FL/2bd^2$ (MPa) …… (Eq……)

Flexural Modulus = $FL^3/4bd^2D$ (MPa) …… (Eq…..)

Where,

F = Maximum Load at break

L = distance between the support spans at both edge of the specimen = 80mm

b = Sample width = 25 mm

d = Sample thickness = 3.2 mm

3.3.3 Impact Strength

The impact test was carried out according to the ASTM D-156 standard; the specimen was cut to specimen dimension 64 mm x 12.7 mm x 3.2 mm and 45^o notched was inserted at the middle of the test specimens from all the produced blend samples. The impact energy test was carried out using Izod Impact Tester (Resil impactor testing machine). The specimen was clamped vertically (IZOD) on the jaw of the machine and hammer of weight 1500 N was released from an inclined angle 150°. The impact energy for corresponding tested specimen was taken and recorded. Impact strength was also calculated and recorded accordingly. The Impact strength was determined using equation;

Impact Strength $= \frac{Average\ Impact\ Energy}{Sample\ Thickness}$ (J/m) ……..... (E.q…..)

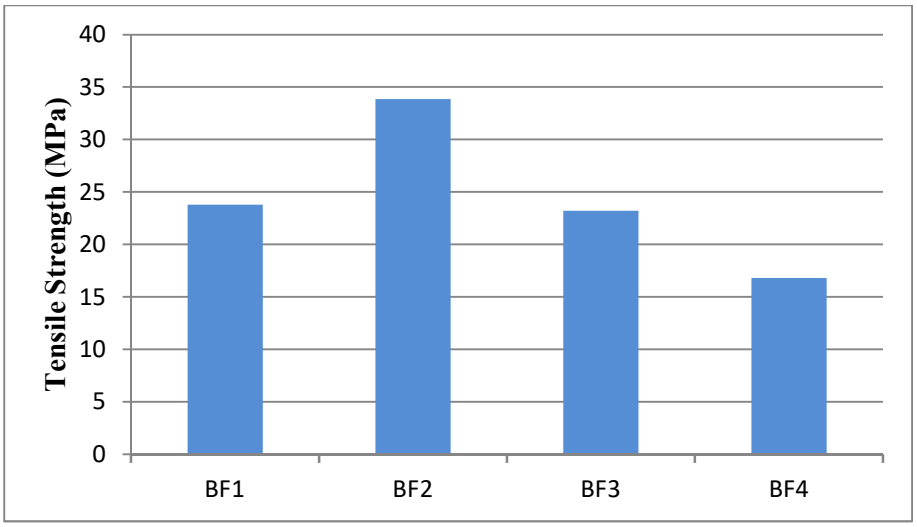
3.3.4 Hardness

The hardness test was carried out in accordance with ASTM D2240 standard using Micro Vicker Hardness Tester. The sample measuring 30 mm x 30 mm x 3 mm was placed on the mounting stage and the stage was raised such that the sample come in contact with the dial point and exacts pressure/force on the sample and the reading was taken directly from the system screen. This was repeated three (3) times at different positions on the sample and average hardness was calculated.

4. Results and Discussion

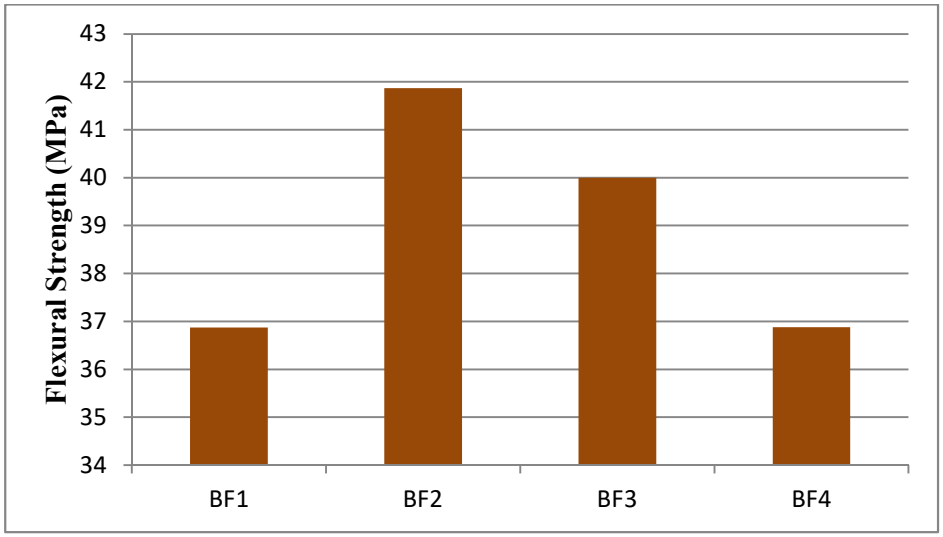
4.1 Tensile Strength of the Manufactured Composite

The PET-Bamboo composite was prepared into samples BF1, BF2, BF3 and BF4 using 10, 20, 30 and 40 % weight fraction of Bamboo fibre, respectively. Fig 1 shows the tensile strength of PET-Bamboo composite at these fibre loadings. It can be observed that the composite with 20 % fibre loading exhibits the highest tensile strength, while the PET-Bamboo composite with 40 % exhibits the lowest tensile strength. This indicates that the tensile strength of the composite largely depends on the PET than on the Bamboo fibre.



4.2 Flexural Strength of the Manufactured Composite

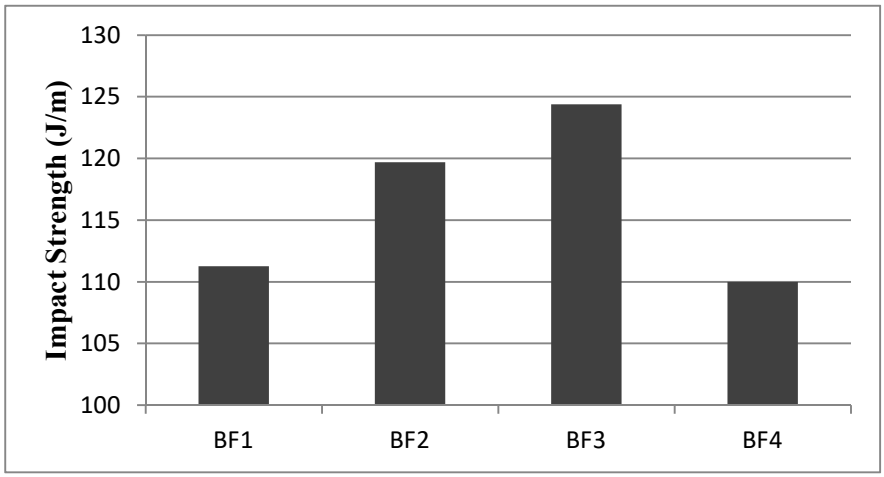
Fig 2 shows the flexural strength of PET-Bamboo composite at different fibre loading. The findings revealed that the composite with 20 % fibre loading exhibits the highest flexural strength, while the minimum flexural strength were attributed to the composites with 10 % and 40 % fibre loading. It can be deduced that the bamboo fibre reinforcement above 30 % fibre loading will result in decreased flexural strength.



4.3 Impact Strength of the Manufactured Composite

Fig 3 depicts the impact strength of PET-Bamboo composite at different fibre loading. It can be observed that the composite with 30 % fibre loading exhibits the highest impact strength, while the PET-Bamboo composite with 40 % fibre loading exhibits lowest impact strength. With fibre

loading, the impact strength increases linearly up to 30 % fibre loading. However, at 40 % fibre loading the impact strength drastically reduces to the minimum.



4.4 Average Hardness of the Manufactured Composite

Fig 4 shows the average hardness of PET-Bamboo composite at different fibre loading. It can be observed that the composite with 40 % fibre loading exhibits the highest hardness strength, while the PET-Bamboo composite with 10 % fibre loading exhibits lowest hardness strength. This finding indicates that the average hardness of the composite depends on both the bamboo fibre and the PET matrix.

5. Conclusion

Recycled PET-Bamboo fibre composite was successfully produced using compression moulding technique. The mechanical properties: tensile strength, flexural strength, impact strength and hardness of the developed PET-Bamboo fibre composite were evaluated. The PET-Bamboo composite with 20 % fibre loading (BF2) was shown to possess higher tensile and flexural strength, thus making it suitable for high strength application. However, sample BF4 with 40 % fibre loading possess higher hardness than other fibre loadings, making it suitable for application

where hardness is the major property needed. This work also reveals the strength dependence on the fibre/matrix; the tensile and flexural strengths of the developed PET-Bamboo composite were observed to be more dependent on the PET matrix, while the impact and hardness properties were more dependent on the Bamboo Fibre than the PET matrix.

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Design and Construction of PET Plastic bottle Crusher for Domestic Use

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Abstract: *A crusher is a machine that is designed such that to reduce the size of plastic into smaller pieces. It is not only for that, but it is also used for recycling of plastic waste materials. Crusher is a multi-dimensional machine. Crusher has the ability of changing the form of material. This work aims to design and fabricate a portable Plastic Bottle crusher that could be installed anywhere and would aid in crushing of used Polyethylene Terephthalate (PET) bottles. This involves the process of designing the crusher considering forces required for crushing and ergonomic factor that an operator needs. The plastic Bottle Crusher thus designed and fabricated is a unique, compact and portable Plastic Bottle Crushing Machine. The final machine is an outcome of a series of processes, in which the first was analysis and study of requirements and conceptualization of machine, then the Design and Fabrication and finally the Testing of Machine. Thus, all the mentioned processes were successfully completed for the Plastic Bottle Crusher. On an average the crusher reduces the volume of bottle to 50% of the initial volume. It was also found that the machine is capable of crushing aluminum Cans as well.*

Keywords: *PET, plastic crusher, waste, recycling*

Introduction

Crushing is one of the process plastics go through before recycling. This process is carried out by a machine called "plastic crusher" which reduces the large solid plastics material into a smaller volume or smaller pieces. Crushers is also used to reduce the size, or change the form of the material so they can be more easily and efficiently used in the purpose intended to. Such purpose can be plastic recycling. Plastic recycling is the process of recycling scrap or waste plastic and processing the material into useful products. Since plastic is non-biodegradable, recycling is part of global efforts to reduce plastic in the waste stream, especially the approximately eight million tons of waste plastic that enter the earths ocean every year. Plastic recycling includes taking any type of plastic, sorting it into different polymers, and then chipping (crushing) it and then molten it down into pellets. After this stage it can then be used to make items of any kind such as plastic chairs and tables. Soft plastic is also recycled such as polyethylene film and bag. Therefore, crushing is an important aspect of plastic recycling.

The world's annual consumption of plastic materials has increased from around 5 million tons in the 1950's to more than 100 million tons; thus, twenty times more plastic is produced today than 50 years ago (Orhorhoro 2016). Today, most of the worlds plastic waste still goes to landfill. Plastic waste disposal is one of the cumbersome process which is very less efficient. In most functions, parties, events etc. water is been served in plastic bottles of different size. The used plastic bottle occupies very large disposal space which usually overflows the bins provided at the places and most of them goes to landfill. Used plastic bags, pieces of plastic sheets and bottles of diverse size, color and texture are found flying around freely, scattered in the street, swimming in the gutters, poising a serious environmental threat which also causes blockage to our sewer system. several attempts were made to discourage plastic bags and other

plastic products but yield minimal result due to its versatility in daily use. The problems highlighted can be minimized by crushing plastics into smatter pieces for either the purpose of proper disposal or recycling into other plastic products. This work aims to investigate the performance of a PET plastic crusher in order to maximize its output.

Economic growth and changing consumption and production patterns are resulting into rapid increase in generation of waste plastic in the world. In Asia and the pacific, as well as many other developing regions, plastic consumption has increase much more than world average due to rapid urbanization and economic development. The world annual consumption of plastic materials has increase from around 5million tons in the 1950s to nearly 100 million tons, thus 20 times more plastic is produced today than 50 years ago. This implies that on the one hand, more resources are being use to meet the increase demand of and on the other hand, more plastic waste is being generated. Due to the increase in generation, waste plastic is becoming a stream in solid waste. After food waste and paper waste, plastic waste is the major constitute of municipal and industrial waste in cities. Even the cities with low economic growth have started producing more plastic waste due to plastic packaging plastic shopping bags, PET bottles and other goods appliances using plastic as the major component. This increase has turned into a major challenge for local authorities, responsible for solid waste management and sanitation. Due to lack of integrated solid waste management, most of the plastic is neither collected properly nor disposed of in appropriate manner to avoid its negative impacts on environment and public health and waste plastics are causing littering and chocking of sewerage system.

Literature review

Different authors have carried out works on the modification, design and construction of plastic crushers. There have been attempts to design and produce shredding machines over the years, Anurag et al. (2014) designed a plastic bottle crusher to be used in public places, and the intent of the project is to assist people crush plastic bottles quickly in public places once the bottle content is consumed. Hence, the design ensured portability, compactness, and ease of use. The design incorporated the use of manually operated gears and a quick return mechanism in order to achieve the set goals of the project. The end product of the design was able to compress plastics which would further need to be cut/shredded into bits. This limits the machine to be used for commercial purposes. Senthil et. al. (2016) showed that the design of a plastic shredder can be such that an optimum load is used to crush plastic waste without straining the operator. Their research achieved this by designing the shredding machine to operate on a slotted lever mechanism powered by a 3-phase induction AC motor. This design proved useful for an industrial application, but costly for a small or medium scale production outfit. Rana et. al. (2020) designed and fabricated a compact sized plastic bottle shredder, in their design pairs of cutting disc with four cutting points were mounted on a pair of shafts. Both shafts where mounted on bearings with an electric motor as the prime mover which is coupled to one of the shafts. Power is transmitted from the driving shaft to the driven shaft by an arrangement of meshing gears. Structural analysis was carried out to determine the total deformation, maximum shear stress and strain of both shaft and cutter. Results show that the design is safe since the maximum stress values exerted on the shaft and cutters did not exceed the yield stress values of the material of both shaft and cutter. The limitation of this design is in the usage, as it cannot function optimally for commercial production of shredded plastic chips. Ayo and Adelabu (2017) designed a plastic shredder with an average throughput capacity and recovery efficiency of 27.3 kg/hr and 95% respectively. This was achieved by driving the shredding shaft with a 3-phase electric motor connected by a belt and pulley system. Although this design would serve a commercial production purpose, the cost of production which is N140,750.00 ($360.87) is a discouraging factor for small scale entrepreneurs in Nigeria. In a related design, Atadious and Oyejide (2018) showed that the throughput of a plastic shredder could be improved upon to be 2070kg/hr with an efficiency of 98.44%. This was achieved by the introduction of a flywheel which is attached to the shaft having most of its weight at the circumference. The flywheel is designed to provide steady rotation of the shaft and even transmission of the torque. This study had the same limitation as that of Ayo and Adelabu (2017). Hence, it is pertinent to

design for affordability to enable easy start-ups in the plastic recycling sector for the small and medium scale entrepreneurs.
Ogunedo and Chukwudi (2020) carried out a recent study which focused on designing and constructing a plastic shredding machine which will assist small and medium scale entrepreneurs in plastic recycling industry. The machine utilizes 3.7kW of mechanical power to produce a torque of 28.49Nm and a shredding force of 1424.5N. With this force, it is able to shred 150kg of plastic in 6.98minutes with an efficiency of 97.8%. Motion simulation analysis run on the machine shows that during operation, the maximum values for buckling amplitude, and deformation of the shaft are 0.1902 Ampres and 0.01634mm respectively. Also, the von Mises stress result showed that all regions of the shaft are far below the yield strength of the shaft material, and the FoS corroborated this result with all regions above 1; having a minimum value of 157.7. This shows that the machine will not breakdown even when running at twice its loading capacity. Furthermore, at a production cost of N109,840.00 the machine is 21.96% cheaper than the current market value of N140,750.00, hence the aim of producing a cost effective, durable and efficient plastic shredding machine was achieved in this study.

Material and methods
The process initiated is a preliminary design wherein the basic mechanism and working of the project is decided. The ideas and innovations about the working of project was be implemented.
We have come up with a concept of designing a crusher in such a way that even a layman can operate it. The manufacturing cost as well as the maintenance cost is very less as compared to that of hydraulic machines. This crusher can crush the waste effectively and also the operating time is very less as compared to the existing ones. This crusher would best suit the small recycling plants and small industries. The maintenance and manufacturing cost are less since it does not use hydraulic or pneumatic fluids.

Design consideration

A. *Crushing force*: The crushing force is the force required to crush the plastic bottles to the desired sizes and is calculated from

$$T = Fr \tag{1}$$

Where,
T = torque
F = crushing force
R = radius or length of the crank

B. *Crushing power required*: The power required to crush the is given by

$$P = \frac{p\omega}{60} \tag{2}$$

Where,

P = power required
ω = angular velocity and is given by

$$\omega = \frac{2\pi N}{60} \tag{3}$$

Where N is the required speed

C. *Determination of belt length*: The belt length can be obtained as

$$L = 2C + \frac{\pi}{2}(D_1 + D_2) + \frac{D_1 + D_2}{4C} \tag{4}$$

D. *Distance between driven and driving pulley:* the center to center distance between driving and driven pulley is given as

$$C = 2D_1 + D_2 \tag{5}$$

Where,
D_1 = diameter of the driver
D_2 = diameter of the driving
C = Centre to center distance between driving pulley and driven pulley

E. *Design for speed ratio for belt drive:* velocity ratio for belt drive is the ratio between the velocity of the driver and the follower (driven). It may be expressed mathematically as:

$$\frac{N_2}{N_1} = \frac{D_1}{D_2} \tag{6}$$

Where,
N_1 = speed of the driver
N_2 = speed of the follower
Therefore;

F. *Determination of lap angle:* the equation is expressed as follow

$$\alpha = 180 \pm 2sin^{-1}\left(\frac{D_2 - D_1}{2C}\right) \tag{7}$$

Where;
α_1 = angle of lap for driving pulley (rad)
α_2 = angle of lap for driven pulley
C = center to center distance between driving pulley and driven pulley

G. Design for shaft

$$T_D = \frac{60PK_L}{2\pi N} \tag{8}$$

T_D = Design torque
KL = Load factor = 1.75 for line shaft
Thus, for diameter of shaft

$$\tau_{max} = \frac{16}{\pi d^3}\sqrt{(K_b M)^2 + (K_t T_d)^2} \tag{9}$$

Where,
M = bending moment
For suddenly applied load (heavy shock), the following values are recommended for K_b and K_t
K_b = 2 to 3
K_t = 1.5 to 3
Selecting material of shaft SAE 1030
S_{ut} = 527MPa
S_{yt} = 296MPa
$\tau_{max} \leq 0.30\ S_{yt}$
$\tau max \leq 0.18 S_{ut}$
Where,
S_{ut} = Ultimate yield strength
S_{yt} = Yield strength

Fabrication procedure

After the design is created the fabrication of the model was carried out according to the design. The motor is mounted at the bottom which is a driving member which drives the pulley by means of a V belt. The pulley drives the shaft mounted with cutters which performs the crushing action. The main components of the machine are: crushing chamber, hopper, belt drive, pulley, power shaft, crushing blade or crushing disc, electric motor, machine frame etc. The main function of the machine frame is to support, guide and hold in accurate alignment all the moving members of the operating machine. The machine frame was constructed from angle bar to give rigidity and stability that will withstand load and vibration. The discharge end is located at the end of the disc while the crushing discs are fixed to the main shaft and enclosed in the barrel. The machine is powered by an electric motor via belt drive connected to the main shaft that turns the disc crushers. The hopper into which the plastic bottle is fed is located at the top of machine (see figure 1 and 2). The design of the plastic bottle crushing machine includes the determination of the force required to crush the plastic bottles and this required a proper selection of inexpensive materials for the construction of each unit components. The bulk of the parts of the machine will be fabricated using mild steel, this is because of its availability at relatively low cost in Nigeria and good machining properties.

Figure 1; Plastic bottle crusher

Figure 2: Crusher blade

Machine operation

The raw materials (waste plastic bottles) are gathered from Nigeria streets and prepared by flattening, to let out trapped air. The neck is thereafter chopped off because it is thicker than the remaining parts. The flattened waste plastic bottles are placed under a guillotine and they are cut into chips. These chips are thereafter fed into the hopper and passed through the feed throat where the chips are conveyed by the screw thread into the crushing discs where they are crushed unto flakes. However, these crushed flakes contain granules of small and large sizes which drop under gravity unto a perforated conveyor belt that vibrates as it moves. The perforation is about 5mm so that the small granules are able to pass through it and received by a trough while the larger ones remain on the conveyor belt and conveyed into another

trough which has orifice that deposit it into a slant placed screw drive. This slant screw drive conveys the larger particles through the manifold, back again into the hopper. This process is repeated until the desired sizes of the granules are obtained which is further used for production of light or heavy dense polyethylene materials.

Testing and experimentation

The testing was conducted after the fabrication is completed. In this stage, the components of plastic crusher were examined for smooth operation and movement. Then the experimentation on crushing was performed. The objective of design was to manufacture a Plastic bottle crushing machine to crush plastic bottles of different dimensions. Experimentation was also conducted to test the agility of machine. Thus, Plastic Bottles of different dimensions and quality were collected and an experiment was conducted. The Experimentation data for Crushed Plastic Bottles is mentioned below in Table 1.

Table 1: Experimentation data

Brand of bottle	Initial volume (m^3)	Final volume (m^3)	% reduction
Coca-Cola	0.065	0.039	0.4
Nestle water	0.085	0.048	0.43
Pepsi	0.055	0.023	0.58
Faro water	0.052	0.021	0.59

The volume occupied by all the bottles were reduced to a certain percentage (Table 1) for any input length and quality of material. Thus, it can be said that the Plastic Bottle Crushing Machine can crush bottles of different dimension. After that, the percentage of crushed volume was determined. Subsequently the percentage reduction in volume was calculated for all the crushed bottles. Reduction in volume was calculated with the help of the following formula.

$$percentage\ reduction\ in\ volume = \frac{initial\ volume - final\ volume}{initial\ volume} \quad (10)$$

Thus, the initial and Final Volume was found out by the dimensions of the Bottles that were measured. The average percentage reduction was calculated to be 50%. The next stage of Experimentation was performed to test the agility of Machine to crush cans. An aluminum Can of Coca-Cola was taken for the experiment. There were no abnormal vibrations nor wear of cutter observed in the crushing process of the can. Thus, it can conclude that the crusher can also crush aluminum Cans.

Conclusion

The plastic Bottle Crusher thus designed and fabricated is a unique, compact and portable Plastic Bottle Crushing Machine. The final machine is an outcome of a series of processes, in which the first was analysis and study of requirements and conceptualization of machine, then the Design and Fabrication and finally the Testing of Machine. Thus, all the mentioned processes were successfully completed for the Plastic Bottle Crusher. On an average the crusher reduces the volume of bottle to 40% of the initial volume. It was found that the machine is capable of crushing aluminum Cans as well. The result of the testing and experimentation carried out on plastic crushing machine design for domestic use revealed that the crushing machine was effective and can be use across Nigerian cities. The plastic crushing machine can help to reduce the volume of plastic bottle wastes dump indiscriminately across cities and this will ensure average Nigerians live in a healthy environment

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Development of a Dawndraft Gasifier for Effective Utilization of Bagasse for Production of Gas

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Abstract: *Energy production is one of the most important economic factors in the development of modern society. Nigeria is purely an agrarian nation and the people depend on Agriculture for their survival. Agricultural waste has been proposed as an alternative energy resources to meet fossil fuel crisis. The sustainable use of this bagasse for bioenergy applications such as electricity generation at low cost and mitigate greenhouse gas emissions is imperative. Conversion of bagasse feedstock to palletization and briquetted could improve the quality of the solid fuel in terms of higher energy density per unit volume and promotes less biomass bridging in a downdraft gasifier. The study was aimed to evaluate the downdraft gasifier using bagasse as feed stock for production heat and gas generation. The experimental factors considered in this studies were bagasse biomass at three level were namely; (pelletized, briquetted and control) respectively, while the particle sizes considered were namely (0.6mm, 1.86 mm and 2.36 mm) respectively, the treatments were laid out in a complete randomized design (CBD) with three replications. The collected data were subjected to the analysis of variance (ANOVA) and the results of the investigation revealed that, briquetted feedstock at all particle sizes had a significant influenced and gave maximum temperature values of 104 ^{o}C, 467 ^{o}C and 1194 ^{o}C during the gasification processes, while pelletized feedstock exhibited closer to the briquetted than control feedstock. Similarly, as affected by particle size bagasse at 2.36 mm produced the highest temperature during the gasification process than all other experiment. Similarly, the finding also discovered that combination briquetted biomass and 2.36 mm particle size have significantly influenced the gasification temperature of the gasifier at the thermocouples (T_1, T_2 and T_3) throughout the experimented period. Based on the findings, a community could generate gas using bagasse husk briquetted to meet demand in most economical way, thereby reducing emission, waste and saving cost which translates to sustainable development.*

Keywords: *Gasifier; Gas; Blower; Energy; Bagasse; Briquetted and Pelletized*

1.0 INTRODUCTION

Biomass represents one of the largest sustainable energy resources in the world and has been perceived as an attractive source of power and fuels. The history of gasification dates back to the seventeenth century. Since the conception of the idea, gasification has passed through several phases of development. During the 1840s, the first commercially used gasifier, which was an updraft style, was built and installed in France. Gasifiers were then developed for different fuels, industrial power and heat applications (Quaak *et al*., 1999). The 1970s brought a renewed interest in the technology for power generation at small scales due to oil crisis (Stassen and Knoef, 1993). Since then, fuels other than wood and charcoal have been applied as feedstock

materials. As a century old technology, gasification flourished quite well before and during World War II. Gasifiers were largely used to power vehicles during that period. Many of the gasoline and diesel driven vehicles during the war were converted to producer gas driven. Today, because of increased fuel prices and environmental concerns, there is a renewed interest in gasification. The use of downdraft gasifiers fueled with wood or charcoal to power cars, lorries, buses, trains, boats and ships have already proved their worth (Turare,2002). Gasification has become a more modern and quite sophisticated technology. Most of the development work was carried out with common fuels such as coal, charcoal and wood. The key to a successful design of gasifier is to understand the properties and thermal behavior of the fuel fed into the gasifier system. It was recognized that fuel properties such as Surface area, size, shape as well as moisture content, volatile matter and carbon content affect gasification performance (McKendry, 2002). Abubakar et al., (2018a) tested and evaluated the performance of a forward curved blower for thermal applications. They determined the performance characteristics of the blower. A peak temperature of 891^{o}C was recorded at 3111 rpm and an air velocity of 23.8 m/s. Major characteristics of the blower such as the power output were found to be 0.56 kW while the mechanical efficiency was varying between 55% and 62% respectively. Abubakar et al., (2018b) designed and developed a forward curved Blower for Downdraft Gasifier Reactor. The geometric parameters, operating conditions and the performance characteristics were determined. It was found that the blower can sufficiently supply air for a gasifier operation even at high temperature. It is against this background that this study was conceptualized to develop a gasifier that will effectively utilize bagasse for the production of combustible gas for electricity generation.

1.2 Current Status of Gasification Technology

Gasification was discovered independently in both England and France in 1798, and through 1850 technology had been developed to the point that it was possible to light much of London with manufactured gas or “down gas” from coal and manufactured gas soon crossed the Atlantic to the United State and through 1920, most American cities and downs supplied gas to the residents for lighting and cooking through the local “gas works” (Doherty *et al*, 2008).

1.3 Biomass

A generally accepted definition of biomass are defined by the United Nation Framework climate change which emphasized that biomass is a non-fossilized and biodegradable organic material originating from plants, animals and micro-organisms that also includes products, by products, residues and waste from agriculture, forestry and related industries (Diana, 2012).

1.3 **Biomass as a Fuel**

Biomass simply refers to organic materials originated from plants (wood, crops etc.) and animal wastes. Different biomass conversion processes produce heat, electricity and fuels. Among all biomass conversion processes, gasification is one of the most promising (Mavukwana, et *al*, 2013).

1.4 Component of Biomass

Cellulose, hemicelluloses, lignin and extraises are found to be the main compkonents of biomas. Cellulose and hemicelluloses are formed by long chains of carbohydrates (such as glucose, whereas lignin is a polymeric lignin has a close relationship with hemicelluloses as it exist as a glue fixing the bunches of cellulose chains and plant tissues together. This is gives mechanical strength to the plant. Lignin is rich in carbon and hydrogen, which are the main heart producing element. Hence lignin has a higher heating value than carbohydrates (Diyoko, *et al*., 2012).

1.6 Gasification Process

Biomass gasification is the conversion of an organically derived, carbonaceous feedback by partial oxidation into a gaseous product, synthesis gas or "syngas", consisting primary of hydrogen (H2) and carbon monoxide (Co), with lesser amount of carbon dioxide (Co_2), water (H_20) methane (CH4), higher hydrocarbons (C_2+), and nitrogen (N_2) (Diana, 2012).

1.7 Drying

In this stage, the moisture content of the biomass is reduced and occurs at about 100 – 200^{0}C with a reduction in the moisture content of biomass of less than 5% (Jamilu, 2016) Resulting water vapour together with water vapour formed at combustion zone partly lead to production of hydrogen and remaining is going with producer gas (Ramzan, *et al*, 2011).

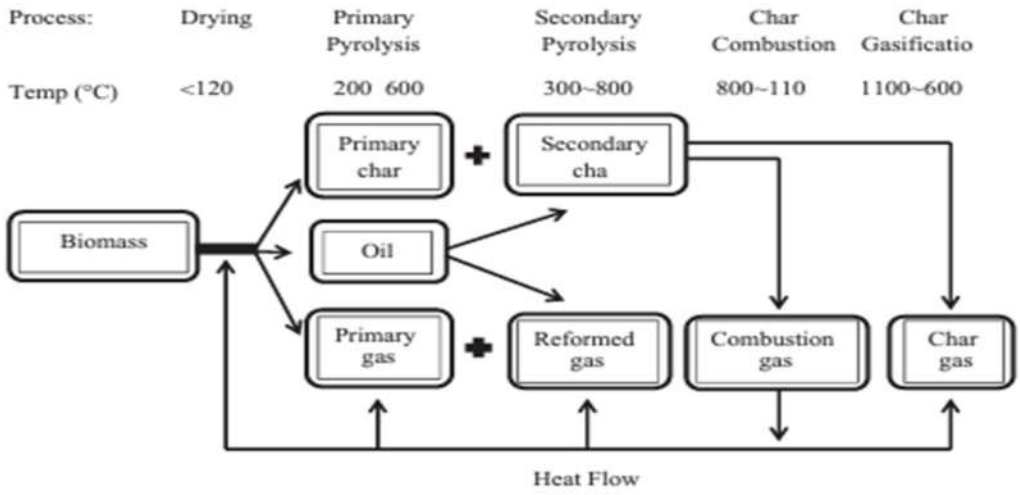

Fig.1 Heat and mass flows in a gasification process

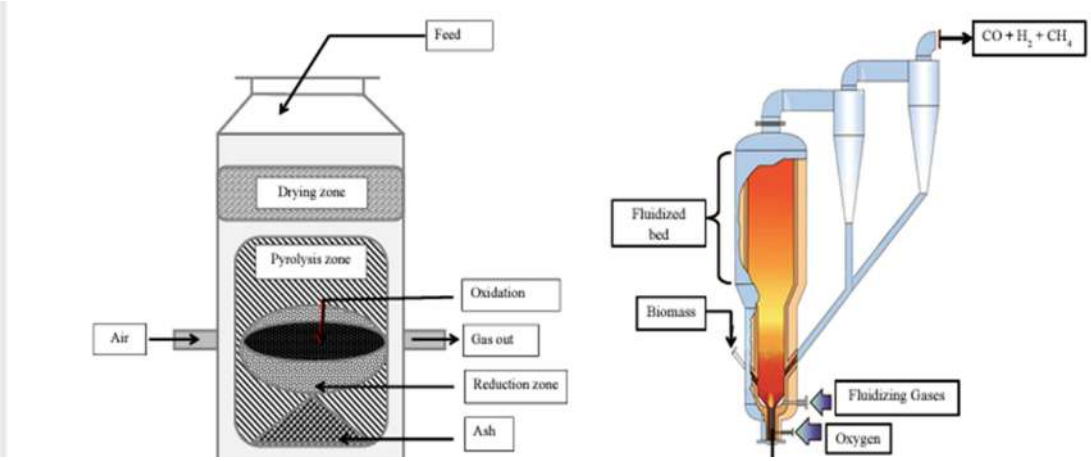

Fig.2 Heat and mass flows in a gasification process

2.0 Materials and Methods

2.1 Site Description

The study was carried out in the Entrepreneur Centre of the University of Maiduguri, the capital of Borno State. It lies between latitudes 11^o 45`N and 11$^o$ 51`N, Longitudes 13^o 2`E and 13$^o$ 9`E and 345m above mean sea level with a mean annual rainfall of about 625mm and annual temperature of 28-32^{o}C Abubakar et al (2019).

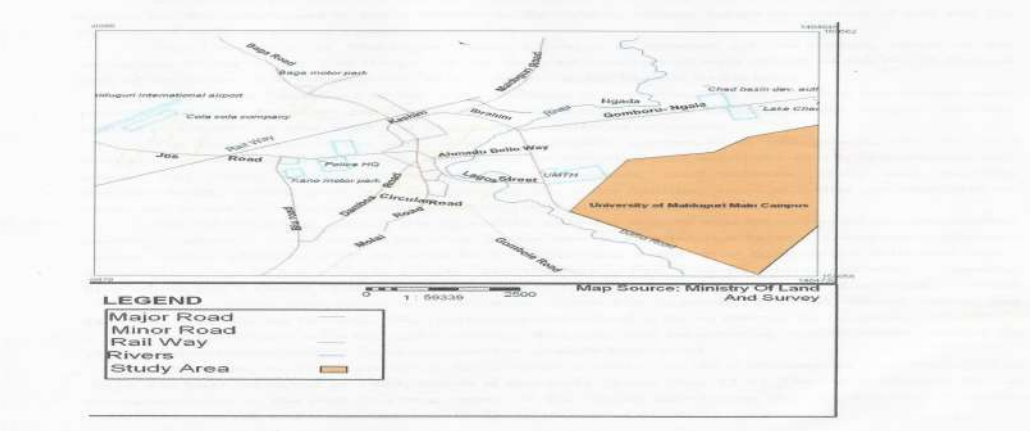

Figure 3.1 Maiduguri Road Map Showing the Study Area (Abubakar., *et al* 2019)

2.2 Treatment and Experimental Design

The experimental factors considered in this studies were feedstock (bagasse) and particle sizes, each at three level, the feedstock selected were namely; (pelletized, briquetted, and control); while the particle sizes considered were namely (0.6mm, 1.86 mm and 2.36 mm) respectively. The treatments were laid out in a complete randomized design (CBD) with two replications.

2.3 Gasification rectors

In the present study, a downdraft fixed-bed gasification reactor was simulated two-dimensionally using the Eulerian method. By considering two-dimensional modeling, the effects of the reactor geometry and gasification properties can be investigated along vertical and horizontal directions. Fluid flow was assumed to be steady (Zhang., 2011) and turbulent [Gerun., 2008) similar to previous studies. Feedstock entered the reactor from the upper part of the geometry, and air inlet nozzles were located on both sides of the reactor. Outlet syngas were discharged from the bottom of the reactor. Mass, momentum, and energy equations were solved using the first-order upwind scheme. Species transport was solved by the Eddy dissipation method. Radiant heat transfer was significant because of the high temperature of the reactor; thus P1 model was used for this type of heat transfer, similar to the literature

2.4 Fuel properties and reactions

Bagasse pellets initially have a moisture content of more than 50%. This moisture should be reduced by pre-drying. Bagasse with higher moisture content requires more energy to begin the gasification process; therefore, pre-drying and decreasing the moisture content of bagasse is necessary. In the present study, sugarcane bagasse properties were introduced to ANSYS Fluent and defined by proximate and ultimate analyses. Different properties are reported for different types of woods in the literature. The properties used in the present study are shown in Table 1.

Table 1 :Proximate and ultimate analyses of bagasse	
Moisture content	1.14%
Volatile matter content	69.99%
Fixed carbon	16.39%
Ash	1.42%

Nitrogen (N)	0.20%
carbon (C)	44.10%
Hydrogen (H)	5.70%
Sulfur(S)	2.30%
Oxygen(O)	47.70%

2.5 Feed Sock Preparation

The Bagasse was collected from mills in Maiduguri, Borno State. The performance evaluation of the adopted gasifier was carried out at the center of entrepreneurship development university of Maiduguri. Initially the Bagasse was sorted, cleaned and sun dried, followed by sieving to the required particle sizes using a sieve obtained from the Civil Engineering Department of Ramat Polytechnic. The feed stock was sieved into different particle sizes such as 2.36 mm, 1.86 mm, and 0.6 mm respectively. The feedstock (rice husk) were divide into three equal each at 2.0 kg respectively. Pelletized and briquetted machine were used for making the Bagasse biomass into pelletized and briquetted was accomplished by the use of bender (bentonite) mixed up with water before pelletized and mounded. Fuel properties and reactions Bagasse pellets initially have a moisture content of more than 50%. This moisture should be reduced by pre-drying. Bagasse with higher moisture content requires more energy to begin the gasification process; therefore, pre-drying and decreasing the moisture content of bagasse is necessary. In the present study, sugarcane bagasse properties were introduced to ANSYS Fluent 16.2, defined by proximate and ultimate analyses. Different properties are reported for different types of woods in the literature. The properties used in the present study are shown in Table 1.

2.6 Thermal Decomposition of Bagasse

There are two distinct stages in the decomposition of Bagasse- carbonization and decarbonation. Carbonization is the decomposition of volatile matter in Bagasse at temperature greater than 300°C and releases combustible gas and tar. Decarbonation is the combustion of fixed carbon in the Bagasse char at higher temperature in the presence of oxygen (Fig. 2.1) [Maeda et al., 2001]. The melting temperature of RHA is estimated as 1440°C, that is, the temperature at which silica melts (Bronzeoak, 2003).

2.7 Gasification in Fixed Bed Reactors

They are sometimes called moving bed because the gasifying agents passes through a bed of solid fuel. If the gasifying agent is fed from the top of the reactor with the biomass, it is term downdraft while if the gasifying agent is feed from the bottom moving counter currently with the biomass the gasifier is called updraft. These reactors are easy to construct, operate and suitable for small scale applications. They are widely available in developing countries but in general have limited scale up properties.

2.8 Downdraft gasifier

In the downdraft gasifier, its upper cylindrical port of gasifier acts as a collection device for wood chips or other biomass fuel and the geometry of the down draft gasifier nearby is a radially directly air nozzle, which permits air to be down into chips as they move down to be gasified and this nozzle constitutes combustion and reduction zones as shown in figure 2.1 below. After the air contact the pyrolyzing biomass before that the flame gas riches as pyrolysis proceeds. Next so the end of pyrolysis zone, the gases consist mostly of CO_2, H_2O, CO, and H_2 and the throat ensures that gaseous products pass through the soothes: hydrocarbon so produces relatively clean

gas. Designed for the application of producer gas in CI engine, downdraft gasifier is more suitable as it produces very less tar (Sanjay, 2015 and Jamilu, 2016.

2.8.1 Classification of Biomass Gasifier

Gasifiers are mainly classified according to their design as fixed bed fluidized bed and entrained flow bed. However, gasifiers can also be classified as:

i. According to gasification agents
ii. According to heat for gasification (isothermal or autothermal) and
iii. According to pressure in the gasifier (atmospheric or pressurized).

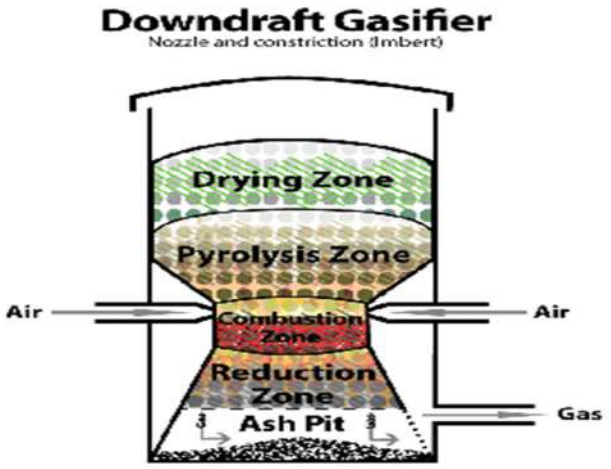

Figure 2.1 Down draft gasifier source (Sanjay, 2015)

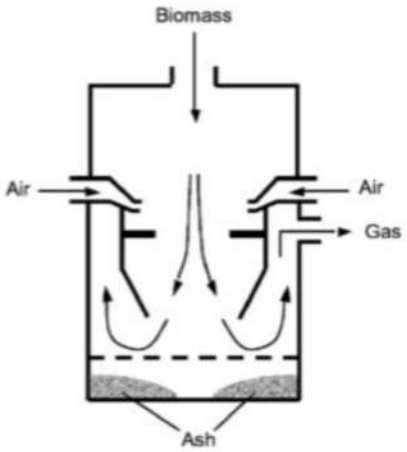

Fig. 2.2: Imbert downdraft Gasifier (Jamilu, 2016).

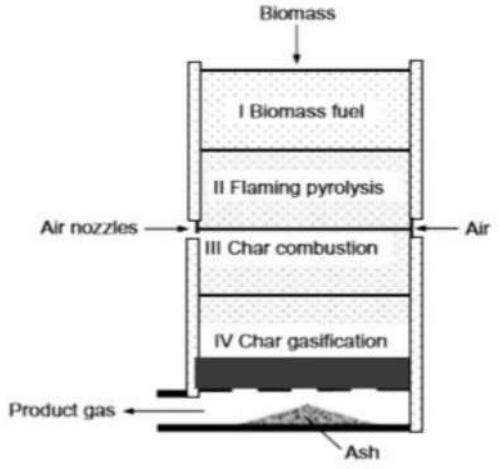

Fig. 2.3: Stratified Downdraft Gasification Design (Jamilu,.2016)

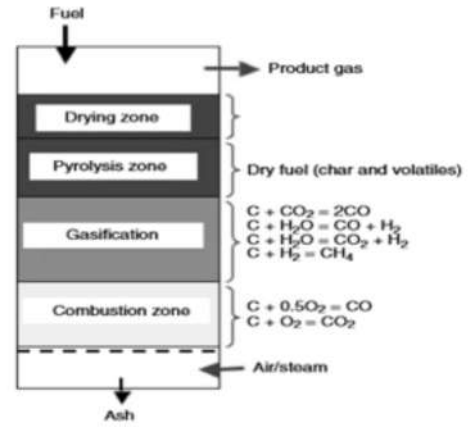

Fig 2.4: updraft gasifier Source: Sanjay, 2015

4.0 RESULTS AND DISCUSSION

The experimental results on effect of pelletized and briquetted bagasse biomass on different particle sizes on the temperatures of downdrafts gasifier were analysed using the Analysis of Variance one-way (ANOVA) as presented in the following tables below.

From the Table 4.1, it was seen that the temperatures of the gasifier increased with increase in mass. Higher temperatures at T_1, T_2 and T_3 were observed with briquetted bagasse biomass with maximum temperature values of 117 ^oC, 471 ^oC and 1109 ^oC respectively. It was narrowly followed by pelletized with corresponding temperature values of 111 ^oC, 452 ^oC and 920 ^oC respectively. Finally, the least gasification temperatures were observed with control biomass. this should also be expected to the fact palletization could improve the quality of the solid fuel in terms of higher temperature and promotes less biomass bridging in a downdraft gasifier as reported by Yoon *et al.* (2012). for more details, see figure 4.1 and table 4.2

Table 4.1: Effect of pelletized and briquetted feedstock on gasification temperatures of bagasse at 2.36 mm particle size

Treatments	Thermocouple 1 (^oC)	Thermocouple 2 (^oC)	Thermocouple 3 (^oC)
Control	87	327	653
Pelletized	111	452	920
Briquetted	117	471	1109

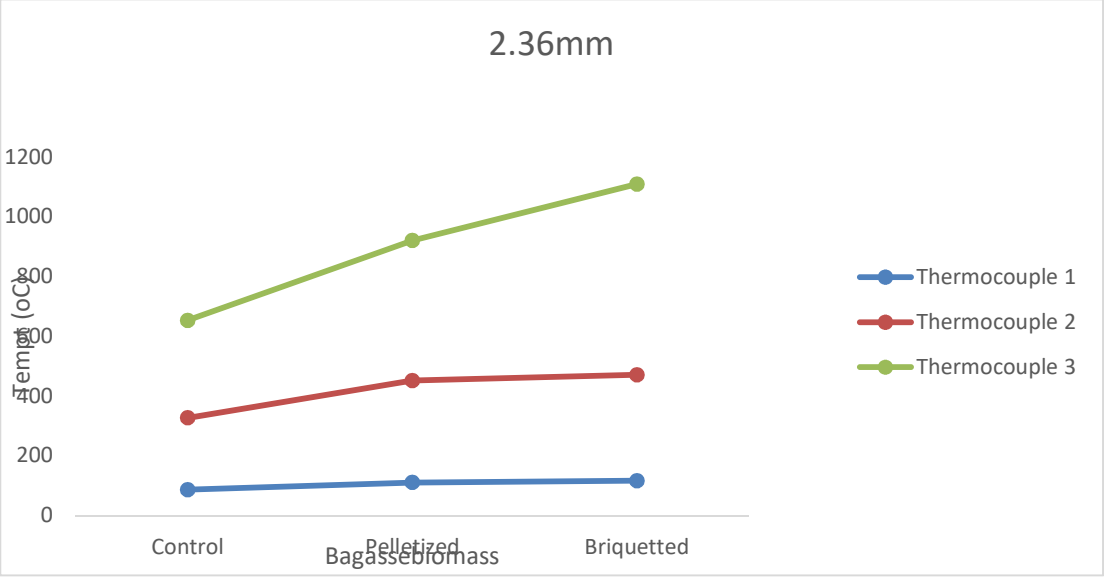

Figure 4.1 Showing the effect of pellet bagasse biomass on gas flow temperatures at 2.36mm particle size

Table 4.2: Shows The Analysis of Variance of the Experiment

ANOVA						
Source of Variation	SS	Df	MS	Fstat	P-value	F crit
Between Groups	947504.2	2	473752.1	24.14502	0.00135	5.143253
Within Groups	117726.7	6	19621.11			
Total	1065231	8				

From the result/summary fstat>fcript. There is a significant difference among the treatments at P>0.05

Table 4.3, shows the result of gasifier temperatures as affected by pelletized and briquetted bagasse biomass at1.86mm particle size. The maximum temperatures values of 104 ^{o}C, 467 ^{o}C and 1194 ^{o}C for T_1, T_2 and T_3 were remarkably observed with briquetted biomass, it was followed by pelletized bagasse during gasification period, while the lowest gasification temperatures at thermocouples T_1, T_2 and T_3 was recorded with control with corresponding gasification temperatures values of 102 ^{o}C, 433 ^{o}C and 910 ^{o}C respectively and similar result was reported by Abubakar., et *al* (2019). For more details, see figure 4.2 and table 4.4

Table 4.3: Effect of pelletized and briquetted feedstock on gasification temperatures of bagasse at 1.86 mm particle size

Treatment (Feedstock)	Thermocouple 1 (^{o}C)	Thermocouple 2 (^{o}C)	Thermocouple 3 (^{o}C)
Control	80	314	634
Pelletized	102	433	910
Briquetted	104	467	1194

Figure 4.2: effect of pellet bagasse biomass on gas flow temperatures at 1.86mm particle size

Table 4.4: Shows the Analysis of Variance of the Experiment

ANOVA						
Source of Variation	SS	Df	MS	F stat	P-value	F crit
Between Groups	89928.22	2	44964.11	10.244337	0.790653	5.143253
Within Groups	1104152	6	184025.3			
Total	1194080	8				

From the result /summary fstat >fcrit. There is a significant difference among the treatments at P>0.05

As shown in table 4.5. Both pelletized and briquetted biomass experimented at 0.6 mm particle size had significantly ($p<0.05$) influenced the temperatures of gasifier. The uppermost T_1, T_2 and T_3 were still observed best with briquetted, it was closely followed by pelletized and the least was obtained with control feedstock throughout the period of the experimentation and result of the experimented is tallied with the work of Abubakar *et al*., (2019). For more details, see figure 4.3 table 4.6

Table 4.5 Effect of pelletized and briquetted feedstock on gasification temperatures of at 0.6 mm particle size

Treatment	Thermocouple 1 (°C)	Thermocouple 2 (°C)	Thermocouple 2 (°C)
Control	54	221	621
Pelletized	92	422	680
Briquetted	96	452	721

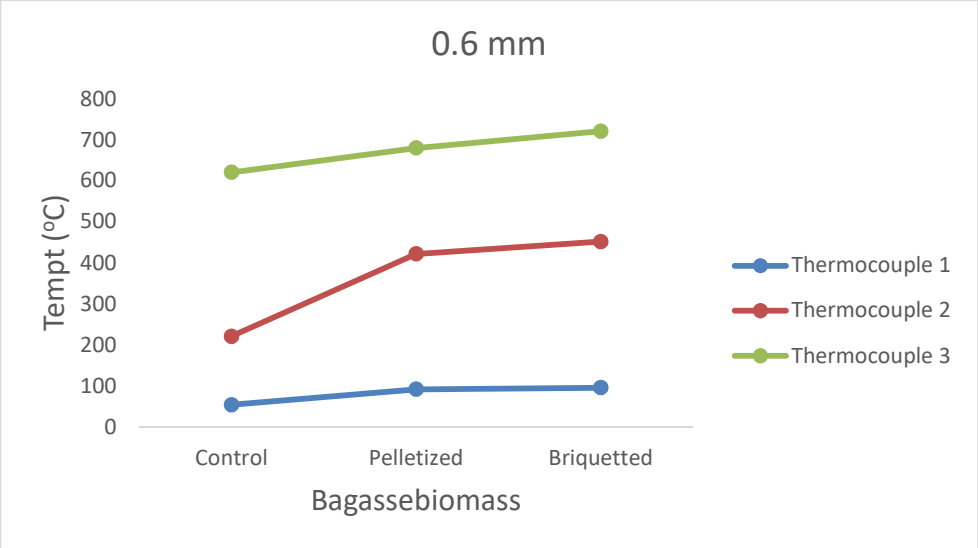

Figure 4.3: Showing the effect of pellet bagasse biomass on gas flow temperatures at 0.6 mm particle size

Table 4.6: Shows the Analysis of Variance of the Experiment

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	25950.89	2	12975.44	0.144144	0.868673	5.143253
Within Groups	540102.7	6	90017.11			
Total	566053.6	8				

From the result/summary fstat>fcript. There is a significant difference among the treatments at P>0.05

4.2 Effect of bagasse particles size on pelletized, briquetted and control sample on gas flow temperatures

As presented in the figure 4.1, The plots revealed that briquetted bagasse experimented produced the uppermost temperature of the gasifier during gas flow process at thermocouples T_1, T_2 and T_3 respectively. It was then closer by pelletized biomass at same thermocouples, and the least gas flow temperatures recorded with control bagasse (unammended).

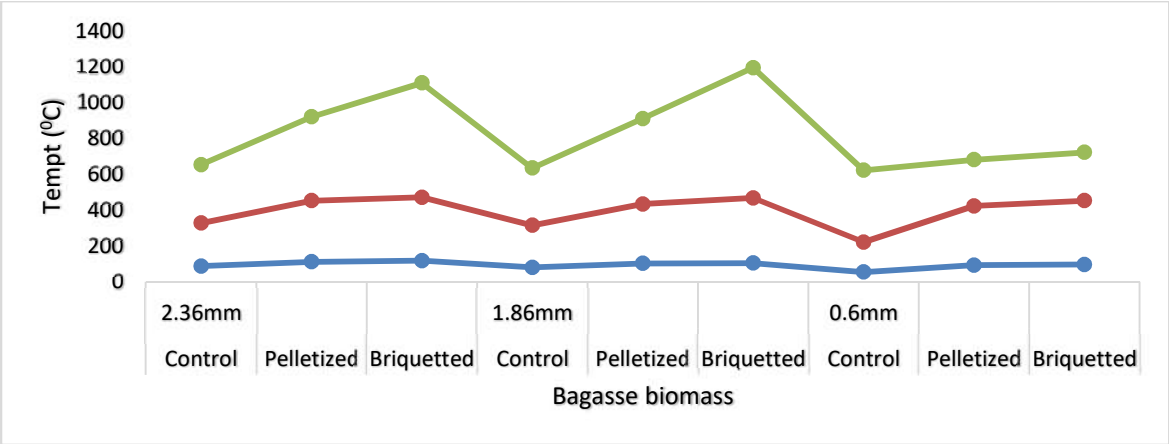

Fig 4.4: Temperatures of the gas flow at different pellet of bagasse biomass and particle sizes

5.0 Conclusion and Recommendations

The study was aimed to evaluate the performance of the existing gasifier to identify the most effective pelleted and particle sizes of bagasse on the temperatures and time of the combustible gas production from the gasifier for effect electricity generation. The collected data were subjected to the analysis of variance (ANOVA) and the result were as follows:

(i) Results of this investigation showed that briquetted bagasse biomass at all particle size experimented had a significant influence on the temperature of the gasifier during the gasification processes and was followed by pelletized and control at all particle size

(ii) Among all particle size experimented, 2.36 mm particle size produced the highest temperature during the gasification process and could be capable for mass syngas generation in the country.

(iii) The highest temperature among thermocouples (T_1, T_2 and T_3) was significantly recorded best with briquetted bagasse biomass.

(iv) In view of the foregoing, it is recommended that briquetted bagasse biomass and 2.36 mm particle size could be used effectively for production as in this region.

(v) It is recommended that, further studies should also be carried out on other agricultural waste using or adopting this approach with a view to re- validating the outcome of this

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Assessment of Groundwater Contamination by Leachate Near Some Selected Municipal Solid Waste Landfill Areas of Maiduguri

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Abstract: *The study was carried out to assess groundwater contamination by leachate near some selected municipal solid waste landfill areas of Maiduguri. Purposive sampling technique was adopted to identify two open Municipal solid waste (MSW) dumpsites A & B which ranged from 18-23 years in age at Kumshe and Bakasi in Maiduguri respectively at a distance of 7.16km apart. Four hand-dug boreholes with depth ranging from 24 – 32m with a distance of 55.2m and 657.8m between the centre of dumpsite A and the two boreholes respectively. While, for dumpsite B the distance was 25.7m and 317.3m respectively. samples. The groundwater analysis revealed that the temperature variations in groundwater were function of climatic conditions. The concentration of heavy metals like Zn, Cu, Pb, Cd, Cr and Mn decreases with rise in water table of an aquifer (dry to wet season) while, Fe and As increases from dry to wet season and this was in line with high concentration of Fe and As in the soil samples. The computed water quality index for the water samples ranged from 10.61-72.4, it was observed that the sampling wells were within the categories of excellent water quality, good water quality and poor water quality. Seasonal variation has advance effect on soil as the concentrations increases with increase in leachate in wet season, which in turn pollute the groundwater source. The uncontrolled accumulation of leachate over time at the dumpsites base will impose a significant threat to the groundwater quality.*

Keywords: *Groundwater, Heavy Metals, Landfill, Leachate, & Pollution*

Introduction

Groundwater is one of the most vital natural resources which contributes to the global freshwater supply. In Nigeria, groundwater provides much of the public and domestic water supply, supports agricultural and industrial economies, and contributes its flow to rivers, lakes and wetlands; and this helps in maintaining balance in the ecosystem (Aizebeokhai, 2011). Groundwater is the prime source of potable water in most parts of Nigeria, particularly in rural areas, which rely on domestic (private) hand-dug wells (Aizebeokhai, 2011). According to Kumar (2013) despite its reliability, this valuable and vital resource is under increasing threats attributed to above ground anthropogenic activities related to uncontrolled urbanization, incessant waste disposal and poor land use management. In addition, the usefulness of groundwater to humans essentially depends on its chemical status, thus, assessment of

groundwater quality is important for the socioeconomic development of most developing and developed countries of the world (Kumar, 2013).

Groundwater quality is a significant aspect in the context of sustainable water management, the integrity of underlying aquifers is largely affected by pollution from above ground sources, particularly solid waste disposal (Kumar, 2013). Uncontrolled urban growth and its resultant effect, especially in developing nations like Nigeria, can adversely affect the quality of underlying groundwater if not properly controlled (Putra and Baier, 2008). With a rapid population growth of about 2.5% per annum, the demand for water supply has progressively increased over the last three decades. The provision of safe drinking water has actually deteriorated - access in urban areas fell from 55 million people to 27 million people in 2002 in African cities (Jacobsen *et al.,* 2012). This is largely due to poor management, inadequate technical capabilities, lack of investment and insufficient manpower and their training (Hanidu, 1990). Furthermore, the institutions responsible for water supply in Nigeria are both ineffective and fragmented; thus, a transition is needed to bring about a thorough and holistic change to the current system (Jefferies and Duffy, 2011).

Leachate Response to Landfill Moisture

Landfill leachate can be considered as a solvable organic and mineral compound produced once water penetrates the waste layers, extracts a sequence of pollutants and generates a complex interaction between the biogeochemical and hydrological responses (Renou *et al*., 2008a). These interactions performance as mass transfer mechanisms for creating moisture content adequately high to initiate a liquid movement (Aziz *et al*., 2004a), encouraged by gravitational force, rainfall, surface overflow, recirculation, liquid waste co-disposal, subsurface water interference, waste decomposition and initial moisture content present inside the landfills (Achankeng, 2004; Foo and Hameed, 2009). Leachate flow rate depends on precipitation, surface run-off, and interference of subsurface water into the landfill (Renou *et al.,* 2008a).

2.0 Materials and Method

The following materials were used for this study as presented in Table 1.

Table 1: Models and Manufacturers of the Materials

Material	Model	Manufacturer
Soil auger	A15-30	local
Sorting platform/bins	-	-
Sampling bottles	P120	-
Weighing balance	ISO900	Panomex Inc. New Delhi, India
pH/mV/temperature	T352	Turbo WF6, United Kingdom
Hanna EC Meter	H198311	Hanna Woonsocket, Rome, Italy
Hach turbidity meter	2100N	Hach Company, Colorado, USA
Hach colorimeter	DR/890	Hach Company, Colorado, USA
TDS meter	TDS-3	Turbo WF6, United Kingdom
Spectrophotometer	MP-AES 4200	Spectro Kleve, Germany

2.1 The Study Area

Maiduguri is located between latitude 11^0 5" – 11^0 55" N and longitude 13^0 02" -13^0 16" E. It lies on a vast sedimentary basin, with gentle undulating gradient of altitude 345m above mean sea level as shown in Figure 3. The vegetation of the study area is of Sahel Savannah, surface water is very limited within the location and its environment. Hence, the people they depend on groundwater for meeting water needs of the metropolis. The area dominantly derives its groundwater resources from the Chad Formation, which is the youngest stratigraphic unit of the Chad Basin and the most prolific in terms of groundwater resources (Hess *et al.,* (1996). Maiduguri is estimated to have a population of about 1,197,497 in 2009 (NPC, 2006). More than 80% of this population depends on groundwater resources, with per capita water consumption of 10-40 litres of water per day.

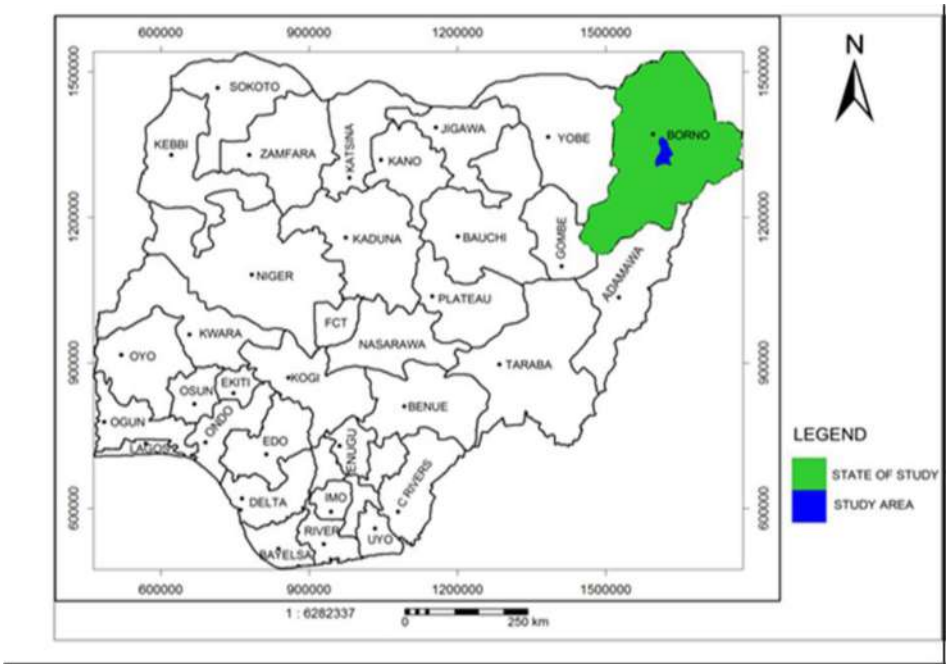

Figure 1: Map of Nigeria showing the study area (Maiduguri)
Source: (Bakari, 2014)

2.2 Sample Collection

Purposive sampling technique was adopted to identify two open Municipal solid waste (MSW) dumpsites A & B which ranged from 18-23 years in age at Kumshe and Bakasi in Maiduguri respectively at a distance of 7.16km apart. Four hand-dug boreholes with depth ranging from 24 – 32m with a distance of 55.2m and 657.8m between the centre of dumpsite A and the two boreholes respectively. While, for dumpsite B the distance was 25.7m and 317.3m respectively as shown in Figure 2. The sampling coordinates for the dumpsites and wells were presented in Table 2 and 3. Composite sampling method was adopted for both the water and soil samples.

Table 2: Sampling coordinates of the hand-dug wells and dumpsite A

Sampling point	Latitude (^{o})	Longitude (^{o})
GWA	11.857836	13.147581
GWA_C	11.864072	13.148281
SAO	11.858228	13.147317
SAN_1	11.858269	13.147347
SAN_2	11.858289	13.147319
SAE_1	11.858242	13.147422
SAE_2	11.858278	13.147458
SAE_c	11.857994	13.147511
SAS_1	11.858214	13.147381
SAS_2	11.858181	13.147411
SAS_c	11.858419	13.147261
SAW_1	11.858222	13.147361
SAW_2	11.858194	13.147317
SAW_c	11.858022	13.146950

Table 3: Sampling coordinates of the hand-dug wells and dumpsite B

Sampling point	Latitude (^{o})	Longitude (^{o})
GWB	11.799939	13.119197
GWB_C	11.798961	13.116678
SBO	11.799906	13.119431
SBN_1	11.799919	13.119436
SBN_2	11.799947	13.119436
SBN_c	11.800094	13.119464
SBE_1	11.799928	13.119450
SBE_2	11.799939	13.119472
SBE_c	11.799964	13.119672
SBS_1	11.799903	13.119428
SBS_2	11.799847	13.119625
SBS_c	11.799550	13.119689
SBW_1	11.799902	13.116667
SBW_2	11.799908	13.119389
SBW_c	11.799833	13.122419

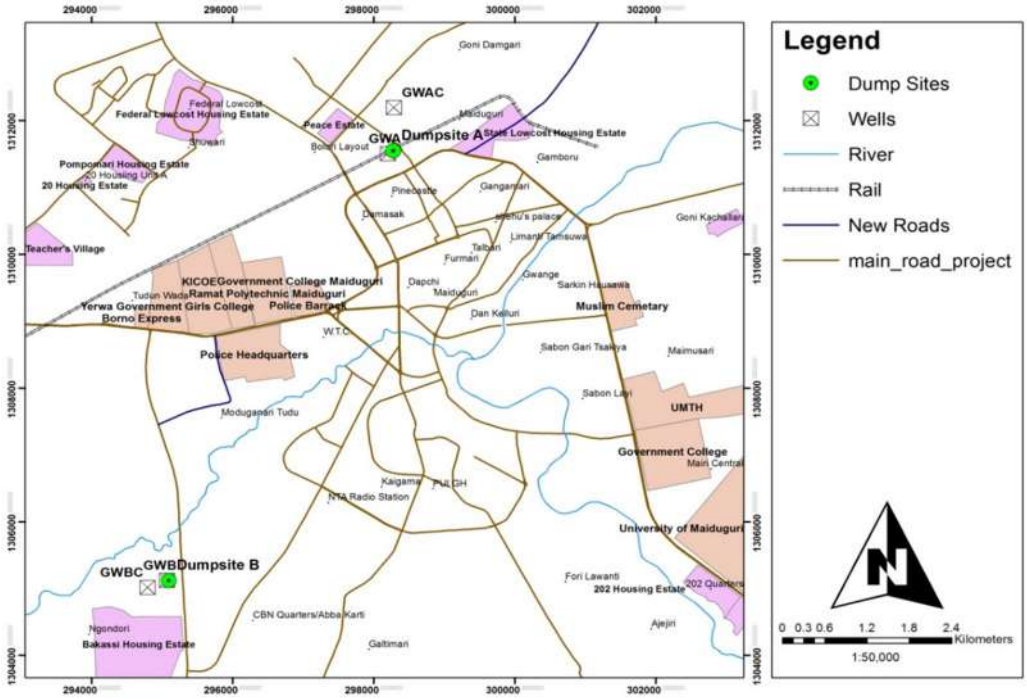

Figure 2: GIS Map of Maiduguri showing the location of the sampling points

Solid waste sampling

Characterization of the solid waste from the disposal sites was carried out according to the ASTM (2004) as presented in Table 4. The sampling was conducted in the month of January and August 2017 for the dry and wet season respectively. The procedure involved random collection of 10kg of solid waste at each dumpsite (three times in a week) for a month. The collected solid waste samples were air dried and weighted before sorting into different categories of plastics, polythene, waste battery, paper, textile, glass, metal and earth/ garbage. The categorized wastes were then weighed using a digital weighting scale and their percentage weight was calculated.

Table 4: Characterization of the dumpsites

	Dumpsite A	**Dumpsite B**
Elevation (m)	312	323
Area (m^2)	17.25	14.46
Depth (m)	1.27	1.45
MC of solid waste (%)	17	14
Topography	Flat	Slopy
Drainage	No	No
Human activities	Industrial/Commercial	Farming

3.0 Results and Discussion

The Biochemical Oxygen Demand (BOD) concentration for dumpsite A and B ranged between 160-208 mg/Kg and 320-128 mg/Kg with mean and standard deviation of 1180±673 and 676±347 for dry season, while for the wet season it ranged from 2.5-128 mg/Kg and 38-144 mg/Kg with mean and standard deviation of 76±38.01 and 90±46.18 for dumpsite A and B respectively. The concentration of BOD decreases from dry to wet season and has no define

pattern in the soil profile, due to increase in the volume of leachate from rainwater, this study agreed with Gajski *et al*. (2012) that rainwater reduces the level of BOD by increasing the DO needed by biodegradable materials.

The concentration of Zn and Fe for dry season at the upper and lower profile ranged from 5.5-2777 mg/Kg and 10-1412 mg/Kg; 1280-7556 mg/Kg and 1031-8890 mg/Kg for the dumpsite A and B respectively. The concentration of Zn for both dumpsites were within NES limit of 300 mg/Kg except for SAS, SBS and SBE, and there was no defined pattern in the soil profile. All the concentrations of Fe for both dumpsites were below minimum limit of 7000 mg/Kg for NES limit except SAW, SBNc AND SBWc, which were within acceptable limit. The concentration of Zn and Fe in the wet season increased due to leachate percolation, which ranged from 2.5-3159 mg/Kg and 873-15918 mg/Kg, and 11.5-2145 mg/Kg and 3673-18378 mg/Kg for dumpsites A and B respectively. The concentration of Zn increased in the wet season and all the values were above NES limit except SAO, SAWc, SBNc, SBWc, SBSc and SBEc for the two dumpsites, while Fe concentrations were within NES limit of 7000-550000mg/Kg except SAO, SBW and SBWc, which were below minimum limit of NES.

The concentrations of Cu and Pb for dry season at the upper and lower profile was found between 2.5 to 51.25 mg/Kg and 11.5 to 392 mg/Kg with highest mean values of 13.13 mg/Kg and 68 mg/Kg, and 0.75 to 160 mg/Kg and 3 to 33.25 mg/Kg with highest mean values of 23.81 mg/Kg and 16.47 mg/Kg for dumpsites A and B respectively. The concentration of Cu within the soil profile has no defined pattern and the values were within NES limit of 2-100 mg/Kg except for SBN and SBS which were below and above NES limit respectively. All the concentrations of Pb in the soil samples were within NES limit of 2-200 mg/Kg except SAE, which was above NES limit.

The concentration of Cu and Pb ranged from 6.5-93 mg/Kg and 0.54-25 mg/Kg with highest mean values of 26 mg/Kg and 12.34 mg/Kg, and 0.25-156 mg/Kg and 6.5-482 mg/Kg with highest mean values of 55.7 mg/Kg and 81.4 mg/Kg for dumpsites A and B respectively. The concentration of Cu increases from dry to wet season due to leachate formation from solid waste and increases down the soil profile for dumpsite A, while decreases down the soil profile for dumpsite B. All values were within NES limit except SBO and SBN, which were above NES limit. The concentration of Pb decreased from dry to wet season for dumpsite A, while increases for dumpsite B and decreases down the soil profile. All values were within NES limit except SAWc, SASc and SAEc, which were below minimum limit of 2 mg/Kg and SBS which were above NES maximum limit. As stated by Ogundiran and Afolabi (2008) that the volume of leachate generated is therefore expected to be high in humid regions with high rainfall, or high runoff and shallow water table.

The concentration of AS and Cd for dry season at the upper and lower profile ranged from 95.25-152 mg/Kg and 0.25-0.75 mg/Kg with highest mean values of 124 mg/Kg and 0.31 mg/Kg; 77.5-163 mg/Kg and 0-1mg/Kg with highest mean values of 134 mg/Kg and 0.36 mg/Kg for the dumpsite A and B respectively. The concentration of As for both dumpsites were above NES limit of 1-50 mg/Kg and increases down the soil profile for dumpsite A. Cd was not detected at SAWc, SASc, SAEc, SBW, and SBWc, and the values were within NES limit of 0.01-0.75 mg/Kg except SAS, SBO, SBS and SBE, which were above NES limit.

The concentration of As in dumpsite A decreased from dry to wet season, which ranged from 0.25-167 mg/Kg and 22-149 mg/Kg with highest mean values of 99 mg/Kg and 95.2 mg/Kg, the values were above NES limit and increases down the soil profile. This indicates high sources of As in the solid waste. The concentration of Cd was higher in the wet season and all the values were above NES limit except SAN and increases down the soil profile. The concentrations of Cr and Mn for dry and wet season at the upper and lower profile were within NES limit of 1-1000 mg/Kg and 20-3000 mg/Kg for both seasons respectively and increases down the soil profile in dry season for dumpsite A.

Table 5: Physico-chemical characteristics of the water samples for dry and wet season in mg/l

Parameter	GWA	GWAc Dry	GWB Season	GWBc	GWA	GWAc Wet	GWB season	GWBc
Temp	24.4	24.67	25.15	24.2	29	30	29	29
Turbidity	0.28	3.63	2.43	4.29	0.94	4.73	0.93	18.2
EC	1105	416	150	146	1329	390	131	140
pH	7.4	7.35	7.47	7.41	9.1	9.8	12.3	8.8
TDS	821	219	69	75	906	220	91	70
DO	70	40	50	60	25	28	28	25
COD	2000	1850	1800	1800	160	150	160	200
BOD	30	20	20	20	16	5	4	10
NO_3	28.5	1.28	2.17	1.18	53.62	2.8	4.48	4.48
Zn	0.082	0.111	0.118	0.110	0.01	0.122	0.021	0.097
Fe	0.12	0.217	0.186	0.108	0.812	0.734	0.684	0.649
Cu	0.119	0.226	0.166	0.095	0.132	0.011	0.135	0.143
Pb	0.155	0.300	0.142	0.068	0.055	0.013	0.003	0.021
As	0.123	0.280	0.116	0.071	0.029	0.514	0.46	0.419
Cd	0.116	0.240	0.226	0.126	0.001	0.002	0.005	0.006
Cr	0.029	0.184	0.001	0.007	ND	ND	0.001	0.001
Mn	0.146	0.357	0.118	0.063	ND	0.004	0.014	0.001

Temp.(^{o}C), Turbidity (NTU) and EC (µs/cm)

Conclusion

The study revealed that the two dumpsites were still in their active stage, with high percentage composition of non-biodegradable solid wastes like glass, metal, polythene and plastic. The seasonal variation of solid waste composition in wet and dry seasons was due to the demanding period of the material. The study also revealed that the particles size analysis for the two dumpsites were sandy loam with high mean percentage of sand. Generally, the seasonal variations in concentration of the soil parameters increase from dry to wet season due to increase in leachate from the solid waste dumpsites and there was no defined pattern of concentration movement within the soil profile. The soil samples collected far away from the solid waste dumpsites (control) have lower concentration compared to those within the vicinity of the dumpsites and all the concentration of the soil parameters were within NES permissible limit. At 95% confidence level there was a significant difference between the Bio physico-chemical characteristics of the soil samples at the two dump sites. The effect of seasons on the Bio

physico-chemical characteristics of the soil samples was significant at 95% confidence level, due to increase in leachate from the solid wastes.

The groundwater analysis revealed that the temperature variations in groundwater were function of climatic conditions. The concentration of heavy metals like Zn, Cu, Pb, Cd, Cr and Mn decreases with rise in water table of an aquifer (dry to wet season) while, Fe and As increases from dry to wet season and this was in line with high concentration of Fe and As in the soil samples. The computed water quality index for the water samples ranged from 10.61-72.4, it was observed that the sampling wells were within the categories of excellent water quality, good water quality and poor water quality. Seasonal variation has advance effect on soil as the concentrations increases with increase in leachate in wet season, which in turn pollute the groundwater source. The uncontrolled accumulation of leachate over time at the dumpsites base will impose a significant threat to the groundwater quality.

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Frontal Car Crash Analysis Using Finite Element Modelling: A Case Study of Toyota Corolla 2005 Model.

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Abstract: *This paper uses a finite element method to conduct a simulation of a car crash by adopting explicit dynamic module. A Toyota corolla body frame was considered with body structure made of aluminium. Only frontal impact on a stationary barrier is simulated. When the car was modelled to crash into the barrier, different incoming speeds were taken into account. The highest total deformation occurred when the car was modelled with incoming speed of 120Km/h. The result of total deformation, directional deformation, equivalent stress and stress intensity of the crash test from the ANSYS simulation is displayed below for easy understanding of driver safety and crashworthiness.*

Keywords: *Crash test, Finite element method, crashworthiness, ANSYS, Total Deformation*

Introduction

In the vehicle industry, one of the design issues is safety. As a result, a crash test is a critical stage in validating automotive design. Cars designed to run on road are typically made for movement of one to eight passengers rather than goods. Therefore, vehicle manufactures have put a significant amount of money on vehicle structures. Because it affects the welfare of drivers and passengers, in consideration of safety in vehicle structure design. With time the focus of automobile safety technology has switched from increasing the rigidity of the vehicle body (the thicker the sheet metal, the safer the vehicle) to addition of bumpers on both end of the vehicle or creating a space for survival (for example, building a vehicle body that deforms to absorb impact energy) (Cherng *et al.*, 2014). Countries have established safety rules, therefore automobiles must undergo several crash test throughout the development stage to guarantee that safety regulations are met before they can be sold for use. The high cost of experimental testing, on the other hand, restricts the number of crash test that can be conducted, and as a result, sufficient data may not be gathered. Numerical modelling and simulation, in addition to experimental testing, have been widely utilized to research car crashes (Akshay *et al*., 2012).

Byeong *et al*., 2012, performed crash analysis was performed of upper body and sub frame for NEV electric car using LS-DYNA. NEV vehicle's front platform assembly behaviour when subjected to a frontal crash was described in the article. The analytical model simulation result predicted that the steel vehicle body frame for electric vehicle crash impact analysis performed upper body of the EV, and sub-frame comparative

analysis of the anterior almost no change in power transfer as a result to the passenger compartment, indicating that a significant strain was created.
An automobile crash analysis in non-linear transient dynamics was used in another study. Frontal and sideways collision analyses are performed during the crash test to determine the car's deformations. FEA is used to test the crashworthiness of automotive simulations. The chassis frame supports the weight of a heavy vehicle, and its purpose is to safely carry the vehicle's loads in all operating conditions. Different chassis components and vehicle structures should be supported by the chassis frame should be able to sustain both static and dynamic loads without distortion or deflection. On the created model, the frontal and side crash situations are evaluated, and the total deformations and stresses developed are calculated (Ananda 2012).
The computer simulation of an automobile crash study was done by Lin *et at.* 2014. They looked at two crash scenarios: a fast automobile driving into a wall and a fast automobile colliding into a stationary car. The goal of the study was to identify the probable sources of harm to the driver and passengers in the car accidents, as well as to develop a bumper model to determine its ability to sustain impact loads. Simulations on bumpers are carried out to ensure that the bumper design compiles with safety regulations.
Andrew and Shaoping, 2017, used the finite element approach to simulate a ford explorer 2002 model crash in wall. Incoming speed of the car was varied and observation shows different level of deformations. At a high speed of 100mph total deformation was approximately 1.8meters, which wrecked the car. To minimize weight, most automobile manufacturers use lightweight materials such as composites, aluminium, magnesium, or new forms of high strength steels. In the event of rupture, which is a regular occurrence during a car collision, these materials have limited strength or ductility. One of the implications of material joining failure is vehicle crashwothiness (Sadhasivam and Jayalakshmi 2014). In a car accident, the front-end of the vehicle absorbs a lot of the impact and deforms plastically. The majority of the automobiles are designed to improve absorption efficiency, as well as passenger safety and vehicle reliability (Sai *et al., 2017*). In a minor collision, a vehicle is intended to provide appropriate protection to the driver and passengers. Many new physical safety measures, including airbags, auto braking system control brakes, and traction control are available to protect car occupants. The accident response behaviour is a less visible aspect that drivers and passengers cannot observe. The car body and numerous components in a well-designed automobile serve as a protective barrier for the vehicle's occupants. They function as a crumpling zone for absorbing impact energy (Vamsi and Chandu, 2014).

In this paper, we digitally simulated a car slamming into a wall to better comprehend the disastrous consequence of car collisions and to investigate the safety of car occupants during impact on the frontal end structure of the car in a frontal hit. The fundamental goal of an accident investigation is to predict how the vehicle will react in the event of a collision. Vehicle body light weighing and crashworthiness are two important factors to consider while designing a vehicle.
The simulation can also be used to assess the safety of driver and passengers, help reduce cost of real case crash test and can be instrumental in the selection of material base on strength. A frontal crash of a real life case of a vehicle moving at around 100Km⁄h is shown in figure 1 below

Figure 1: - frontal crash of a vehicle at a speed around 100Km⁄h (Patil and Patil, 2021)

Car body alone was examined in this research to keep things simple. The model of the car in 3D form was generated using 3D modelling software SOLIDWORKS and the imported to the FEM analysis software ANSYS. The ANSYS workbench software was used mesh generation and also for the FEM analysis. We adopted Explicit Dynamic module and speed of the car was varied 80Km⁄h, 90Km⁄h, 100Km⁄h, 110Km⁄h and 120Km⁄h were selected for the crash analysis considering no difference in body dimension and material selected for the body frame.

Methodology

The 3D design made in the SOLIDWORKS was done to be a lookalike of the actual real life model of a car. The car under consideration for the purpose of this study is a 2005 Toyota Corolla model. The dimension of the car designed in Design Modeller was approximately same in width, length and height of the actual Toyota Corolla – keeping in mind only the body frame was designed. The car frame material was set as aluminium alloy and the barrier set as structural steel used in construction of bridges.

The next procedure was the mesh generation in ANSYS – which is the adopted software for this crash simulation. A tetrahedral mesh was generated on the car as shown in figure below. The finer the details the more nodes and element thus resulting to a better approximations. The model created was generated as a single body, this is to ease the operation of the computer during meshing and solution solving. The number of elements and nodes in the analysis are 24195 and 9500 respectively. The material of the car body is unchanged when varying the speed as well as the barrier material and position. Directional stress, strain and total deformation due to crash of the frontal surface on the barrier is the basis of the result analysis shown below.

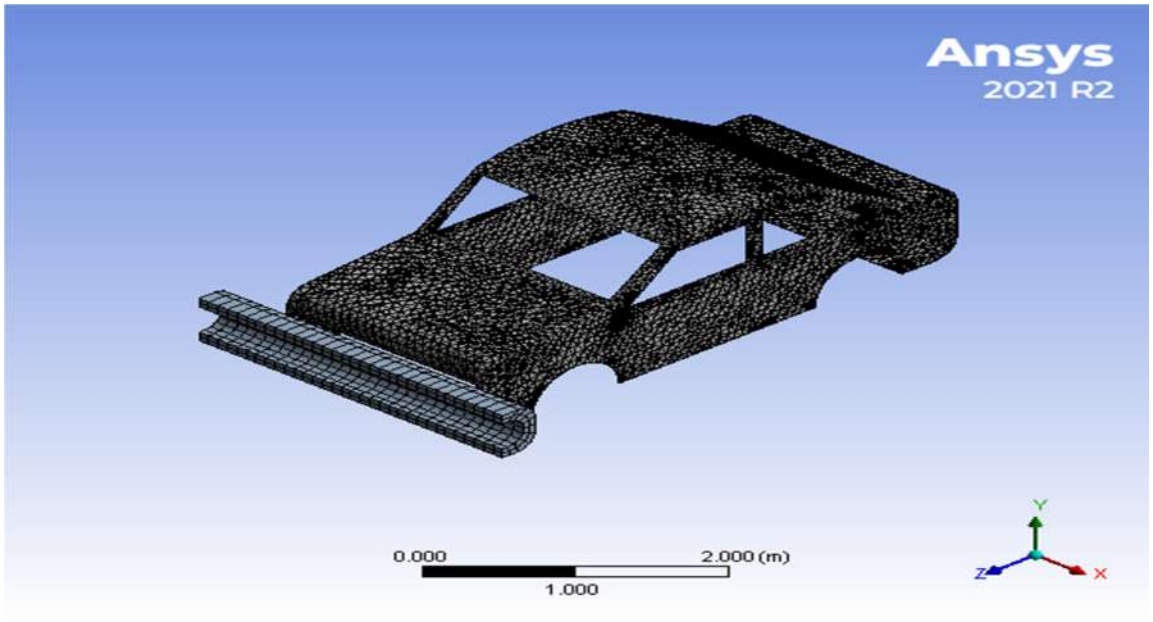


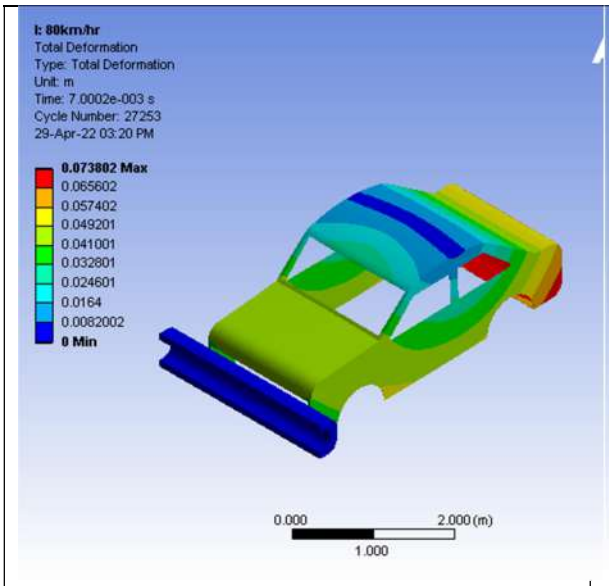
Figure 2:- Mesh generation of the car body

Result and discussion

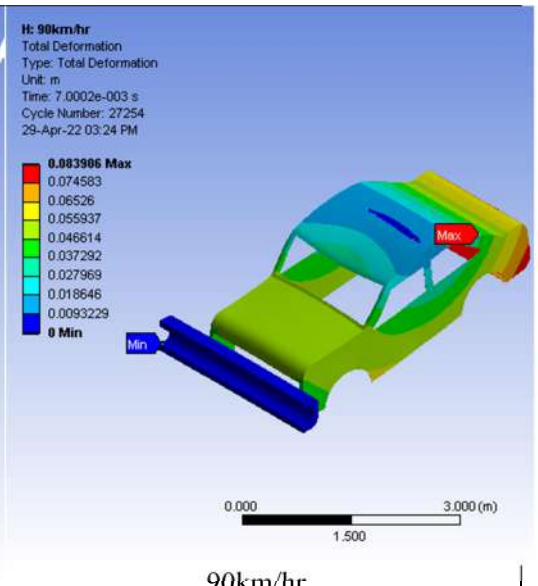
As stated above the speed varies from 80Km⁄h, 90Km⁄h, 100Km⁄h, 110Km⁄h and 120Km⁄h, Table 1 below shows the total deformation, equivalent stress, directional deformation and stress intensity at various speeds due to impact on the barrier. The profile of the total deformation and equivalent stress distribution of the car after impact is also shown in the figure 3 – 6 below. As seen in the Table, the maximum total deformation occurs in the highest speed which 11.2950 $\times 10^{-2}$ meters toward the driver and passenger in the vehicle as simulated in split seconds.

Table 1: Average and Maximum value of total deformation, directional deformation, equivalent stress and stress intensity at various car speeds.

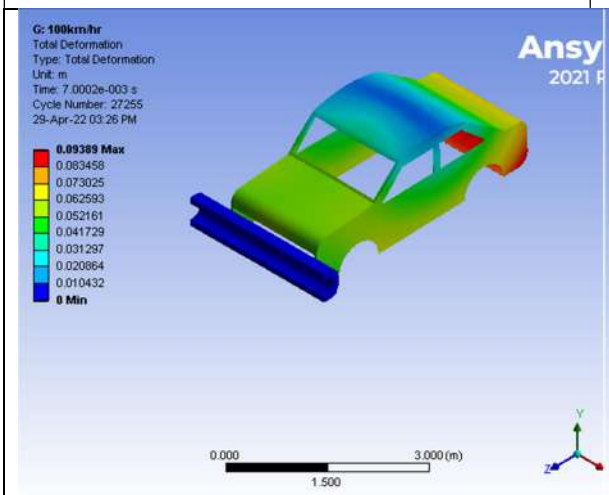
Car speed(Km/h)	**Total deformation $\times 10^{-2}$(meters)**		**Directional deformation $\times 10^{-3}$(meters)**		**Equivalent stress $\times 10^{9}$(pa)**		**Stress intensity $\times 10^{9}$(pa)**	
	average	max	average	max	average	max	average	max
80	3.4806	7.3802	-0.01448	7.0407	0.11305	1.2762	0.1207	1.2970
90	3.9752	8.3906	-0.02911	8.2253	0.1260	1.4538	0.1346	1.4811
100	4.4696	9.3890	-0.0299	9.5364	0.1388	1.6489	0.1482	1.6820
110	4.9487	10.3740	-0.2208	11.3610	0.1523	1.8430	0.1627	1.8807
120	5.4029	11.2950	0.0005	12.2900	0.1672	2.0592	0.1786	2.0999



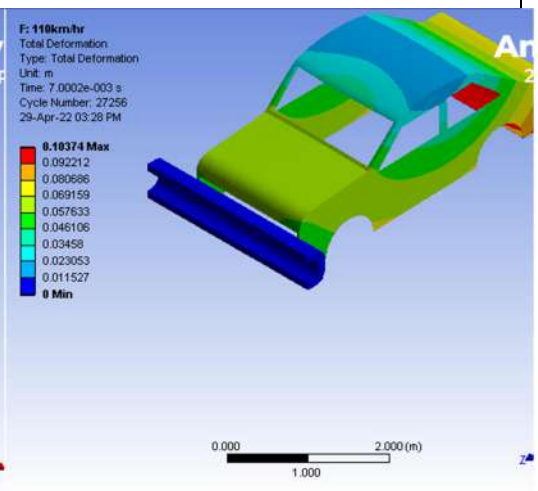
80km/hr



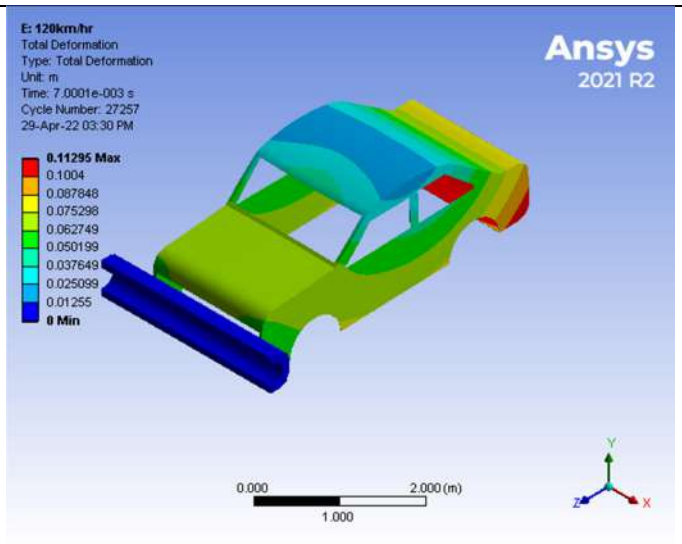
90km/hr



100km/hr

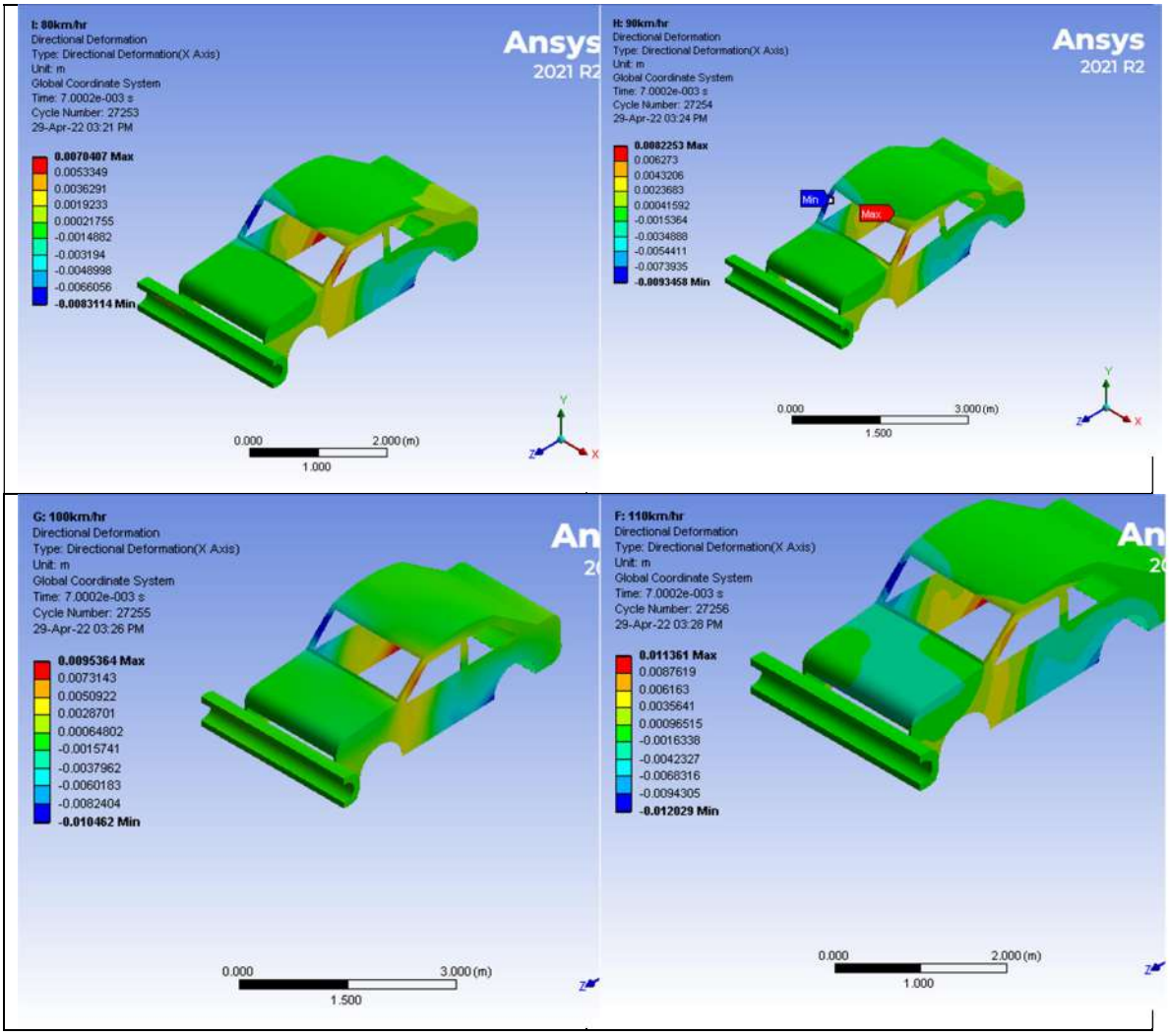


110km/hr



120km/hr

Figure 3: - Picture showing total deformation of car at 80Km⁄h, 90Km⁄h, 100Km⁄h, 110Km⁄h and 120Km⁄h respectively.



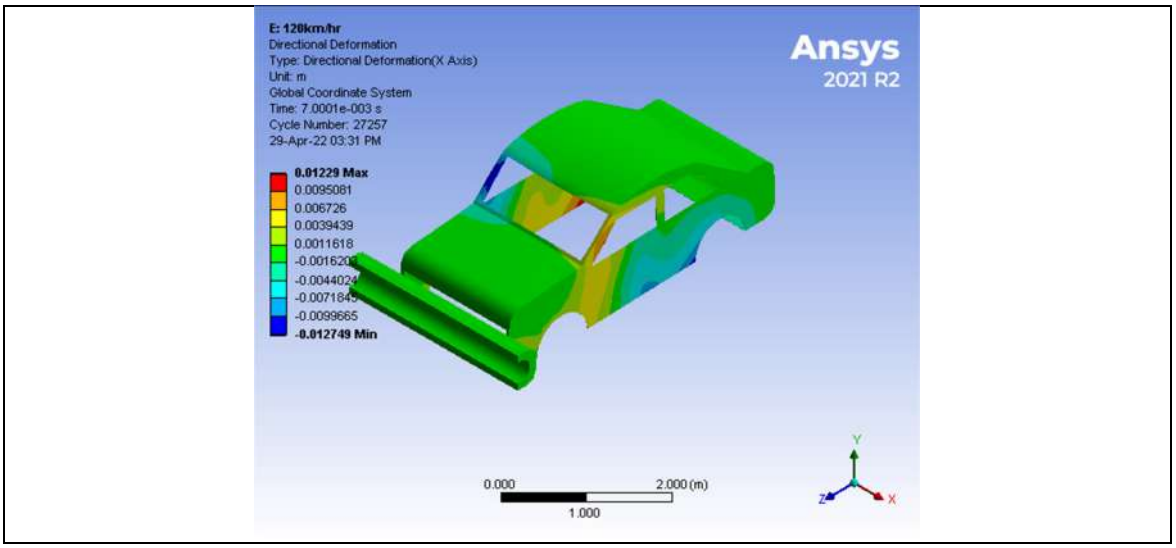
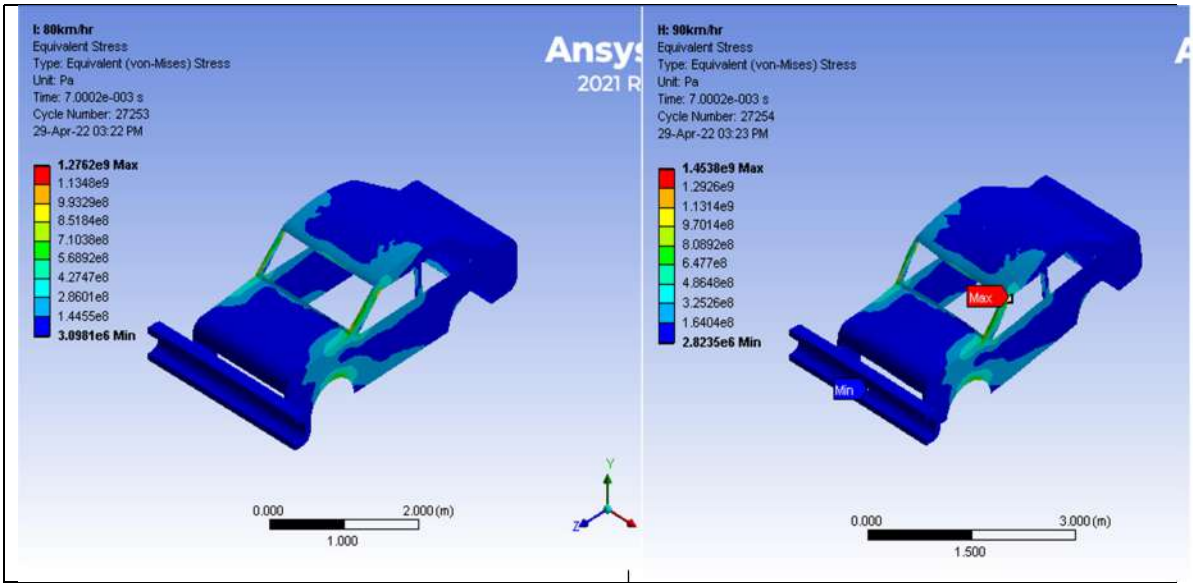


Figure 4: - Pictures showing directional deformation of car at 80Km⁄h, 90Km⁄h, 100Km⁄h, 110Km⁄h and 120Km⁄h respectively.



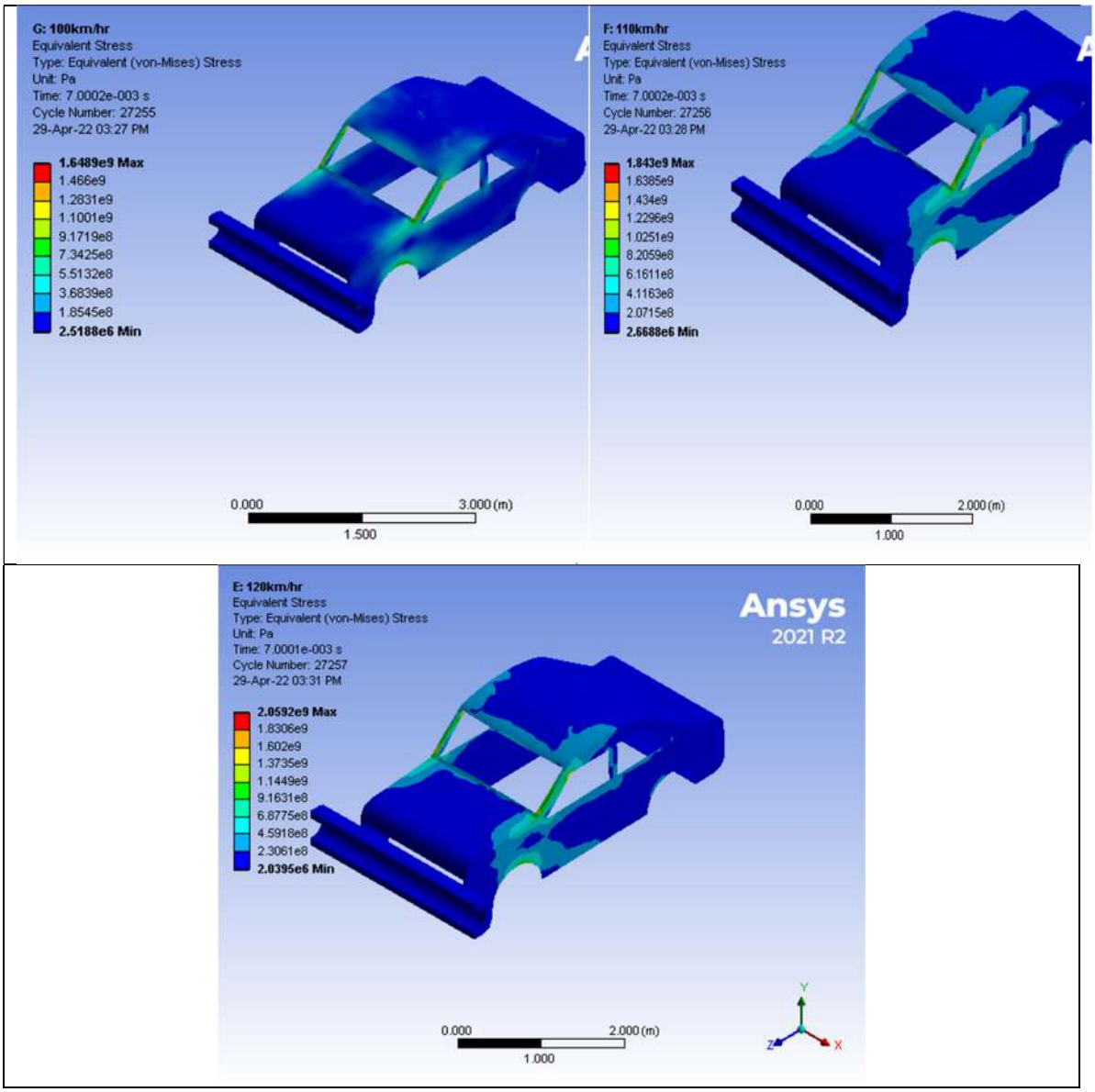
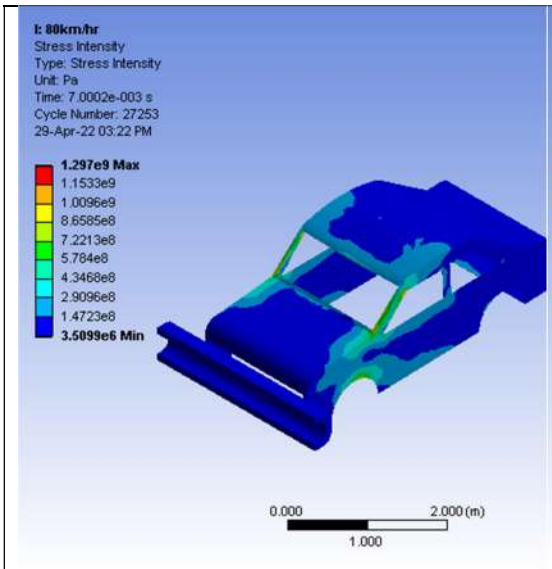
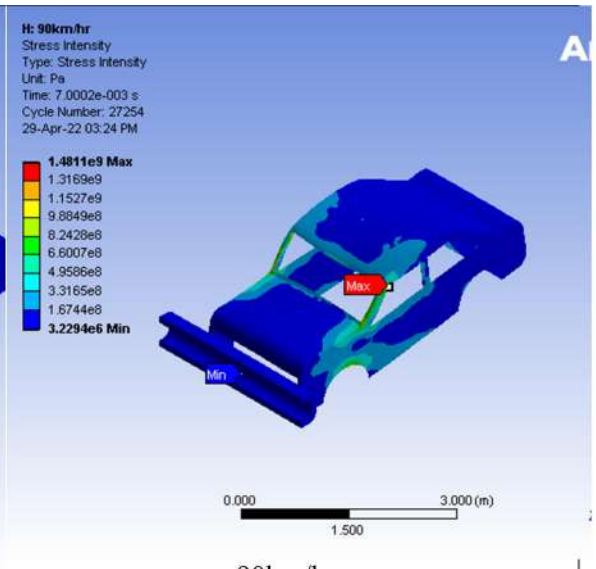


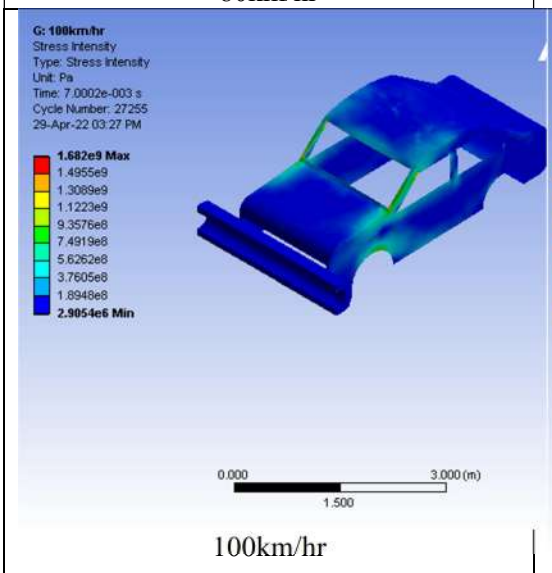
Figure 5: - Pictures showing equivalent stress of car at 80Km⁄h, 90Km⁄h, 100Km⁄h, 110Km⁄h and 120Km⁄h respectively.



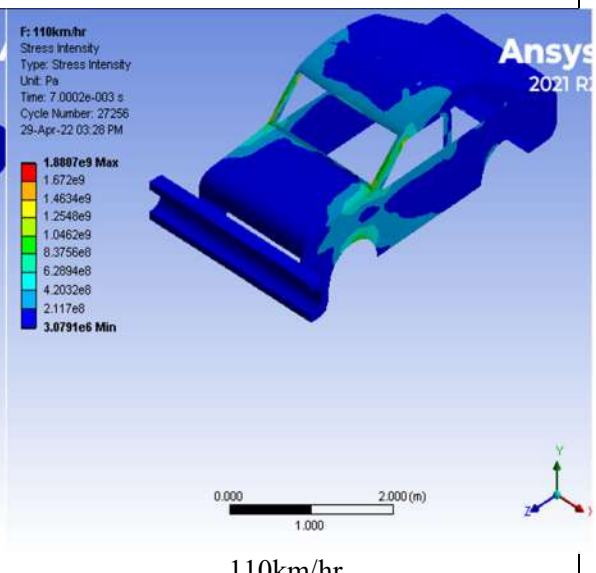
80km/hr



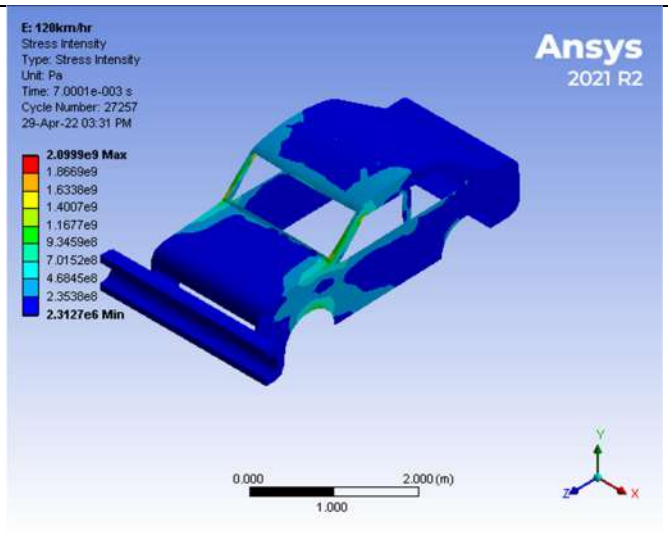
90km/hr



100km/hr



110km/hr



120km/hr

Figure 6: - Pictures showing stress intensity of car at 80Km⁄h, 90Km⁄h, 100Km⁄h, 110Km⁄h and 120Km⁄h respectively.

When comparing the visual deformation between the simulation and what might happen in a real life there might be discrepancies. One of the major causes is the time of simulation and difference in car dimension. However, it is not expected that SUV would deform same way as smaller cars. A probable explanation for this occurrence is that the simulation only employed the automobile's frame – not including the chassis, engine and interiors as the real life test will (Praveen and Sandeep, 2018).

Conclusion

For years, automobile companies have been using numerical modelling and simulation to simulate car crashes. FEM analysis can produce realistic result to assist engineers understand how different crash situations affect vehicles. Simulation automobile crash using software like ANSYS is far more cost effective than performing real-life scenarios. The results of the simulations were validated comparing to Andrew and Shaoping, 2017 crash test conducted on ford explorer. Although dimensions differ but it can be observed that the frontal has the most total deformation distribution. Due to limited resources of computer available a simpler model was chosen and the crash initiation time was in millisecond. A more exact model would be necessary for a more accurate outcome, but the computer resources required for the simulations would be significantly greater. As a result, a compromise had to be established so that the simulation could be run without too much deviation in the results.

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