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Physicochemical and Bacteriological Assessment of Drinking Water Sources in Achusa Community Benue State, Nigeria

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Abstract:
This study was aimed at determining the physicochemical and bacteriological properties of hand dug wells and boreholes in Achusa community, Benue State, Nigeria. For this study a total of 16 water samples were collected from 4 Boreholes, 4 brands of sachet water commonly consumed within the locality, and 4 hand dug wells. The analyses for 13 physicochemical parameters were carried out in the laboratory using the PalinTest water test instructions manual on photometer method, 2014 while bacteriological assessment of the samples was carried out using the membrane filtration method and the results compared with World Health Organization (WHO) and Nigerian Standards for Drinking Water Quality (NSDWQ) guideline values. Results showed that Most of the physicochemical parameters were in compliance to the WHO/NSDWQ guideline values especially from the sachet water samples. However, some borehole samples were above the given standard value which included iron with mean values of 0.32mg/l, 0.35mg/l, and 0.41mg/l. Well samples with higher mean values included turbidity 6.0mg/l, 39.85mg/l, chloride 327.50mg/l and nitrite 2.07mg/l. Bacteriological properties of the sachet water samples were also in compliance with the compared standard values. Total viable counts above WHO/NSDWQ standard values were obtained from well samples with values of 128cfu/100ml and 131cfu/100ml. total coliform count in borehole samples included 12cfu/100ml and 15cfu/100ml while in well samples were both 20cfu/100ml. however it was interesting to note that a particular well sample had no TVC or TCC or E. coli count present. Bacteria isolates of pathogenic importance isolated in this study were E. coli, Faecal streptococcus, Salmonella species, Pseudomonas species, Bacillus species and Vibro cholerae. Based on these results the boreholes and sachet water sources were found to be better for drinking than the well water sources.

Keywords: borehole, guidelines, parameters, sachet water, standard wells.

INTRODUCTION

Studies have shown that over one billion people in the world lack access to safe drinking water and 2.5 billion people do not have access to adequate sanitation services (Tar *et al.*, 2009). Drinking water in developing countries especially in Nigeria in particular is susceptible to toxins as a result of effluents and pollutants (Dabi and Jidauna, 2010; Jidauna et al., 2013). Most communities in Nigeria are faced with the challenges of poor waste management system especially within the township. Indiscriminate waste disposal coupled with bad land practices are common scenes that can easily pollute water bodies and consequently degrading the water quality (Dabi and Jidauna, 2010).

Majority of the human population in semi-urban and urban areas in Nigeria are heavily reliant on well water as the main source of water supply for drinking and domestic use due to inadequate provision of potable pipe borne water. These ground water sources can easily be contaminated by faecal matter and thus increase the incidence and outbreaks of preventable water-borne diseases (Alonge et al., 2018). The Nyiman, communities in the South Region of Makurdi, Nigeria have a lot of wells and an increase of boreholes which provide drinking water to curb the acute water shortages experienced by the inhabitants, there are various improperly managed sanitation systems, including Ventilated Improved Pits (VIPs).

Water is an essential element for life but when polluted it may become undesirable and dangerous to human health (Aremu *et al.*, 2011). Poor water quality and Water pollution is a main global problem, a leading cause of diseases and deaths thus the need for evaluation and revision of water resources at all levels (Sibanda *et al*., 2014). The purity of water depends on its source, treatment received and storage facilities available (Ishaku *et al.*, 2010). Ground water serves as a source of water for many people; however, can be contaminated by biological and chemical pollutants arising from point and non-point sources (Venkateswara, 2010). Irrespective of sources, domestic water supply should be water of high quality, while water for other uses can be of moderate quality (Agrawal and Jageta, 2009).

Packaged water is any potable water that is manufactured or processed for sale which is sealed into food-grade bottles, sachet or other containers and intended for human consumption (Warburton, 2000). Sale of packaged water has exploded all over the world in recent years, largely as a result of public perception that it is safe, taste better and has a better quality compared to raw tap water (de França Doria et al., 2009; Fisher et al., 2015).

Packaged water has been implicated as a source of outbreak of cholera and typhoid fever as well as traveller's disease in countries such as Portugal and Spain (Bordalo and Machado, 2014). Several studies have shown that packaged water can be contaminated with bacteria at various stages of production (Semerjian 2011; Gangil et al., 2013). Under improper or prolonged storage of bottled water, bacteria can grow to levels that may be harmful to human health (Warburton, 2000). Accurate and timely information on the quality of water is necessary to shape a sound public policy and to implement the water quality improvement programme efficiently.

Previously no study has been done on the drinking water statue of Achusa community hence, it is interesting to carry out an analysis of the physicochemical and bacteriological quality of drinking water sources in Achusa community in Makurdi area of Benue State, this will reveal the quality and level of purification of their water sources and ascertain the extent of safety for drinking or if the water consumed poses threats to the health of consumers. This will serve as a forecast in tackling water borne diseases and creation of awareness to people living within the community.

MATERIALS AND METHODS

Description of the Study Area

According to Kogbe *et al,* (1998), Makurdi metropolis, the capital city of Benue State Nigeria is located within the Niger-Benue trough along the bank of the River Benue.

The town is located between latitude 7°30:7°431N and longitude 8°30:8°351E. The mean monthly temperature is between 22°C-38°C and the mean annual rainfall range is between 150mm-180mm. The town has a typical high tropical climate with two clearly marked out seasons: rainy

season which is prolonged and starts from the month of April to early October and the dry season that begins in late October and ends in March. During the prolonged rainy season, most areas become swampy and wells become filled up due to the low water table of the town. The lack of pipe-borne water throughout 95% of the town, causes residents to resort to constructing hand dug wells or drilling boreholes. The people of Makurdi are predominantly civil servants and farmers. The most spoken languages are Tiv, Idoma, Igede and Etulo. (Eneji *et al* 2012).

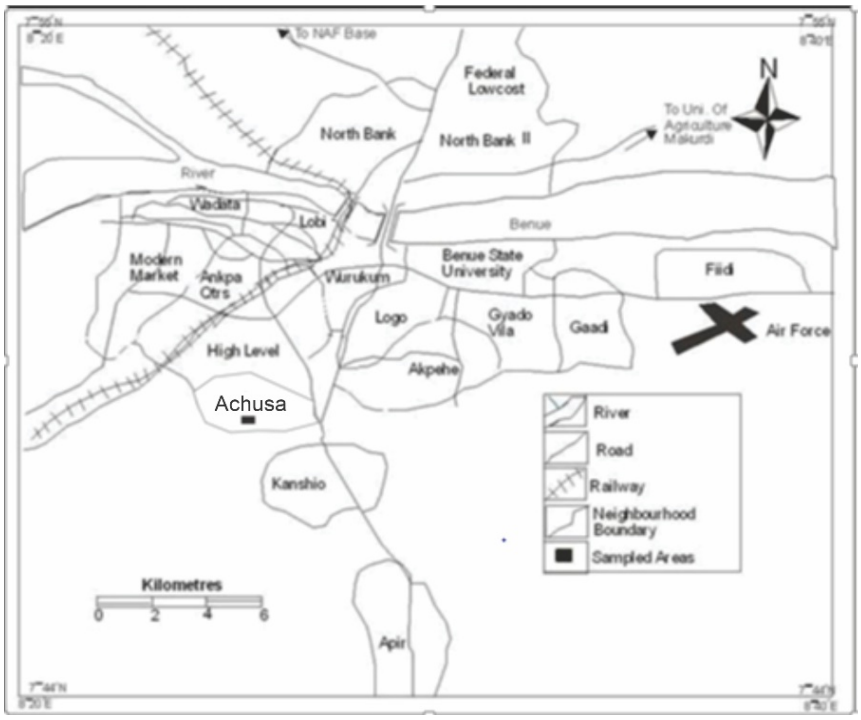

Figure 1: Map of Makurdi showing the sampled area.
Source: Ministry of Lands and Survey Makurdi, 2013

Water Sample Collection:

Sample collection was taken randomly from Nyiman. A total of 16 samples of water from 4 hand dug well and 4 boreholes. Samples were labelled B1, B2, B3, B4, S1, S2, S3, S4, W1, W2, W3, W4, (B for borehole and W for well water samples) for easy identification. Water samples were taken twice in a month from April to September 2019, three replicates were collected per source. Well water sample was collected directly from each well by means of a sterile plastic container fitted with a weight at the base; taking care to avoid contamination by surface scum. The outlet of each borehole was disinfected using cotton wool soaked in 70% (v/v) ethanol and was allowed to run for at least five minutes before taking the sample into a sterile plastic container. The water samples were transported to Benue State Rural Water and Sanitation Agency (BERWASA) laboratory in insulated containers with ice, samples were stored in a refrigerator at a temperature at 4^{o}C, according to the method prescribed by American Public Health association (APHA, 2002) and analyzed within twenty-four hours of collection.

Methods

Physicochemical Analysis:

The water samples collected were analyzed for turbidity, electrical conductivity, pH, total dissolved solids (TDS), total hardness, chloride, nitrate, nitrite, sulphate, iron, copper, manganese and fluoride using the PalinTest water test instructions manual on photometer method, 2014. Turbidity levels of the water samples were determined using the Wagtech turbidity meter. The

pH of the water samples was determined using the Wagtech pH meter. Electrical Conductivity and Total Dissolved Solids were determined using the Wagtech Conductivity and TDS meter. While determination of Chloride, Nitrate, Nitrite, Total Hardness, Iron, Copper, Manganese and Fluoride concentrations were analyzed using the Wagtech photometer 7100 model.

Bacteriological Analysis:

The membrane filtration method of water analysis was employed. Membrane filters of 0.45µm pore size with diameter of 47mm were used in line with recommendations by APHA, 2002. 100mls each of water samples, from different locations, were filtered and the bacteria isolated and identified using the methods described by Cheesbrough (2006) and APHA (2002).

Isolation of Microorganisms:

Membrane filtration technique was used to isolate the microorganisms present in the water samples. The funnel of the membrane filtration unit has a capacity of 50ml and the funnel was mounted one receptacle fixed to the vacuum pump which allows the water to flow over the porous sterile membrane filter (0.45µm). Aseptically, the membrane filters were placed on each microbial growth medium using sterile forceps after passage of 100ml of water sample. The following media Membrane Lauryl Sulphate broth was used to isolate only total and thermotolerant coliforms, (Baired Parker broth, McConkey broth, Plate count broth, Potato dextrose broth and Pseudomonas broth base) were prepared and autoclaved at 121^{o}C for 15 minutes at 15lb before being inoculated with membrane filters. (Buchanan and Gibbons, 1994)

The Method of Data Analysis:

GenStat 2014 was used to analyze the data. Data were represented as mean. Tables were used to present the results. Analysis of variance (ANOVA) was carried out using the statistical package for the social science (SPSS version 20.0) software.

RESULTS

Table 1: Mean concentration of values of physicochemical properties of borehole water samples

Parameters	B1	B2	B3	B4	WHO	NSDWQ
Turbidity (NTU)	0.15	0.18	0.15	0.13	5.00	5.00
Conductivity mg/l	219.50	230.00	191.00	218.00	500	500
TDS mg/l	117.00	123.00	127.00	136.00	500	1000
pH	7.77	6.68	7.30	7.40	8.5	8.5
Total hardness mg/l	42.50	47.50	45.00	64.00	150	150
Chloride mg/l	41.00	64.00	32.00	44.00	250	250
Iron mg/l	0.32	0,35	0.27	0.41	0.3	0.3
Nitrate mg/l	3.22	4.14	3.18	3.14	10	50
Nitrite mg/l	0.03	ND	0.05	0.03	0.2	0.2
Sulphate mg/l	1.00	22.00	7.00	20.00	500	100
Copper mg/l	0.16	0.11	0.02	0.12	1	1
Manganese mg/l	0.16	0.11	0.02	0.12	0.2	0.2
Fluoride mg/l	1.42	1.56	1.41	1.46	1.5	1.5

Table 2: Mean concentration of values of physicochemical properties of well water samples

Parameters	W1	W2	W3	W4	WHO	NSDWQ
Turbidity (NTU)	2.55	39.85	4.15	6.00	5	5
Conductivity mg/l	250.00	119.00	230.00	130.00	500	500
TDS mg/l	135.00	58.70	137.00	193.00	500	1000
pH	7.30	7.01	6.85	7.00	8.5	8.5
Total hardness mg/l	42.50	54.00	72.50	88.00	150	150
Chloride mg/l	327.50	200.00	155.00	261.00	250	250
Iron mg/l	0.08	0.05	0.06	0.04	0.3	0.3
Nitrate mg/l	2.57	2.80	4.02	3.10	10	50
Nitrite mg/l	0.03	2.07	0.05	0.08	0.2	0.2
Sulphate mg/l	18.50	15.50	11.00	31.00	500	500
Copper mg/l	0.16	0.14	0.14	0.18	1	1
Manganese mg/l	0.08	0.14	0.14	0.18	0.2	0.2

Table 3: Mean concentration of values of physicochemical properties of sachet water samples

Parameters	S1	S2	S3	S4	WHO	NSDWQ
Turbidity (NTU)	0.10	0.04	0.07	0.01	5	5
Conductivity mg/l	210.00	192.00	215.00	138.00	500	500
TDS mg/l	104.00	110.00	102.00	99.00	500	1000
pH	7.40	7.50	7.00	7.05	8.5	8.5
Total hardness mg/l	32.00	44.00	47.00	38.00	150	150
Chloride mg/l	48.50	102.00	57.00	62.00	250	250
Iron mg/l	0.05	0.13	0.12	0.19	0.3	0.3
Nitrate mg/l	3.01	3.26	3.41	3.06	10	50
Nitrite mg/l	0.04	ND	0.02	0.03	0.2	0.2
Sulphate mg/l	9.50	1.00	ND	2.00	500	100
Copper mg/l	0.02	0.13	0.05	0.04	1	1
Manganese mg/l	0.02	0.13	0.05	0.04	0.2	0.2
Fluoride mg/l	1.21	1.32	1.10	0.88	1.5	1.5

Table4: Bacteriological properties of borehole, sachet and well water samples

Sample Water	Total viable count cfu/100ml	Total coliform count cfu/100ml	Faecal coliform or *E. coli* count cfu/100ml
B1	8	6	3
B2	50	15	4
B3	55	12	6
B4	40	10	2
S1	8	4	2
S2	6	2	2
S3	9	0	0
S4	1	0	0
W1	0	0	0
W2	128	20	4
W3	131	12	8
W4	80	20	6
NSDWQ	100	10	0
WHO	100	10	0

Table 5: Bacterial isolates from drinking water sources (borehole, sachet and well)

Water samples	*E. coli*	*Faecal streptococcus*	*Salmonella spp*	*Pseudomonas spp*	*Bacillus spp*	*Vibro cholera*
B1	+	+	+	-	+	-
B2	+	+	-	+	+	-
B3	+	+	-	-	+	+
B4	-	+	-	+	-	-
S1	-	-	-	-	-	-
S2	-	-	-	-	-	-
S3	-	-	-	-	-	-
S4	-	-	-	-	-	-
W1	+	-	-	-	-	-
W2	+	+	+	-	+	-
W3	+	+	+	+	-	-
W4	+	-	-	-	-	+

+ Present, - Absent

DISCUSSION

The importance of good and safe drinking water cannot be overemphasized as regard to the health of the population. Turbidity defines the presence of suspended solids in water and causes the muddy or turbid appearance of water body (Tiwari *et al.*, 2015). In this study, Turbidity values of boreholes and sachet water samples had mean concentration values below 5 NTU. However, high turbidity values were recorded in well samples with values of 6.0NTU and 39.85 NTU which were far above the WHO/NSDWQ guideline limit on turbidity. High turbidity values is an indication of high presence of inorganic particulate matter and non-soluble metal oxides which are usually responsible for high turbidity values. High turbidity values in well water were also reported in similar findings in Makurdi, Benue state by Akaahan *et al.* (2016), Taraba state by Odoh *et al.* (2018) and Zangu, Kaduna state by Ali *et al.* (2012). The authors recorded turbidity values ranging as high as 5.70 NTU-49.0 NTU in well water samples. Due to the unlined structure of the wells, Soil particles may find their way into the water sources either through runoff or from the unstable side walls thereby increasing turbidity of the water sources.

The conductivity and Total Dissolved Solids (TDS) and total hardness values across the water sources studied were within the maximum permissible values of WHO/NSDWQ guidelines. These results are also similar when compared to the findings of Adenkunle *et al.* (2007), Apkoveta *et al,* 2011 and Malek *et al,* (2019) who observed low conductivity and TDS values in drinking water sources. pH is a term used universally to express the intensity of the acid or alkaline condition of a solution. The pH of samples of bore holes, sachet water and well samples had normal pH values however, this contradicts the works of Yusuf *et al.* (2015) in their studies on well water samples in Zaria, Kaduna State, documented a high alkalinity of the studied water samples. Adefemi *et al.* (2007) reported that high alkalinity in water is due to certain human activities near water sources. The concentrations of Iron and manganese were within the maximum permissible limit of WHO/NSDQW guideline value which implied that iron and manganese did not contribute to the pollution of the water sources. this result agrees with the findings of Adekola *et al*, (2015) and Odoh *et al,* (2018) who reported minimal concentrations of iron and manganese in well and borehole samples in Benue and Taraba states, Nigeria respectively.

Copper contaminated water is responsible for health hazards such as abdominal pains, nausea, vomiting, diarrhea, headache, and dizziness (Okeola *et al.*, 2010). Moreover, high copper

concentration in water influences the rapid deterioration of aluminum utensils and galvanized steel fittings. The mean concentration values of copper recorded in this study were low and below 1.0 mg/l which is the maximum permissible limit Low concentration values of copper were also observed from the findings of Apkoveta *et al*, (2015) in Edo state and Odoh *et al*, (2018) in Benue State.

Mean values of nitrate obtained in all the water samples were within the acceptable values of WHO/NSDWQ guideline limit of 10 mg/l and 50 mg/l. this implies that there was no significant indication of the water being polluted by nitrate however, Nitrite's concentration in the well sample contributes significantly to the pollution status of the well water. Nitrite in drinking water is an important risk factor, for bottle-fed infants (under three months) given increases in asphyxia (blue baby syndrome) and possible cyanosis (Tiwari *et al.,* 2015). These results are similar to the findings of Malek *et al,* (2019) who reported absence of water pollution by nitrate compound in well water samples from Sedrata, Algeria. Odoh *et al,* (2018) also reported similar result in well water samples from Oturkpo, Nigeria.

Fluoride concentration in the sample location were within the permissible limit of WHO and NSDWQ. Similar reports were observed by Sadrina *et al.* (2013) in Legoon valley, Cameroan; Shigut *et al.* (2017) in Robe town, Ethiopia and Adekola *et al*. (2015) in Taraba state Nigeria. High concentration of fluoride contaminant in ground water tends to be found in association with crystalline rocks containing fluorine rich minerals especially granite and volcanic rocks. Fluoride has long been found to have beneficial effect on dental health as such it is an additive in toothpastes and food. However, when present in drinking water at concentration much above the guideline value of 1.5mg/l, long term use can result in development of dental fluorosis or at its worst, crippling skeletal fluorosis (Nishtha *et al.,* 2012). It is important for water managers to constantly monitor this parameter as other studies within the North central region have also revealed high incidence of water samples showing high fluoride concentrations.

It is interesting to note that a particular well sample had no record for total viable counts (TVC) or total coliform count (TCC} or presence of *E. coli.* This also implies that well water sources if properly handled can as well be safe for drinking and other domestic purposes. The TVC of microbes in the borehole and sachet samples were within the maximum permissible limit of NSDWQ guidelines whereas for well samples. Total coliform count (TCC) across the samples in this study had the presence of coliform count highest in well and borehole samples. Sachet samples had no coliform count. Presence of coliform in the well and borehole sample indicates the presence of contaminants in the water. Presence of *E. coli* were observed highest in the well and boreholes and a few sachet water samples, this indicates the extent of faecal contamination in the water sources. This result varies from the findings of Ali *et al.* (2012) who observed TCC and *E. coli* counts within the maximum permissible limit set by NSDWQ. Also, their findings indicated low level of faecal contamination in well water in Zangu Kaduna State.

The number of both total and faecal coliform bacterial were found to be similar to that found by Yusuf *et al.* (2015), Magami *et al.* (2013), Casanova *et al.* (2001) among other researchers. Adeboyega *et al.* (2015) documented those proper excreta disposal and improvement in general hygiene would enhance the quality of *E. coli* infested wells and borehole water sources and reduce possible infection by the indicator bacteria.

Virtually all the samples of sachet water analyzed in this study exhibited values of physicochemical and mean coliform and *E. coli* counts per 100 ml below the WHO/NSDWQ, maximum permissible levels except for sachet samples S1 and S2 in Achusa sample location. This may be attributed to the level of treatment of water sources before packaging for sale. It could be attributed to the total adherence to strict quality assurance procedures in the production premises of the companies concerned.

Contamination may however come from handling from person to person or where the sachet water was kept. The results of the physicochemical and bacteriological assessment of the collected sachet water samples agrees with earlier works done in Zaria (Yusuf *et al.* 2015), Abuja (Atiku *et al.*, 2017) and Ota (Chinedu *et al*., 2011). It is noteworthy, however, that some assessment of sachet water brands vended in Kebbi, Kalpana *et al.* (2011), Ogbomoso, Oladipo *et al.* (2009) have physicochemical values of concern and evidence of faecal coliforms. These varying reports highlights the need for ongoing implementation of the several legislations put in place by National Agency for Drug Administration and Control (NAFDAC) in Nigeria, and continuous monitoring to increase reduction in the sales of contaminated brands of sachet water and this may be the reflection of what we have observed in this study.

Bacteria isolates of pathogenic importance isolated in this study were *E. coli*, *Faecal streptococcus*, *Salmonella* species, *Pseudomonas* species, *Bacillus* species and *Vibro cholerae*. These microbes have been reported to be associated with various water borne diseases and their control depends on being able to assess the risks from any water source and to apply suitable treatment to eliminate the identified risks. Similarly, these microbial isolates were observed in studies in Cameroon (Tamungang *et al.*, 2016), Abeokuta (Shittu *et al.*, 2008), Algeria (Malek *et al.*, 2019), and Abuja (Atiku *et al.*, 2017) in their studies on bacteriological assessment on drinking water sources.

CONCLUSION

In this study, water samples from borehole, sachet and well of Achusa communities in Makurdi, Benue State, Nigeria were analyzed for physicochemical and bacteriological properties of the water sources to predict the drinking water quality status. Most of the results of the physicochemical parameters were within the maximum permissible limits of WHO/NSDWQ drinking water guidelines. However, physicochemical parameters that were above the maximum permissible limits of WHO/NSDWQ drinking water guidelines includes turbidity, chloride, nitrite, iron and fluoride which also implied that the parameters individually contributed to the pollution status of the water sources.

Bacteriological properties of the water sources also showed that Total Coliform Count (TCC) and *E. coli* counts were above maximum permissible limits of NSDWQ in boreholes and well samples indicating higher level of faecal contamination in the drinking water sources. Minimal contamination was observed in the sachet samples. Bacterial isolated from the water samples in order of their presence includes, *E. coli, Faecal streptococcus, Salmonella* species, *Pseudomonas* species, *Bacillus* species and *Vibrio cholerae* with the least presence Based on these results, it can be deduced that most sachet water and borehole water samples were more suitable for drinking than some well water sources.

Based on the findings in this study the following recommendations are suggested
(a) Drinking water quality routine should be done on a regular basis across communities. (b} Health education: this is to explain the importance of clean water and the relationship which exists between water, health, hygiene and sanitation. (c) Wells and bore holes should be properly located and constructed to avoid contamination of drinking water. {d) NAFDAC and other agencies should be monitoring the quality of water sold in packaged forms in order to ensure satisfactory quality. {e) Water sources for private use should be disinfected either by boiling to eliminate any trace of faecal contamination before drinking.

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Evaluation of Heavy Metal Contents in the Leaves, Stem and Rhizospher Soil of Selected Medicinal Plants Growing in Selected Polluted Sites in Makurdi-Nigeria

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Abstract:
The study assessed the concentration of Lead (Pb), Iron (Fe), Copper (Cu), Manganese (Mn) and Cadmium (Cd) in selected medicinal plants, Azadirachta indica and Phyllanthus niruri; the rhizosphere soil in mechanic and dump sites on which the plants were growing Analysis of selected heavy metals was done using Atomic Absorption Spectrophotometer (AAS) machine. Statistical analysis was done using analysis of variance (ANOVA) at a probability level of 0.05. From the results, it was shown that, Pb, Cd, Fe, Cu and Mn were generally higher in the rhizosphere soil and leaves than in the stems of the medicinal plants (A. indica and P. niruri). P. niruri accumulated more of the heavy metals than A. indica. There were significant differences in heavy, metals concentrations among the leaves, stems of the medicinal plants and rhizosphere soil at P≤0.05. Heavy metals concentrations in sampled plants in the polluted sites were higher than those of the control sites and were statistically significant (P≤0.05). Comparing with WHO standard, the heavy metals investigated where within the acceptable set limits. However, their presence in the investigated plants calls for concern as accumulation over time may increase the level of these metals above set limits. Based on the findings, the study recommended that medicinal plants for therapeutic use should be obtained away from polluted environments and that sorting and recycling of wastes should be intensified to reduce the quantity of these toxic metals in the dumpsites which can subsequently be leached into the soil where they could be taken up by plants.

Keywords: Heavy metals, Medicinal plants, Soil, Stem, Leaves, Polluted sites.

INTRODUCTION

Environmental contamination of pollutants is on increase and the uptake by plants is a problem of significant concern for ecological, evolutionary, nutritional and environmental reasons [1]. Metal contamination issues are becoming increasingly common in Nigeria as reflected in many documented cases of metal toxicity. They are natural part of the environment in soil, rock, air and water with a few metals like Fe, Cu, Mn, among others being essential to plant metabolism in trace amounts but harmful when present in bio available forms at excessive levels [2]. Human beings, animals and plants take up these heavy metals from all possible environments like soil, air, water. These metals have the tendency to accumulate in various plants and as well as in human organs. Since plants and animals contain essential nutrients for man either through dietary sources and various herbal preparations, it is necessary to monitor the levels in biological systems that are explored by man for both dietary and medicinal purposes because deficiencies or excesses of nutrients can be a threat to good health.

The author in [3] defined medicinal plants as any plant which provides health promoting characteristics, temporary relief from symptomatic problems or has curative properties to ailments. Heavy metal is a general term used to classify a group of metals or metalloids with an atomic density greater than 5g/cm^3 [4-5]. They have been reported to play positive and negative roles in human life. Some heavy metals like Cadmium (Cd), Lead (Pb) and Mercury (Hg) even in trace amounts, are considered very harmful to the environment since they do not biodegrade while others like Iron (Fe), Zinc (Zn) and Copper (Cu) are essential for biochemical reactions in the body [6-8].

Moreover, uptake and accumulation of heavy metals in plants is influenced by attributes such as natural occurrences derived from parent material (rock), atmospheric deposition (depending on traffic density), concentration and bioavailability of heavy metals in soil (through addition of pesticides, herbicides, and fertilizers), the nature of soil where herbs are grown (pH and organic matter concentration), individual plant performance (degree of maturity of the plant, time of harvest) [9,10]. These metals accumulate in the living tissue and may affect the central nervous system, kidneys, liver, brain, skin which will in turn impact negatively on memory and reproductive systems [11,12].

Soil is recognized as a repository for pollutants due to the absorption processes which binds inorganic and organic substance to it [13]. Soil to plant transfer of heavy metals is the key process of human exposure to heavy metals through the food chain, top soil and soil near heavy traffic roads in urban areas are indicators of heavy metals contamination from atmospheric deposition [14]. Therefore, the use of herbal medicine derived from medicinal plants in polluted areas raises concern in relation to its safety, as there is a wide misconception that 'natural' means 'safe' [15]. In line with these assertions, this study posits the determination of heavy metal concentrations in the soil, stem and leaves of some medicinal plants growing in selected polluted sites in Makurdi.

MATERIALS AND METHOD

Analytical reagent grade (Analar) chemicals, deionized and distilled water were used throughout the study. All glasswares and plastic containers were washed with detergent in running tap water, followed by rinsing with Nitric acid (HNO_3) and distilled water [16].

Sample Collection and Preparation

Medicinal plant samples and corresponding soil rhizospheres were randomly collected in triplicates from four locations within Makurdi metropolis. The sampled plants specimens were taken to the Department of Biological Science, Benue State University Makurdi for identification and confirmation. The locations for the sampling were: a mechanic site at Kanshio and an abandoned dump site along university of agriculture road, all within Makurdi, Benue state. Each site had a control 250 m away from it. Soil samples were collected at a depth of 0-15cm using a stainless-steel soil auger (2.5 cm diameter). The samples were pulled together as composite and wrapped in moisture free polythene bags, labelled accordingly and conveyed from the field to the laboratory for pre-treatment and subsequent analysis [17]. Collection of samples was done from July to September. The plant samples were thoroughly washed with tap water and rinsed with distilled water to remove soil debris. The stems were cut into smaller pieces of 1cm. Soil samples were air dried for 3 days and made lump free by crushing.

All plant samples were oven dried using GNLAB Mino economy oven of model MINO/75 at 105 ^{o}C to a constant weight and crushed using wooden mortar and pestle [18]. Porcelain mortar and

pestle were also used to crush the soil samples to a homogenized state. The mortar and pestles were rinsed with distilled water and dried after each sample ground to avoid cross contamination [19]. Each sample was passed through a Sachi standard test sieve of 2mm, the fine powder of the samples was stored in air tight plastic containers with lid [20].

ANALYTICAL PROCEDURE

Digestion of samples was done in the Department of Chemistry, University of Benin, Edo state. The method of [18] was adopted in analysing the heavy metals. Each plant sample of 0.5g was weighed into a clean flat bottom flask of 250ml using a scale of model AR2130 Ohaus Corporation China. Clean crucibles were used for soil samples; 5ml of concentrated Nitric per Chloric acid (HNO_3 / $HCLO_4$) in the ratio of 2:1 was added to each sample and shook for proper mixing. Plant samples were allowed to stay for two minutes before been placed on the hotplate of model ES-3615, Everest China in a fume cupboard. This was heated gently until a clear solution was obtained which signified a complete digestion. Soil samples in the crucibles were placed in the fume cupboard and allowed to stay for 24 hours before being filtered.

The crushed plant material was allowed to cool to room temperature (25 ^{o}C), both the plant and soil mixture were filtered using Whatman no.1 Filter Paper. The filtrate was diluted with deionized water to 25ml mark and transferred into clean plastic bottles with lid and labelled for heavy metals analysis. Analysis of selected heavy metals (Cadmium Cd, Lead Pb, Iron Fe, Manganese Mn and Copper Cu) was done using Atomic Absorption Spectrophotometer AAS of Model 210, VGP, Buck scientific USA in the Eco-toxicology laboratory of the Department of Animal and Environmental Science, Faculty of Life Science University of Benin. All samples were analyzed in triplicates.

STATISTICAL ANALYSIS

Data obtained from the laboratory analysis on the selected heavy metals were subjected to inferential statistics using ANOVA at a significance level of P≤ 0.05. Figures were used to present the results.

RESULTS AND DISCUSSION

In Figure 1, data showed that Pb, Cd, Cu, Mn and Fe concentrations were higher in the rhizosphere soil of *A.indica* in the mechanic site than in the leaves and stem. The mean values of the heavy metals were from Fe 0.756±0.006 – 7.219±0.002 mg/kg, Pb 0.169±0.013 - 5.659±0.003 mg/kg, Cd 0.151±0.007 – 5.882±0.012 mg/k, Cu 0.682±0.006 – 3.649± 0.050 mg/kg and Mn 0.230±0.008 – 1.072±0.051 mg/kg. Fe and Cu were higher in concentrations in the rhizosphere soil and leaves while Pb and Cd were lowest in the stem and leaves of the sampled plant. Similarly, the accumulation of Pb, Cd, Cu, Mn and Fe were higher in the rhizosphere soil followed by the leaves with the least concentrations of the metals in the stem of *P.niruri* at the mechanic site (Figure 2). The mean values of the investigated heavy metal ranged from 0.119±0.002 – 5.228± 0.002 mg/kg for Pb, 0.114±0.002 – 5.872± 0.004 mg/kg for Cd while Fe, Cu and Mn had a mean range of 1.995±0.003 – 7.221±0.001 mg/kg, 0.886±0.002 – 3.768±0.004 mg/kg and 0.056±0.002 – 1.115±0.002 respectively.

Result of this study showed that, at the abandoned dump site, the rhizosphere soil accumulated higher amounts of Fe, Mn, Cu, Cd, and Pb, followed by the leaves while the stem had the least concentrations of the investigated heavy metals. The mean values of the heavy metals were from 0.080±0.006 – 2.546±0.021 mg/kg, 0.043±0.003 – 1.369± 0.002 mg/kg, 0.513± 0.003 – 3.161± 0.104

mg/kg, 0.840±0.004 – 3.124± 0.002 mg/kg and 0.220± 0.001 – 0.770± 0.002 respectively for Pb, Cd, Fe, Cu and Mn (Figure 3)

Results in Figure 4 showed higher concentrations of Pb, Cd, Cu, Mn and Fe in the rhizosphere soil than in the leaves and stems of *P.niruri*. Fe and Cu had higher concentrations in the leaves than in the stem. The mean values of the heavy metals ranged from 0.205± 0.012 – 2.293±0.084 mg/kg for Pb, 0.031±0.002 – 1.378± 0.020 mg/kg for Cd, 0.713± 0.002 – 5.612± 0.008 mg/kg for Fe, 0.864± 0.002 – 3.402± 0.004 mg/kg for Cu and 0.271± 0.003 – 0.815 ± 0.005 for Mn respectively.

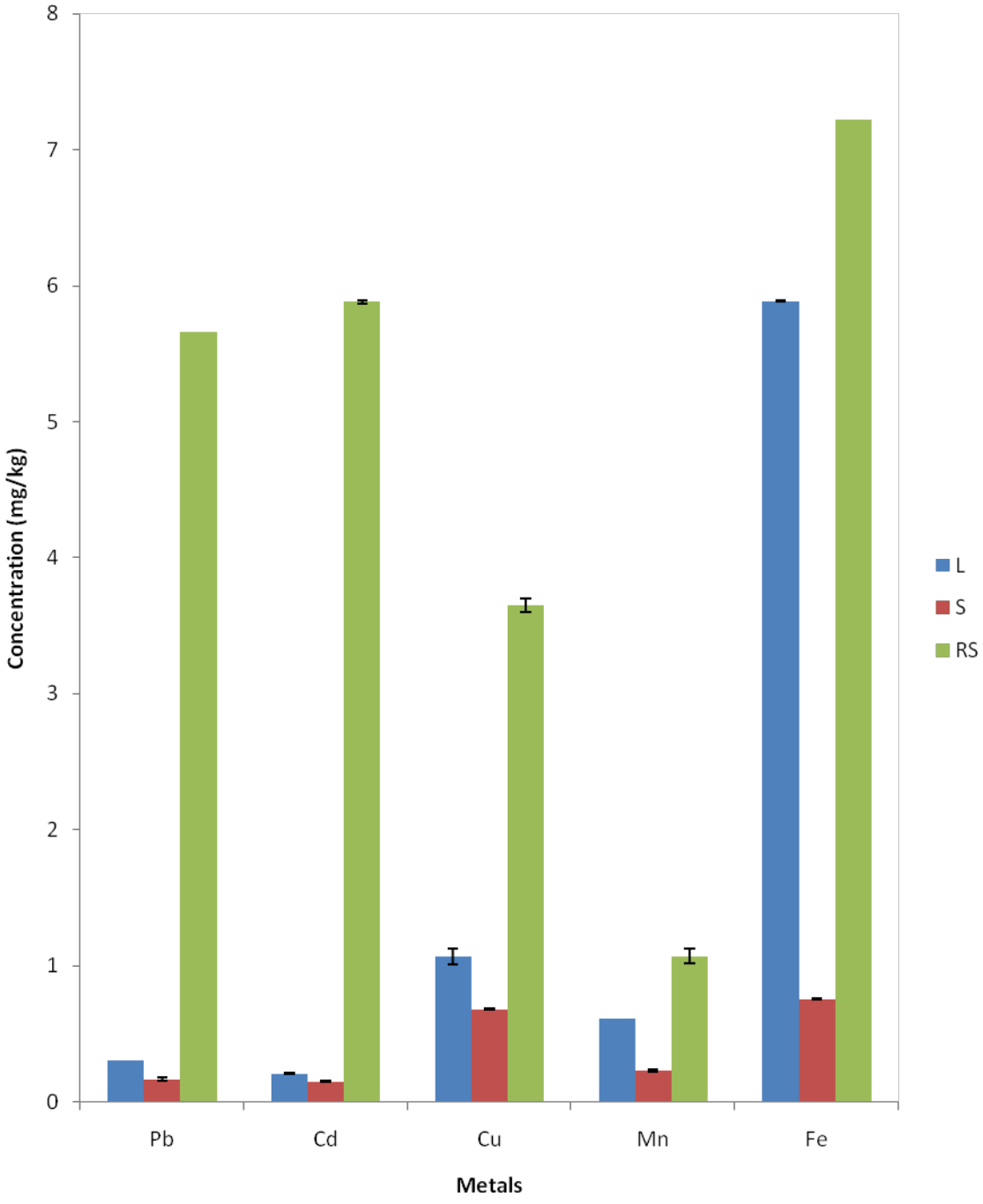

Figure 1: Concentration of Heavy Metals in the Leaves, Stem and Rhizsphere soil of *Azadirachta indica* in the Mechanic Site. Key: L- Leaves, S-Stem, RS- Rhizosphere Soil.

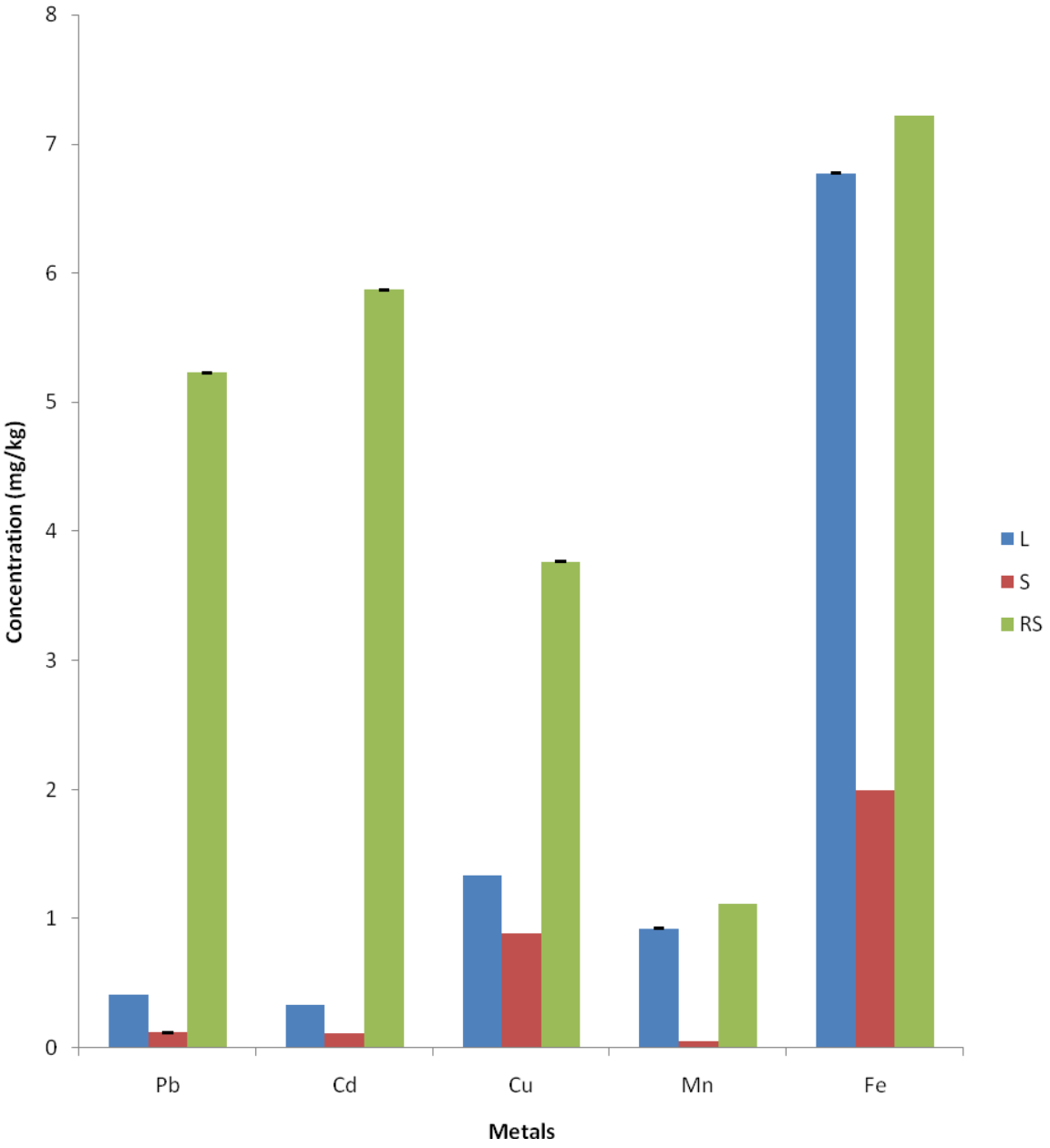

Figure 2: Concentration of Heavy Metals in the Leaves, Stem and Rhizsphere Soil of *P.niruri* at the Mechanic Site. Key: L- Leaves, S-Stem, RS- Rhizosphere Soil.

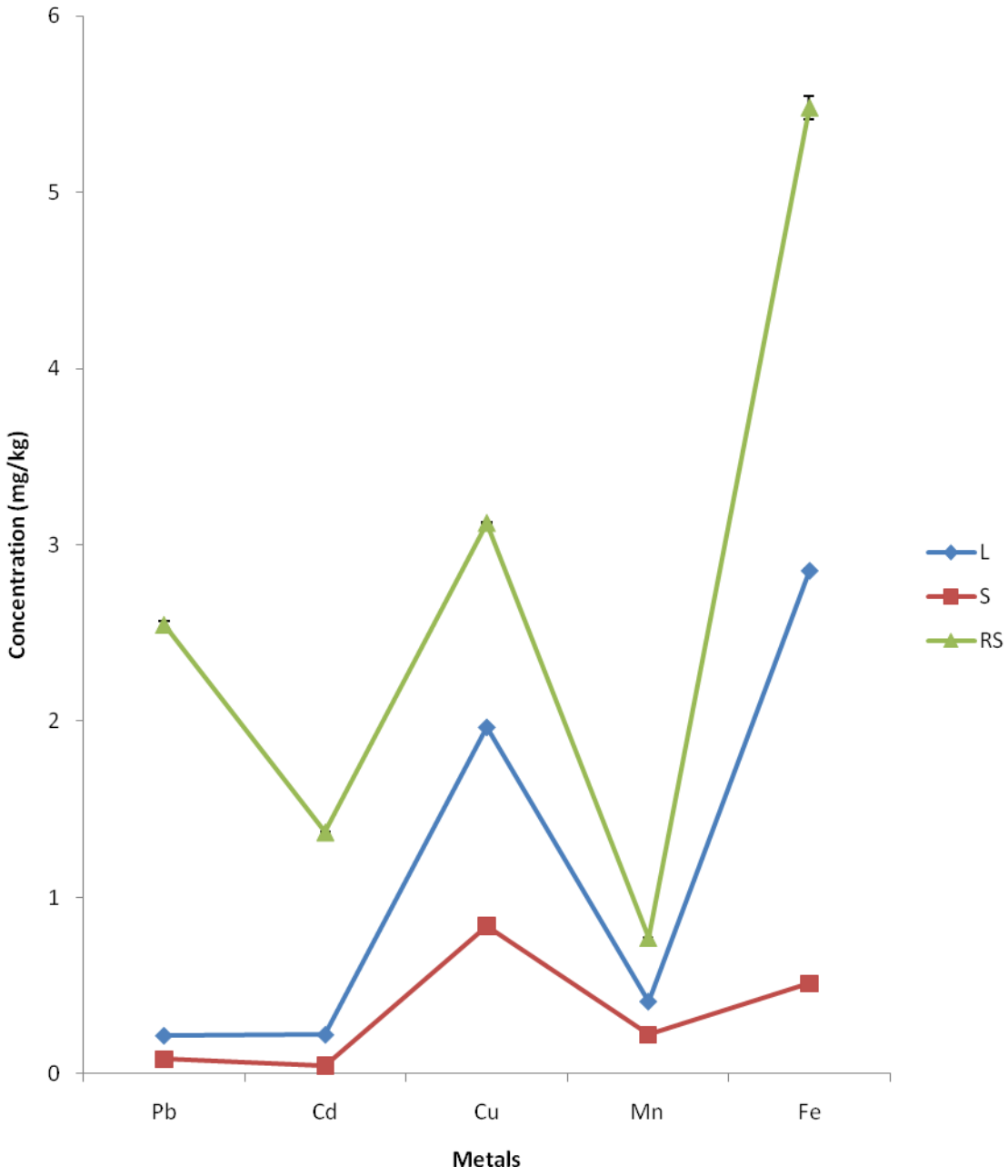

Figure 3: Concentration of Heavy Metals in the Leaves, Stem and Rhizosphere soil of *Azadirachta indica* in the Abandoned Dump Site. Key: L- Leaves, S-Stem, RS- Rhizosphere Soil.

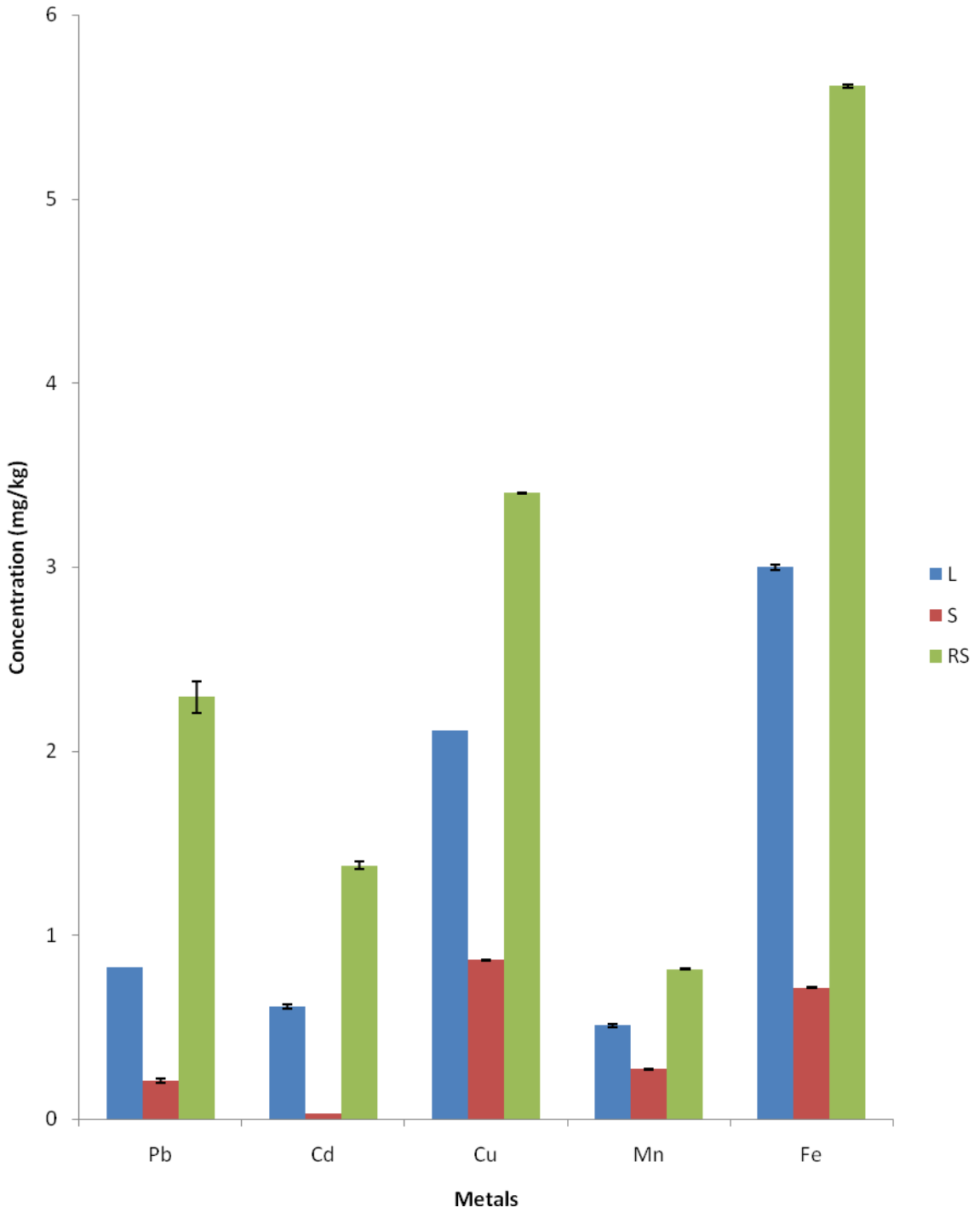

Figure 4: Concentration of Heavy Metals in the Leaves, Stem and Rhizosphere Soil of *P.niruri* in the Abandoned Dumpsite. Key: L- Leaves, S-Stem, RS- Rhizosphere Soil.

From the results in Figures 1-4, it is shown that, Pb, Cd, Fe, Cu and Mn were generally higher in the rhizosphere soil and leaves than in the stems of the medicinal plants (*A.indica and P.niruri*). The leaves of *P.niruri* accumulated metals more than *A.indica* in the leaves. This could probably be that, *P.niruri* had higher capacity to take up more of these metals than *A.indica*. It is also possible that the indiscriminate disposal of acid batteries, waste motor oil, grease and paints, disposal and burning of wastes was more on the soil on which *P.niruri* plant grew. The ability of different plant species to store or accumulate various metals in different parts could also contribute to the variations in the heavy metal's accumulation in the plant parts and between

plant species. This agrees with the findings of [20] who reported that heavy metals accumulation in plants varied with plant species and tissues.

In *P.niruri*, similar trend of accumulation was observed with high mean value in the leaves than stems of the medicinal plants but *P.niruri* accumulated higher Pb than *A.indica* in the leaves. This variation in accumulation of Pb in the leaves of *P. niruri* and *A.indica* could be as a result of variation in plant species as some plant species accumulate more metals than others. The high metal concentrations in the rhizosphere soil could be attributed to indiscriminate disposal of lubricants and vehicle batteries, wearing of paint on the body of vehicles, corrosion of vehicle parts which leached into the soil. The low concentration in the stem could be attributed to low metal mobility in the plant tissues as some of the elements like Pb and Cd have been reported to have low translocation from soil to leaves. The high concentration of Pb in the rhizosphere soil than in the leaves and stem buttress the fact that soil on which a particular plant grows or is cultivated may have a high concentration of heavy metals but same may not be the case in the plants tissues and could be at a minimal concentration (22).

There was significantly high difference in the concentrations of Cd in the rhizosphere soil and tissues of the selected medicinal plants and heavy metals investigated at $p \leq 0.05$. The concentration of Cd was high in the leaves of *P.niruri* and *A.indica* than the stems both at MS and ADS. The high Cd concentration in the rhizosphere soil of sampled sites than the leaves and stems of selected medicinal plants may be attributed to dumping of PVC plastics, burning of waste, disposed batteries, motor oil/lubricant disposed on the soil, tear and wearing of tyres and wearing of paint on the body of vehicles. The uptake and translocation of Cd from the soil through the xylem to the leaves might have attributed to high Cd concentration in the leaves than the stem. Also, the differences in ability of plant to control the movement of trace metals from xylem to phloem and via the phloem to other parts of the plant might have contributed to variation of Cd concentration in the investigated samples. Findings of this study agrees with the report of (23)

High concentration of Fe was found in the rhizosphere soil than in the leaves of sampled plants with the stems accumulating the least amount of the metal. *P.niruri* accumulated more Fe in its leaves than *A.indica.* The high Fe concentration in the rhizosphere soil could be attributed to metal scraps, warn out parts of automobile and high Fe content in the soil. High Fe concentration in the leaves could be attributed to the fact that Fe is very important in plant photosynthesis and its deficiency could produce symptoms such as chlorosis, thus Fe may be transported and stored in the leaves mostly. These findings uphold the submission of (24, 25) who opined that, the uptake and accumulation of heavy metals in plants is through the root system of the plant or the foliar surface by dry or wet deposition of metal particles.

Cu concentration was higher in the rhizosphere soil and the leaves than the stems of *P.niruri* and *A.indica. P.niruri* accumulated more Cu than *A.indica*. High accumulation of Cu in the rhizosphere soil may be attributed to waste metals containing at the dump site which could eventually leached into the underlying soil, used motor oil, break lining of modern automobiles which wears away over time, fertilizer, pesticide and fungicide application as agricultural activities are being carried out around the Mechanic site and the Abandoned dump site. The variation in heavy metals concentration in the plants species may be as a result of the difference in metal accumulation in plant parts and species as plants ability to accumulate heavy metals varies. This result is consistent with report of (25) who found high concentration of Cu in the leaves than the stem of *Datura stramonium and Amaranthus spinosus.*

Manganese (Mn) concentration was significantly lower at p≤0.05 between plant parts (Stem and Leaves) and heavy metals investigated. Its accumulation was in the increasing order of magnitude: rhizosphere soil, leaf and stem. The accumulation of Mn in the rhizosphere soil could be attributed to the fact that Manganese is one of the most abundant metals in soils, also, fertilizer from agricultural activities and fossil fuel in automobiles could contributes to its concentrations. *P.niruri* accumulated more Mn than *A.indica* with high concentration observed in the leaves both at ADS and MS. This could be attributed to fossil fuel combustion around the mechanic site and the closeness of the abandoned dump site to the road. This result agrees with the report of (26) who found higher accumulation of Mn in the leaves of *Talfairia occidentalis* cultivated on the South Bank of river Benue.

CONCLUSION

This study has established the presence of heavy metals in the sampled medicinal plants and in the rhizosphere soil upon which the plants grew. From the results, Fe and Cu accumulated more than Mn and Pb while Cd was least. The accumulation of the metals was more in the rhizosphere soil and leaves than in the stems of sampled medicinal plants.

This study has clearly shown that the level of absorption and accumulation of these metals varied in the two plant species (*A.indica and P.niruri*). The accumulation also varied among the different plant tissues and organs for each of the plant studied. This is an indication that some metals though present in the soil, have low translocation from soil to plant parts (22). Also, the high presence of metals in the soil does not necessarily mean that it would be taken up by plants in the same high concentrations. Heavy metals concentration of *A.indica and P.niruri* in the polluted sites were higher than those of the control. This implies that, plants collected for medicinal use should not be taken from polluted areas because there is the risk of having these metals in the concentration that can affect health adversely over time. In comparing with the set standard by [9], the heavy metals investigated where within the acceptable set limits. However, their presence in the investigated plants calls for concern as accumulation over time may increase the level of these metals above set limits. Additionally, findings of this study revealed that, anthropogenic activities play a major role in metal accumulation in the environment which in turn, pose a serious environmental and health challenges to man. Based on these findings, the study recommends that medicinal plants for therapeutic use should be obtained away from polluted environments. Also, Sorting and recycling of wastes should be intensified to reduce the quantity of these toxic metals in the dumpsites which can subsequently be leached into the soil where they could be taken up by plants.

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Innovative Approaches to Enhancing Food Security: Saline Water Kitchen Gardening

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Abstract:
Food security, a critical global concern, hinges on our ability to sustainably produce nutritious food in the face of mounting challenges such as climate change, water scarcity, and soil degradation. This study investigates how saline water affects the initial growth and adaptability of vegetable crops in a Kitchen Gardening Model designed for saline environments. Chili peppers demonstrated the highest germination rate at 90%, followed by tomatoes at 85%, and eggplants at 82%, while okra had the lowest rate at 75%. Adaptability of seedlings varied with salinity levels; the initial irrigation with a TDS of 700 resulted in 81% adaptation, while the fourth irrigation with 2250 TDS had 65% adaptation. Chili peppers exhibited the highest overall adaptability at 76%, followed by tomatoes at 74% and eggplants at 72%, with okra having the lowest adaptability at 9%. Plant height ranged from a maximum of 32 cm (okra) to a minimum of 23 cm (tomatoes). The number of leaves per plant correlated with genetics and increased salinity, with a maximum of 10 leaves (tomatoes) and a minimum of 4 leaves (chili peppers). This research highlights the importance of managing water quality and selecting suitable crops for sustainable food production in saline-prone areas.

Keywords: Kitchen Gardening Model, Saline agriculture, Adaptability, Sustainable food production.

INTRODUCTION

Food security is a global necessity that necessitates creative solutions to produce wholesome food in a sustainable manner in the face of escalating difficulties such soil degradation, water scarcity, and climate change (FAO, 2020). A rising number of people are challenging conventional agricultural paradigms, especially in arid and semi-arid countries where soil salinity and water scarcity typically work together to limit agricultural production (Hanjra & Qureshi, 2010). Creative solutions are not only needed in these situations, but also essential. Using the potential of saline water to cultivate a wide variety of crops and ultimately increase food security is one such option known as "Saline Water Kitchen Gardening," which goes beyond the confines of conventional farming. The accessibility and sustainability of kitchen gardening, sometimes referred to as home or backyard gardening, has long been praised. It increases local food production and lessens reliance on centralized agricultural systems by enabling people and communities to grow a range of fruits, vegetables, and herbs just outside their door (Kumar et al., 2018). This strategy has great potential to supply households with wholesome, fresh vegetables while also encouraging dietary diversification and self-sufficiency. However, the lack of freshwater and the predominance of saline or alkaline soil conditions pose severe obstacles to conventional agriculture in dry and semi-

arid regions (Munns & Tester, 2008). Fortunately, there has been a growing chance to turn these constraints into opportunities in a time of scientific and technical progress (Rengasamy, 2010). Due to its high salt content, saline water has long been thought to be harmful to plant growth, preventing the uptake of nutrients, the absorption of water, and the general health of crops (Rengasamy, 2006). However, there is a growing chance to turn these constraints into opportunities in a time of scientific and technical progress. Additionally, self-sufficiency and dietary diversity are encouraged by kitchen gardening, which enhances food security (Biradar and Ananda, 2020). This study focuses on the largely unexplored field of saline water kitchen gardening in an effort to determine how it might be used to alleviate issues with food security in arid and semi-arid areas. In order to shed light on an innovative strategy that has the potential to change food production in difficult conditions, this research investigates the effects of saline water on crop growth and develops customized models for kitchen gardening. The creative use of salt water in kitchen gardening techniques offers a ray of hope amidst the overwhelming issues of our day, such as population expansion and shifting climatic patterns. It holds the potential to improve food security, strengthen community bonds, and revolutionize the agricultural industry.

MATERIAL AND METHOD

The research was carried out at the Arid Zone Research Centre (PARC) adopting a specific model of a kitchen garden. The garden model, which is about 20 feet wide and 40 feet long, was made prior to the start of my internship. It had four equal portions, with planting furrows in each for seedlings. The garden was kept uniform in terms of plant-to-plant spacing, and these furrows functioned as places where the seedlings could be transplanted. In order to gather data for the study, a variety of crops were cultivated, including tomatoes (Solanum Lycopersicon), chili peppers (Capsicum spp.), eggplants (Solanum melongina), and okra (Abelmoschus esculentus). All of these crops were grown in salty water.

Selection and Preparation of Plants

The experiment involved the careful selection of seeds for tomatoes, chili peppers, eggplants, and okra. These seeds were sourced from reputable suppliers and underwent an initial assessment of their tolerance to salinity to ensure consistent seed quality. Healthy and uniform seedlings were subsequently transplanted into the greenhouse beds.

Transplantation and Plant Spacing

Before transplanting, the field received thorough watering. The seedlings were then transferred to the primary planting area on the same day to maintain uniform observations and facilitate data collection. Data collected for various treatment groups were tabulated and graphically presented. Plant-to-plant spacing was maintained at specific intervals: 80 cm for tomato plants, 40 cm for chili peppers, and 30 cm for eggplants.

Saline Water Treatment

To replicate the conditions of kitchen gardening using saline water, the plants were subjected to saline water irrigation. Different levels of saline water treatments, each with varying salinity concentrations, were administered. In the nursery, normal, non-saline water was used for seedling irrigation. However, after transplantation, the seedlings received four irrigations with water of different salinity levels. The first irrigation, with a total dissolved salts (TDS) of 700, was conducted immediately after planting. The second irrigation, with a TDS of 800, took place three days after transplanting. The third irrigation, with a TDS of 2250, occurred after one week, and the fourth irrigation, also with a TDS of 2250, was carried out after ten days.

Intercultural Activities

Weeding and hoeing for inter-cultivation were performed manually seven days after transplanting the seedlings.

Data Collection

Germination Percentage:

The germination percentage (%) was determined by counting the number of successfully sprouted seedlings and expressing it as a percentage of the total seeds sown.

Plant Height:

Plant height was measured from the base of the stem to the tip of the main shoot, and these measurements were recorded in centimeters (cm) at regular intervals throughout the experiment.

Number of Leaves:

The number of leaves per plant was counted, and this count was used to calculate the average number of leaves in each treatment group.

DATA ANALYSIS

The data collected for germination percentage, plant height, number of leaves, and other variables were subjected to analysis using Statistix 8.1 computer software, and visual representations and diagrams were created using MS Excel.

RESULT AND DISCUSSION

Germination Percentage

In this experiment, the highest germination rate was recorded in chilies at 90%, followed by tomatoes at 85%, and Brinjal at 82%. Conversely, the lowest seed germination rate was recorded for okra at 75% (Fig. 1). Germination is a complex physiological process that sets in motion a series of biological and biochemical reactions leading to seedling development (Poudel et al., 2019; MEI and Song, 2008). During the initial stages of germination, a phase known as imbibition, seeds rapidly absorb water, resulting in the expansion and softening of the seed coat, particularly at optimal temperatures (FU et al., 2021; Koornneef et al., 1994). The variations in germination rates observed in our study may be attributed to genetic factors and the overall seed viability of different vegetable seeds (Fig. 1). Koornneef et al. (1994) and Bewley et al. (2005) have previously reported that these differences activate inner physiological processes within the seeds, subsequently initiating seed respiration.

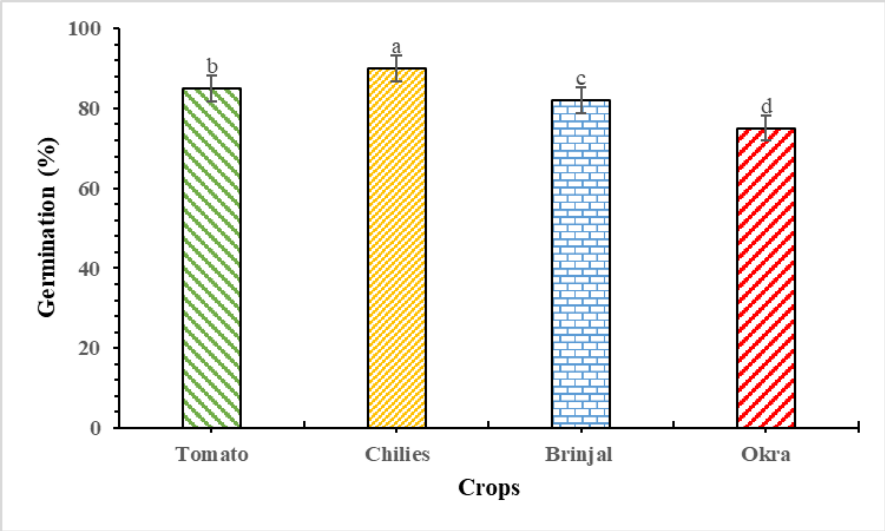

Fig. 1: Seed germination percentage (%) of various crops grown in nursery.

The different lower-case letter shows the difference between various crops on germination percentage.

Adoptions of Seedling (%)

In our investigation, we found that the adaptation of plants after transplanting was notably influenced by shifts in water salinity, transitioning from lower to higher Total Dissolved Solids (TDS) levels, as outlined in Table 1. Across all the tested vegetable seedlings, the most successful adaptation, standing at 81%, occurred following the initial irrigation with a TDS of 700. This was followed by a 78% adaptation rate after the second irrigation with a TDS of 800, and a 69% adaptation rate following the fourth irrigation with a TDS of 2250. In contrast, the lowest adaptation rate, at 65%, was observed after the fourth irrigation with a TDS of 2250 (see Table 1). Regarding specific vegetables, chili peppers exhibited the highest average adaptation rate at 76%, followed by tomatoes at 74% and eggplants at 72%. On the other hand, okra displayed the lowest adaptation rate at 9% (refer to Table 1). These findings suggest that heightened salinity levels can diminish the adaptability of various vegetables when exposed to higher salinity levels of water during the early seedling stage. However, as plants progress through their growth stages, they tend to enhance their stress tolerance potential, leading to improved adaptation. This aligns with the observations made by Pangapanga-Phiri and Mungatana (2021) and Gallardo et al. (2001), who noted that abiotic stress, soil conditions, and environmental factors may reduce seed germination percentages while promoting adaptation to induced stress.

Table 1: Percentage of seedling adaptation in different vegetable varieties as influenced by the number of irrigations with rising salinity levels.

Adoption percentage of Seedling (%)					
Treatments	**1st irrigation (700 TDS)**	**2nd irrigation (800 TDS)**	**3rd irrigation (2250 TDS)**	**4th irrigation (2250 TDS)**	**Average**
Tomato	82	79	70	65	**74**
Chilies	85	81	73	68	**77**
Brinjal	80	78	67	64	**72**
Okra	75	74	65	63	**69**
Average	**81**	**78**	**69**	**65**	

The terms "1st," "2nd," "3rd," and "4th" irrigation refer to the sequence and timing of applying irrigation water with different levels of salinity stress, while "TDS" stands for Total Dissolved Salts.

Plant Height (cm)

Plant height exhibited significant variations due to different saline water treatments at various irrigation times. Generally, the tallest plants, reaching 32 cm, were observed following the first irrigation with 700 TDS. This was followed by a height of 30 cm after the second irrigation with 800 TDS and 27 cm following the third irrigation with 2250 TDS, occurring seven days after transplanting. The shortest plants, with a height of 27 cm, were reported after the fourth irrigation with 2250 TDS, conducted ten days after transplanting (see Table 2). Across all the tested vegetable seedlings, plant height ranged from highest to lowest, with okra at 32 cm, chili peppers at 30 cm, eggplants at 29 cm, and tomatoes at 23 cm (refer to Table 2). These findings align with previous research indicating that, among various vegetables, tomatoes exhibit a moderate sensitivity to salinity. De la Peña and Hughes (2007) noted that salt stress has three main effects, leading to reduced water potential, ion imbalances, and toxicity. Similarly, Parida and Das (2005) reported that salt stress affects several crucial processes, including germination, germination rate, root and shoot dry weights, and the Na+/K+ ratio in both roots and shoots. Furthermore, these findings suggest that the growth and development of seedlings were adversely impacted by an excessive salt content in the irrigation water when applied beyond a certain threshold, leading to a deceleration in the accumulation of dry matter in the seedlings.

Table 2: Plant Height (in centimeters) of different vegetable varieties in response to varying numbers of irrigations with increasing salinity levels.

Plant height (cm)					
Treatments	**1st irrigation (700 TDS)**	**2nd irrigation (800 TDS)**	**3rd irrigation (2250 TDS)**	**4th irrigation (2250 TDS)**	**Average**
Tomato	28	26	20	19	**23**
Chilies	33	31	29	28	**30**
Brinjal	32	30	28	26	**29**
Okra	35	32	30	29	**32**
Average	**32**	**30**	**27**	**26**	

The designations "1st," "2nd," "3rd," and "4th" irrigation refer to the specific irrigation events and timing when water with different salinity levels was applied, and "TDS" stands for Total Dissolved Salts.

Number of Leaves

The count of leaves per plant consistently followed a particular pattern throughout this research. The greatest number of leaves per plant (9) was observed in the 1st irrigation (700 TDS) and the 2nd irrigation (800 TDS), followed by 7 leaves per plant with the 3rd irrigation (2250 TDS), administered seven days after transplanting. In contrast, the fewest leaves per plant (5.5) were documented after the 4th irrigation (TDS 2250), which took place ten days after transplanting (see Table 3). Regarding specific vegetables, tomatoes exhibited the highest leaf count (10), while chili peppers displayed the lowest leaf count (refer to Table 3). In this investigation, the noticeable increase in the number of leaves per plant across various vegetable varieties might be attributed to their distinct genetic and morphological characteristics. Conversely, the decrease in the number of leaves per plant, observed with increased irrigation and salinity, may be attributed to the excessive salt content affecting the physiological attributes of the vegetables. This impact not only contributed to leaf senescence but also influenced other morphological features of the vegetables under study.

Table 3: Number of leaves per plant (per plant-1) in different vegetables in response to varying numbers of irrigations with increasing salinity levels.

Number of leaves plant^{-1}					
Treatments	**1st irrigation (700 TDS)**	**2nd irrigation (800 TDS)**	**3rd irrigation (2250 TDS)**	**4th irrigation (2250 TDS)**	**Average**
Tomato	10	13	9	7	10
Chilies	5	5	4	3	4
Brinjal	11	10	9	7	9
Okra	9	7	6	5	7
Average	9	9	7	6	

The designations "1st," "2nd," "3rd," and "4th" irrigation refer to the specific irrigation events and timing when water with different salinity levels was applied, and "TDS" stands for Total Dissolved Salts.

CONCLUSION

The study was conducted to explore the impact of saline water on the initial development and acclimatization of various essential vegetables cultivated within a Kitchen Gardening Model specially designed for thriving in saline water environments. The findings revealed that seed germination percentage plays a crucial role as it influences post-transplant growth in the field. However, the growth rate is significantly altered by the water's salinity level. In our research, plant height, measured in centimeters, was notably affected by the saline water treatment. Likewise, the adjustment of seedlings to field conditions and the number of leaves per plant were influenced by the salinity level of the irrigation water applied. In general, the 1% saline treatment resulted in taller plants for all plant types, indicating that lower salinity levels can promote plant growth under certain circumstances.

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On Farm Performance Evaluation of Abera Sheep Under Abera Community-Based Breeding Program in Hula and Dara Districts, Sidama Regional State, Ethiopia

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Abstract:
Community-based breeding programs (CBBP) have been viewed as appealing breeding schemes that have significantly contributed to improving the performance of small ruminants in many developing countries. The current study aims to assess the productive and reproductive performance of sheep owned by CBBP households in the Dara and Hula districts of the Sidama region using performance records retained over an eight-year period since 2013. A total of 3552 birth records, 3263 weaning age (90-day) records, 2845 180-day records, and 1786 yearling age (360-day) records were analyzed using the general linear model under Statistical Analysis System (SAS) procedures. The model considered fixed effects like lamb sex, birth type, dam parity, birth year, birth seasons, and breeder cooperatives. Sheep body weight at birth, 90 days, 180 days, and 360 days, as well as pre-weaning daily weight gain and post-weaning daily weight gain, were 3.14±0.01 kg, 15.13±0.06 kg, 20.8±0.05 kg, and 28.89 kg, 135.3±0.5 g, and 63.64 g, respectively. Body weight at birth and at 90 days was significantly influenced by all fixed effects except birth seasons. All considered fixed effects have significantly ($p<0.05$) affected body growth at 180 days, pre-weaning daily gain, and post-weaning daily weight gain. A mean litter size of 1.19 was recorded in the present study, which was significantly ($p<0.05$) different across years but not across breeder cooperatives. The results of the current study indicated considerable improvements in the growth traits of sheep since the breeding program was implemented. The consequences of significant fixed effects should be properly incorporated during breeding ram selection, especially at 180 days. The inclusion selection index, along with growth traits under selection and improvements in management, can be an important intervention strategy to improve the prolificacy of sheep.

Keywords: Abera sheep, CBBP, growth traits, on farm

INTRODUCTION

Sheep are the most important livestock species in Ethiopia and other developing countries. Ethiopia has a large sheep population, estimated at 42.9 million (CSA, 2021), which is raised from arid pastoral areas to a cool alpine climate. Previous comprehensive characterization work recognized fourteen sheep groups (Ayalew et al., 2004), whereas Solomon (2008) recognized nine distinct breeds of sheep through his molecular characterization. These sheep have made immense contributions to small-holder farmers in Ethiopia across the country. They provide food items such as meat and milk as well as non-food items like skin and wool. They are also significant sources of monetary income (savings) and serve as a form of protection against extreme events like crop failure. They also contribute significantly to the country's income by generating foreign currency (Gebremedhin et al., 2006). Hence, sheep have a variety of socioeconomic and cultural

functions for their producers (Tibbo, 2006). Despite Ethiopia's vast sheep population and diverse genetic resources, productivity has remained considerably below expectations due to a variety of constraints (Tibbo, 2006). Lack of technical capacity, feed scarcity, poor feed quality, disease, inadequate infrastructure development, and weak market linkage were some of the challenges that hampered sheep productivity (Gizaw et al., 2013). Low performance was also due to a lack of a well-planned breeding program that inadequately took into consideration the interests of targeted producers. Crossbreeding programs intended to improve the performance of indigenous sheep by crossing them with exotic rams at different times hardly impressed the targeted producers and consequently failed to be sustainable. Centralized nucleus breeding programs, typically controlled by the government, were unable to address long-term production issues and thus failed due to a lack of active participation by targeted producers.

The community-based breeding program has therefore emerged as an attractive option and resulted in impressive progress (Haile et al., 2018) since the interest of target producers was identified and incorporated into the improvement efforts. As part of CBBPs in Ethiopia, a community-based breeding program has been implemented for the indigenous sheep population, now known as the Abera sheep. Abera sheep are known for meat production in the region and are characterized by long, fat tails with straight tips and short, smooth hairs with straight head profiles (Melesse et al., 2013). The aforementioned breeding program was initiated to make better use of indigenous genetic resources and increase the income of sheep producers by applying a selection-based intervention strategy to targeted growth traits. There have been eight breeder cooperatives established under the Abera CBBP. As per the policy of the breeding program, performance data collection on animals is routinely conducted. Monitoring the current growth performance of sheep under a community-based breeding program is important to know the animals' performance, which could be used to design further improvement directions and add improvement inputs. Therefore, the current study was aimed at the performance evaluation of Abera sheep using current performance records under the Abera community-based breeding program.

MATERIALS AND METHODS

Description of the Study Area and Breeding Program

The study was carried out in the Hula and Dara districts, Sidama regional state, where the Abera community-based breeding program has been implemented. Hula district, one of the study areas, is bordered on the south by the Oromia Region; Dara district on the west; Aleta Wendo district on the northwest; Bursa district on the north; and Bona Zuria on the east. Hula district's longitudinal and latitudinal coordinates are 38° 46'–38° 78' E and 6° 40'–6° 75' N, with a mean altitude of 2809 masl. The district's mean minimum and maximum temperatures were 6.2 °C and 19.1 °C, respectively, with an average annual rainfall of 1425 mm. The other study area, Dara, is found in the eastern parts of southern Ethiopia, 85 km away from Hawassa, the capital city of the Southern Nation nationalities and people's region and Sidama Regional State. The longitudinal and latitudinal positions of the district ranged between 38°38′–38°51′ E and 6°36′–6°54′ N, respectively, with an altitudinal range of 1200–2900 masl. The mean minimum and maximum temperatures of the district were reported to be 19 oC and 28 °c, respectively. A mixed crop-livestock farming system is mostly practiced in both districts, where each component complements the other. Farmers in both study districts grow maize, barley, wheat, potatoes, and other crops. Enset is a popular food crop that is commonly used by all households.

Natural pasture, *inset*, and agricultural leftovers are the main feed sources in the study area. Farmers keep sheep and other livestock species during the day on pasture land, around homesteads, and on farmland after crop harvest. In line with the common consensus of community-based breeding program policy, sheep producers practice a controlled mating system. Selective breeding programs based on paternal lines have been used since the implementation of CBBP in 2013. Sheep usually graze on natural pastures during the day on grazing land and around the home. Crop residue is also used as a source of feed after harvest. In line with the common consensus of community-based breeding program policy, sheep producers practice a controlled mating system. Selective breeding programs based on paternal lines have been used since the implementation of CBBP in 2013. Ram selection usually takes place twice a year with a selection intensity of 10%–15%. Selections of breeding rams were conducted based on the estimated breeding value (EBV) of the animals, which is done at six months of age. Then, selected breeding rams were shared based on ram-utilizing groups, with a ratio of one ram to twenty to twenty-five ewes.

Data Collection and Management

Eight-year performance data retained for sheep owned by CBBP participants was obtained from the Southern Agricultural Research Institute. Growth records of sheep were taken at birth, 90 days, 180 days, and 360 days by trained enumerators for each breeder cooperative. Body weight records were taken shortly after birth, at 90 days, 180 days, and 360 days, and necessary weight corrections were made before real analysis. The sex of the lamb, birth type, birth year, and seasons across breeder cooperatives were recorded. Pre-weaning (0 to 90 days) and post-weaning (90 to 180 days) were also estimated. Animals were hanged in a sac connected to a spring balance with a capacity of 50 kg, and their weight was measured. Individual ear tags were used to identify the animals.

Data Management and Analysis

The Mixed Procedure in SAS, version 9 was used to analyze growth traits. Preliminary analysis was used to identify the fixed effects having a significant impact on growth traits. The significant effects included in the model were sex (male, female); parity (1, 2, 3, 4, 5, 6); birth type (single, twin, triple); year (2013, 2014, 2015, 2016, 2017, 2018, 2019, 2020); birth season-main rainy season (June-September), dry season (October-May); breeder cooperatives (Abera Atela, Abera Gelede, Abera Doko, Abera Doda, Abera Bongodo, Bochesa Gobe). The Tukey-Kramer test was used to compare the least square means of having more than two levels.

The statistical model used was: $Y_{ijklmon} = + A_i + D_j + G_k + T_o + R_m + H_o + e_{ijklmon}$

Where $Y_{ijklmon}$: growth trait response variable; overall mean A_i denotes the fixed effect of lamb sex; D_j denotes the fixed effect of dam parity; and G_k denotes the fixed effect of birth type; T_o represents the fixed effect of birth year; R_m represents the fixed effect of birth seasons; H_o represents the fixed effect of breeder cooperatives, and eijklmon represents random error.

RESULT AND DISCUSSION

Growth Performance of Abera Sheep

The growth performance of Abera sheep under a community-based breeding program is presented in Table 1. The overall mean body weight of Abera sheep at birth in the present study was heavier by 0.34 kg than the corresponding value for the same sheep breed (Marufa et al., 2017). Similarly, a lower corresponding value was reported for Gumuz sheep (2.79 kg; Abegaz,

2007); Arsi-Bale sheep (2.89 kg; Legesse, 2008); Washera sheep (2.7 kg; Taye et al., 2010); indigenous sheep in the Fentale area (2.84 kg; Worku et al., 2019); sheep reared around the Jimma zone (2.45 kg; Berhanu and Aynalem, 2009); and 2.3 kg for Alaba sheep (Gemiyu, 2009). In contrast to the result of the present report, a heavier birth weight of 3.71 kg was found for Rutana desert sheep (Dagnew et al., 2018). Birth weights of Afar (2.7 kg) and Horro (2.34 kg) sheep managed at the station were found to be lower than reported in the present study, as respectively reported by Yacob (2008) and Tibbo (2006). The heavier weaning weight of sheep is a good indicator of sheep productivity and ewes' ability to gestate lambs. The overall mean of 15.13 kg of weaning weight recorded in the present study was heavier than previous reports for Sekota sheep (Yeheyis et al., 2012), Gumuz sheep (Abegaz, 2007), and local sheep around the Fentale district (Worku et al., 2019); who recorded 11.9 kg, 12.6 kg, and 7.95 kg, respectively. The weaning weight of sheep investigated at the station level reported by previous studies (Tibbo, 2006; Yacob, 2008) found for Afar (11.5 kg), Menz (9.1 kg), Horro (9.9 kg), and Black-Headed Somali sheep (11.3 kg) was lighter compared with the present report. Heavier weaning weight (15.55 kg) was, however, reported for Bonga sheep under a community-based breeding program (Mestafe, 2015). The pre-weaning body weight difference among many sheep breeds could have resulted from differences in management systems, feed resource availability, and genetic potential of the breed. In addition to this, performance improvement programs such as selective breeding programs could have resulted in better growth performance for sheep breeds under these intervention activities.

The post-weaning growth rate of Abera sheep in the present study is presented in Table 1. In the current study, the overall least-square means of sheep at six-month age (180 days) and yearling age were 20.80 kg and 28.08 kg, respectively. Previous reports (Berhanu and Aynalem, 2009; Marufa et al., 2017; Dagnew et al., 2018; Asmare et al., 2021) found lower six-month weight for the same population (18.5 kg), for indigenous sheep of southwest Ethiopia (18.8 kg), Gumuz sheep (15.77 kg), and Washera sheep (13.94 kg). Dagnew et al. (2018) reported a nearly comparable six-month weight of Rutana desert sheep. However, the corresponding value of Bonga sheep (22.2 kg) reported by Mestafe (2015) was heavier than that reported in the current study. The yearling weight of Abera sheep recorded in the present study was heavier than reports by Asmare et al. (2021) for Gumuz sheep (20.37 kg) and Washera sheep (21.8 k), Horro Highland sheep (Tagaynesh, 2014), Begait sheep (Bahran, 2014), and Hararrghe highland sheep (Negussie, 2015). The yearling weight of Rutana desert sheep (27.6 kg) reported by Dagnew et al. (2018) was nearly comparable with the corresponding value in the present study.

Fixed Effects Affecting the Growth Performance of Abera Sheep

Birth Year:

The year of birth was among source of variation during the pre-weaning and post-weaning periods. Heavier pre-weaning average daily weight gain was observed during 2015, whereas heavier post-weaning average daily weight gain was observed during 2015, 2016, and 2018. The observed difference in the growth rate of Abera sheep across the years could be associated with a difference in the availability of feed resources and other management issues.

Growth performance of sheep can be greatly improved by improvement and genetics. However, many non-genetic factors influence sheep growth performance (Berhanu and Aynalem, 2009), implying that these effects should be considered for the planned improvement intervention. The least-square means of fixed effects influencing the growth performance of Abera sheep are presented in Table 1. Lamb sex highly influenced growth traits at all ages significantly ($p < 0.001$).

Male lambs were heavier than females by an average mean value of 0.09 kg, 0.56 kg, 0.66 kg, and 1.95 kg, respectively, at birth, 90 days, 180 days, and yearling age.

Table 1: Least square mean ± standard error of fixed factors affecting growth performance (kg) of Abera sheep at birth, weaning age, six-month weight and yearling age.

Variable	N	BW (kg)	N	WW (kg)	SMW	YW
Overall	3552	3.14±0.01	3263	15.13±0.06	20.80±0.05	28.89
R^2	3552	0.48	3263	0.06	17.80	14.41
CV%	3552	9.87	3263	20.8	11.57	8.28
Year		0.001		0.001	<0.0001	0.001
2013	157	2.72^{f}±0.02	157	14.85^{bc}±0.14	20.80^{abcd}±0.16	27.76^{c}±0.28
2014	209	2.85^{e}±0.02	209	15.74^{a}±0.14	21.24^{abc}±0.15	28.80^{bc}±0.19
2015	571	2.84^{e}±0.01	560	15.19^{ab}±0.08	21.41^{a}±0.11	29.25^{a}±0.11
2016	494	3.12^{d}±0.02	486	15.55^{a}±0.31	21.31^{ab}±0.11	29.13^{a}±0.13
2017	372	3.26^{bc}±0.02	358	14.70^{bc}±0.11	20.17^{cd}±0.15	29.51^{a}±0.21
2018	729	3.35^{a}±0.02	702	14.79^{bc}±0.10	20.29^{bcd}±0.1	28.85^{ab}±0.13
2019	750	3.29^{ab}±0.02	718	15.23^{ab}±0.07	20.33^{abcd}±0.11	28.76^{ab}±0.28
2020	270	3.21^{c}±0.03	73	14.51^{c}±0.23	20.06^{d}±0.65	
Sex		0.001		0.001	<0.0001	<0.0001
Male	2092	3.18±0.010	1330	15.36±0.09	21.02±0.06	29.22±0.08
Female	1460	3.09±0.011	1933	14.80±0.05	20.36±0.08	27.77±0.08
Litter size		0.001		0.001	<0.0001	NS
Single	2411	3.23^{a}±0.009	2242	15.35^{a}±0.08	20.87^{a}±0.06	28.92^{a}±0.08
Twin	1126	2.96^{b}±0.011	1008	14.66^{b}±0.06	20.56^{a}±0.09	28.84^{a}±0.1
Triple	15	2.59^{c}±0.13	13	12.78^{c}±0.98	18.82^{b}±1.27	28.0^{a}±0.7
Parity		0.01		NS	0.0008	NS
1	1796	3.08^{d}±0.01	1715	15.13±0.1	20.67^{ab}±0.05	28.88±0.10
2	770	3.14^{cd}±0.02	692	15.24±0.07	21.05^{a}±0.08	28.73±0.17
3	550	3.22^{bc}±0.02	441	15.11±0.10	20.82^{a}±0.11	28.74±0.24
4	272	3.26^{ab}±0.01	255	14.95±0.12	20.95^{a}±0.13	29.60±0.31
5	119	3.31^{a}±0.04	103	15.17±0.22	19.95^{bc}±0.18	29.84±0.59
6	45	3.35^{a}±0.06	39	14.86±0.33	19.80^{c}±0.29	29.29±0.94
Seasons		NS		NS	<0.0001	28.67±.09
DS	1395	3.12±0.01	1349	15.18±0.08	21.08^{a}±0.1	28.81±0.12
SRS	1021	3.16±0.01	812	15.21±0.06	20.67^{b}±0.1	28.41±0.10
MRS	1136	3.14±0.01	1103	14.99±0.05	20.48^{b}±0.1	
BC		0.001		0.001	<0.0001	
A Atela	825	3.26^{a}±0.01	774	15.41^{b}±0.06	21.15^{b}±0.08	Na
A Gelede	901	3.26^{a}±0.02	828	14.96^{bc}±0.06	20.69^{c}±0.10	Na
A Bongodo	590	3.15^{b}±0.01	547	16.06^{a}±0.05	21.95^{a}±0.10	Na
B Gobe	356	3.03^{c}±0.02	326	14.96^{b}c±0.10	20.33^{d}±0.14	Na
A Doko	406	2.95^{d}±0.02	384	14.96^{c}±0.11	21.07^{b}±0.14	Na
A Doda	474	2.95^{d}±0.02	404	14.24^{d}±0.38	18.40^{e}±0.17	Na

BW: Birth weight; WW: Weaning weight; SMW: Six-month weight; YW: Yearling weight; SRS: Short rainy seasons; MRS: Main rainy season; A: Abera. Column mean with same letter are not significantly different, LSM – least square mean; BC- Breeder cooperatives; SE – standard error; NS: Non-significant.

In agreement with the present result, many studies (Tibbo, 2006; Taye et al., 2010; Marufa et al., 2017; Dagnew et al., 2018) have widely reported the body weight superiority of males over female counterparts. This difference in body weight between sexes at a given time could be associated

with the action of sex hormones that favor more growth in males when compared with females. Single-born lambs were significantly heavier than multiples (twin and triple) at birth and weaning age, whereas triples had a lower body at sixth-month age. On the other hand, the present result observed no significant ($p > 0.05$) variation in birth type at yearling age. More space in the dam's uterus and a lack of competition during pregnancy would have facilitated a higher birth weight for a single lamb at birth.

Litter Size:

The number of lambs born per birth was observed as a significant ($p<0.001$) source of variation at all ages except for yearling age, where observed body weight was not significantly ($p > 0.05$) different. At birth, weaning, and six months of age, single-born lambs achieve significantly heavier body weight than multiple-birth lambs. Similarly, the body weight of twin births was significantly heavier than that of triple births at birth and weaning age. More space in the dam's uterus and a lack of competition during pregnancy would have facilitated a higher birth weight for a single lamb at birth. The absence of competition for milk utilization for lambs born as singles could have facilitated a better growth rate before weaning age. Many previous studies have widely documented heavier body weight and better growth in single-born lambs over multiple-born counterparts (Abegaz et al., 2011; Zeleke *et al.*, 2017; Dagnew *et al.*, 2018). Better feeding management of dams during pregnancy could thus partially improve body weight at birth and later age because lambs with a higher birth weight typically have better growth performance throughout their lives (Kosgey, 2004).

Dam Parity:

Dam parity was observed as a significant source of variation in body weight at birth and at 180 days. However, no significant parity effect was observed at 90 days or yearling age (360 days). The lamb of an older dam (four to six) had a heavier birth weight compared with the younger dam. This is associated with older dams developing more useful physiological processes than younger dams, which is consistent with previous research (Sodiq, 2012). The significant effects of parity at 180 days were slightly increasing up to parity four and starting to decline. This implies that lambs of lower parities had lower body weight performance, which might be associated with the reproductive physiological process not being well developed in a younger dam when compared with an older one.

Year Effect:

The growth performance of Abera sheep was significantly ($p<0.001$) different across years (2013–2020). The least-square mean of birth weight observed during 2018 was significantly ($p<0.01$) heavier (3.35±0.017 kg) than the lowest least-square mean observed during 2013—when Abera CBBP was implemented. Observed body birth weight performance differences across years could be associated with selective breeding programs which increase the overall performance of sheep.

Birth Seasons:

The present study observed no significant difference in seasons at birth and at 90 days. The current result was in agreement with a previous study (Ashebir *et al.*, 2019) that did not observe significant effects of the birth season at 90 days for a study conducted for sheep reared in the Fentale district of Oromia regional state. However, the current result was contrary to a previous study (Legesse, 2008), which observed significant effects of the season at birth.

The Daily Growth Rate of Abera Sheep

The least-squares mean (standard error) of fixed effects having significant effects between 0 and 90 days and 90 and 180 days were presented in Table 2. The observed pre-weaning average daily weight gain (135.31±0.50) g/day in the present study was heavier by 29.32 g/day for the same sheep population (Marufa *et al.*, 2017). The pre-weaning daily weight gain of Washera sheep (107.1 g/day) was also lower than the corresponding value in the present study (Taye *et al.*, 2010). The post-weaning average daily weight gain of Abera sheep was observed to be 63.64±0.49 g/day. The present study showed Abera sheep gained more daily weight during the pre-weaning age than after weaning, which indicated strong maternal dependence of lambs on their dams during pre-weaning periods. Weaning shock could also be a significant factor causing lower daily weight gain during post-weaning periods. The result of the present study was somewhat heavier than the corresponding value for Rutana sheep (59.01 g/day), as reported by Dagnew *et al.* (2018).

Lamb Sex:

Lamb sex had a significant effect on both pre-weaning and post-weaning daily weight gain (g/day) of Abera sheep. The male lambs were significantly heavier than their female counterparts by 4.41 g/day and 2.52 g/day, respectively, during pre-weaning and post-weaning periods. The result of the pre-weaning average daily weight of male superiority over females was in agreement with previous studies (Marufa *et al.*, 2017; Dagnew *et al.*, 2018). The possible reason for male superiority over females could be associated with a difference in testosterone secretion between males and females. Previous studies (Marufa *et al.*, 2017) did not observe a significant average daily weight gain difference between male and female lambs during post-weaning periods, which was contrary to the result of the present study.

Birth Type:

Birth types had significant effects ($p<0.05$) on the body weight gain of Abera sheep. Single and twin births had a heavier growth rate (g/day) during 0 to 90 days than triplet births—triplets had a lower daily weight gain. From 90 days to 180 days, single-born lambs had a higher daily weight gain than their multiple-born counterparts. The superiority of single-born lambs during post-weaning periods could be associated with their previous better condition during pre-weaning periods. The previous studies, in agreement with the present study, observed significant effects of birth types on the growth rates of sheep reared in different locations (Tibbo, 2006; Cloete *et al.*, 2007; Taye *et al.*, 2010; Marufa *et al.*, 2017; Dagnew *et al.*, 2018).

Birth Seasons:

The daily weight gain (g/day) of Abera sheep differed significantly ($p< 0.05$) from 0 to 90 days and from 90 days to 180 days. From ninety days to 180 days, the average daily weight gain of Abera sheep was higher for lambs born during the dry season than for those born during the short and main rainy seasons. The higher body growth rate of lambs born during dry seasons could be associated with ample feed resource availability during the main rainy seasons when lambs born during dry seasons achieve their 180-day age.

Breeder Cooperatives:

The average body growth rates of Abera sheep were significantly ($p<0.01$) different across the breeder cooperatives. Sheep in Abera Bongodo cooperatives had a higher average daily weight gain (g/day) from 0 to 90 days, followed by sheep in Abera Atela breeder cooperatives, whereas the lowest 0 to 90-day daily weight gain was observed for sheep owned by Abera Doda cooperatives. Sheep in the Abera Doko cooperative gained more weight from 90 to 180 days,

followed by sheep in the Abera Bongodo and Abera Gelede breeder cooperatives. The difference in feed resources and management conditions could be the most possible reasons for the difference in the body growth rate of Abera sheep across breeder cooperatives.

Table 2: Least square mean ± standard error (g/day) of fixed effects affecting body growth rate of Abera sheep from 0 to days and 90 days to 180 days.

Fixed effects	Pre-weaning daily weight gain		Post weaning daily weight gain	
	[1]N	[2]LSM±SE (g/day)	N	LSM±SE (g/day)
Overall	2838	135.31±0.50	2692	63.64±0.49
R^2	2838	18.46	2692	7.92
CV%	2838	14.16	2692	38.95
Sex		**		*
Male	1716	137.04±0.63	1634	64.50±0.61
Female	1122	132.63±0.79	1058	61.98±0.77
Litter size		**		*
Singleton	1956	136.77^{a}±0.57	1855	81.81^{a}±0.58
Twin	871	132.55^{a}±0.74	829	65.53^{b}±0.91
Triplet	11	121.69^{b}±11.94	8	62.71^{b}±6.59
Seasons of lambing		*		**
Dry season	1118	136.98^{a}±0.77	1069	67.19^{a}±0.77
Short rainy season	689	134.59^{a}±0.95	653	61.07^{b}±0.98
Main rainy season	1031	133.82^{b}±0.65	970	61.45^{b}±0.85
Year of lambing		**		**
2013	157	142.95^{ab}±1.61	157	66.37^{a}±1.69
2014	209	142.91^{ab}±1.1	209	61.64^{ab}±1.31
2015	551	145.28^{a}±0.72	552	69.14^{a}±1.08
2016	452	134.11^{c}±7.21	457	67.92^{a}±1.16
2017	321	125.67^{d}±1.25	317	58.85^{ab}±1.34
2018	642	121.96^{d}±1.37	499	63.11^{a}±1.19
2019	498	138.56^{bc}±0.97	494	56.84^{ab}±0.98
2020	8	143.74^{ab}±3.06	7	50.42^{b}±8.41
Dam parity		*		*
1	1520	136.33^{a}±0.52	1443	62.72^{b}±0.66
2	606	136.89^{a}±0.84	581	65.03^{b}±1.04
3	388	132.51^{a}±1.10	372	64.34^{b}±1.26
4	211	131.80^{a}±1.45	198	67.41^{a}±1.75
5	80	136.50^{a}±2.70	74	54.13^{c}±2.54
6	22	124.68^{b}±5.12	24	52.43^{c}±4.70
Breeder cooperatives		**		**
Abera Atela	668	136.28^{b}±0.73	667	62.92^{c}±0.75
Abera Bongodo	462	143.66^{a}±0.63	462	65.75^{b}±1.00
Abera Doda	307	118.13^{d}±1.40	307	54.91^{d}±1.62
Abera Doko	360	130.58^{c}±1.25	360	71.39^{a}±1.89
Abera Gelede	752	130.35^{c}±0.70	751	63.50^{b}±0.92
Bochesa Gobe	289	132.32^{c}±1.10	289	60.50^{c}±1.50

N: number of records, LSM: Least square mean, SE: Standard error, * and ** significant at $p<0.05$ and $p<0.01$, respectively. Means with different superscript are significantly different.

Reproductive Performance

Litter Size:

Sheep prolificacy is an important reproductive trait that determines farm productivity. Although there has been a slight improvement in the prolificacy of Abera sheep over the past year (Table4), the recorded mean litter size (1.19) was lower than corresponding values for many sheep breeds such as Bonga sheep (1.4; Edea, 2008), Gumuz sheep (1.43; Asmare et al., 2021), and Adilo sheep (1.42; Getahun, 2008) under different management conditions. In contrast to this, however, lower mean litter size was reported for Gumuz sheep (1.17; Solomon, 2007), Washera sheep (1.1; Taye, 2010), and Menz sheep (1.13; Mukasa-Mugerwa et al., 2002). The observed mean litter size of sheep in the present study was significantly ($p<0.05$) different across the year but not across breeder cooperatives (Table 3). The lowest mean (1.09) of litter size was observed in 2013, followed by 2014. The mean litter size observed between 2015 and 2020 was not significantly ($p<0.05$) different and higher (Table 3). In 2013, more than 90% of observed births were single, whereas in 2020 the corresponding proportion was nearly 80%, which indicated the improvement in prolificacy as the chi-square test showed (Table 4).

Table 3: Mean litter size of Abera sheep across year and breeder cooperatives.

Year	N	Mean ± SE	Breeder cooperatives	N	Mean ± SE
2013	144	1.09^{b}±0.03	Abera Atela	703	1.17±0.01
2014	180	1.15^{ab}±0.03	Abera Bongodo	514	1.22±0.02
2015	478	1.19^{a}±0.02	Abera Doda	395	1.19±0.02
2016	404	1.21^{a}±0.02	Abera Doko	340	1.18±0.02
2017	312	1.19^{a}±0.02	Abera Gelede	738	1.21±0.02
2018	600	1.19^{a}±0.02	Bochesa Gobe	295	1.17±0.02
2019	644	1.22^{a}±0.02			
2020	223	1.20^{a}±0.03			
Overall	2985	1.19±0.01		2985	1.19±0.01
p-value		0.0263			0.1371

SE: standard error. Column means with different letter are significantly different ($p<0.05$)

Table 4: The proportion (%) of single and twin of sheep between 2013 and 2020

Prolificacy	Year								X^2	*p*-value
	2013	2014	2015	2016	2017	2018	2019	2020	15.86	0.026
Single	91	85	80.8	78.7	81.1	81.2	78.1	80.3		
Multiple	9	15	19.2	21.3	18.9	18.8	21.9	19.7		
^{1}N	144	180	478	404	312	600	644	123		

N: Number of records

CONCLUSIONS

The present study evaluated the growth and reproductive performance of Abera sheep owned by community-based breeding program participants using retained performance records since 2013. The result showed considerable improvement in growth traits since the breeding program was implemented. Many of the considered fixed effects had a significant influence on growth traits, indicating that these fixed effects should be considered when breeding rams are selected. The selection index should be used to consider the fixed effects significantly affecting growth performance for further selection of breeding rams. Although the proportion of ewes lambing multiples per lambing showed considerable increment over years, the overall mean of sheep prolificacy was found to be low under a community-based breedingprogram. As community-based breeding programs have made considerable contributions to improvement in growth traits,

further selection and scaling up should be encouraged. Inclusion of the selection index along with growth traits targeted for improvement can be used as an important strategy to improve sheep prolificacy per lambing.

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Evaluation of Rhizobial Inoculants for Symbiotic Performance of Faba bean (Vicia faba L.) in the Arsi Zone, Southeastern Highlands of Ethiopia

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Abstract:
This study was initiated to evaluate the effect of locally isolated Rhizobium inoculants on nodulation and yield of faba bean at Arsi Zone, Ethiopia for two consecutive years. Eight treatments comprising six effective isolates of rhizobia, un-inoculated (negative control), and recommended N-fertilized (18kg N ha-1) were laid out in a randomized complete block design with three replications. The result of the experiment indicated that all inoculation treatments increased nodule number, nodule dry weight, and nodule fresh weight, yield, and yield components over the control check in all experimental sites. The result, however, showed the non-significant ($p < 0.05$) effect of Rhizobium inoculation on 100 seed weight in all Experimental sites as compared to each treatment. Inoculating FB-24 and FB-120 gave the highest mean grain yield (4273.4 kg ha-1 and 4192.2 kg ha-1) respectively. These records were 61 and 58% over the un-inoculated treatment respectively. In all experimental sites, FB-24 and FB-120 inoculation resulted in the highest nodulation and grain yield production as compared to the other treatments. In general, isolates from the Arsi zone showed good performance in all yield and yield parameters Therefore, FB-24 and FB -120 were recommended as candidate isolates for faba bean biofertilizer production in the Arsi Zone of Ethiopia.

Keywords: Rhizobium, inoculants, faba bean, biofertilizer, yield.

INTRODUCTION

One of the main pulse crops produced in Ethiopia's highlands is the faba bean (Vicia faba L.) (Fedaku et al., 2019). Ethiopia is second only to China among the major producers of faba beans in the globe (FAO, 2019). The edible seed of the high-value crop known as the faba bean serves as an essential source of protein for Ethiopians who eat a diet high in cereals, especially the less fortunate who cannot purchase animal products. According to estimates, it makes up 15% of the protein consumed, which would help 36% of the undernourished people. The faba bean should be included in a sustainable farming scheme in Ethiopia as a crop to rotate with cereals (Tamene Temesgen et al., 2015). It currently takes up 31% of the nation's 1,863,445 hectares dedicated to growing pulses (CSA, 2019). The crop is important for improving land fertility and providing food for humans and animals (Mulugeta et al., 2019). However, compared to the average yield (3.7 t ha-1) achieved in the world's main faba bean-producing nations, the productivity of the crop in the nation is low (2.12 t ha-1) (FAOSTAT, 2017; CSA, 2019). Currently, intensive agricultural practices confront several difficulties that seriously jeopardize the security of the world's food supply. Chemical fertilizers and pesticides are used extensively to increase crop output to meet the growing global population's nutritional needs (Matthews et al., 2019). Due to excessive use of harmful pesticides and chemical fertilizers, modern agriculture has lost the ability to be sustainable, which has increased cultivation costs, decreased food security and safety, and

ultimately decreased soil fertility (Saritha and Prasad Tollamadugu, 2019). Without allowing any crop or livestock manure residues on farmland, Ethiopia is gradually using more chemical fertilizers. This action results in a reduction in the spread of soil fauna and flora, poor soil structure, low soil nutrient and water holding capacity, and distracted soil microorganisms. The role of biological nitrogen fixation in increasing crop output plays an undeniable role in minimizing these environmental and soil damages brought on by chemical fertilizers, especially in preserving soil health.

Although using rhizobia in inoculating legumes can significantly increase growth and yield productivity and improve soil fertility, low productivity in grain legumes is caused by declining soil fertility and reduced N_2 fixation. There is no doubt that specificity exists between rhizobia strain and the legume variety, and compatibility between the two is essential for successful nodulation and nitrogen fixation (Raja *et al*., 2013). High yield and land fertility are both significantly impacted by the biological nitrogen fixation of faba beans. Additionally, the N and P that plants can uptake and share with grain and straw have a beneficial residual effect on soil fertility, the quality, and the production of faba bean seed (Klippenstein, 2019). A yearly global total of 175 million tons of biological N_2 fixation is produced by rhizobium symbiosis with legumes (Yadav and Verma, 2014). Microbial inoculants' biological activity aids in recovering nutrients and mobilizing their availability, which improves the overall condition of the soil (Yadav and Sarkar, 2019). A ground-breaking innovation, biofertilizer, promises to have a substantial effect on farmers' crop production and productivity. It is referred to as bio-inoculants that contain living organisms that aid plant roots in the rhizosphere in the availability and absorption of nutrients. Rhizibial inoculants may be able to stop nitrification for an extended length of time while enhancing the soil's fertility (Sun *et al*., 2020; Fasusi *et al*., 2021). They are among the essential elements of Integrated Nutrient Management (INM) strategies, which aim to balance the productivity and sustainability of the soil while also maintaining environmental safety, being pollution-free, economically viable, and providing plants with renewable nutrients to supplement synthetic fertilizers in a sustainable production system (Yadav and Sarkar, 2019). De Vives-Peris *et al*., (2020); Fasusi *et al*., (2021) have developed microbial inoculants that contain the culture of dormant or live cells of the efficient strains of N-fixing, P-solubilizing/mobilizing, and K-solubilizing. It has become innovative and environmentally friendly to use beneficial microorganisms as bio-fertilizers in sustainable agricultural practices to increase soil fertility and plant development (Bertola *et al*., 2019; Murgese *et al*., 2020; Fasusi *et al*. 2021). Therefore, the goal of this research is to assess how well rhizobial inoculants perform in terms of faba bean grain and biomass yields in the main Arsi zone faba bean growing regions.

MATERIALS AND METHOD

Description of the Research Site

The field evaluation experiment was conducted in three districts of the Arsi zone, Kulumsa, Hitosa, and Bekoji during the 2019 and 2020 crop seasons under rain-fed conditions. The soil was not infused with any previous rhizobia strains nodulating faba beans.

Nodule Sample Collection

The samples were collected in the Arsi Zone's 11 principal faba bean farming regions (Table 1). These districts were picked because they have never received a faba bean rhizobia inoculation and have a history of having a high faba bean yield. The root nodules were taken during the blossoming period. The roots were harvested for their pink nodules. As the rhizobia were isolated and identified, the nodules were collected, placed in vials with a desiccant (silica gel), and wrapped

in 1 centimeter of cotton wool before being transported to the Holleta soil microbiological laboratory at the Holleta agricultural research facility (Somasegaran, P. and Hoben, H. J, 1994). In the Holleta soil microbiological laboratory at the Holleta Agricultural Research Center, sand culture under greenhouse conditions was isolated, characterized, and tested for symbiotic efficacy. The six best native faba bean rhizobia (FB-8, FB-24, FB-120, FB-EAR-5, FB-EAR-15, and FB-EAR-13) were then chosen for field testing. Faba bean (Numan variety) from Kulumsa Agricultural Research Center was utilized.

Table 1: Soil samples and Nodule collection GPS data at different Agro-ecology of Arsi Zone

No	Sample cod	Location (Kebele)	Woreda (district)	Previous crop	GPS Coordination		
					Altitude (M)	Latitude (N)	Longitude (E)
1	FB-120	Kulu-on station	Tiyo	wheat	2161	08^0 00' 989"	39^0 08' 976"
2	FB - EAR60	Kulu-on station	Tiyo	wheat	2176	08^0 01' 206"	39^0 09' 393"
3	FB -01	Lemu Tijo	Shirka	maize	2695	07^0 34' 368"	39^0 26' 301"
4	FB -02	Lemu Tijo	Shirka	barley	2820	07^0 33' 918"	39^0 24' 970"
5	FB -03	Bedi-Micael	Lemu bilbilo	barley	3137	07^0 31' 138"	39^0 17' 895"
6	FB -04	Cheba micael	Lemu bilbilo	barley	3019	$07^0$31' 249"	39^0 17' 018"
7	FB - EAR05	Meraro Station	Lemu bilbilo	wheat	2993	07^0 24' 423"	39^0 14' 959"
8	FB - EAR6	Dawa-bursa	Lemu bilbilo	fallow	2925	07^0 26' 672"	39^0 14' 846"
9	FB - EAR13	Bekoji-station	Lemu bilbilo	barley	2811	07^0 32' 728"	39^0 15' 383"
10	FB – EAR15	Lemu dima	Lemu bilbilo	barley	2683	07^0 34' 857"	39^0 14' 543"
11	FB -08	Ashebeka wolkte	Digelu Tijo	potato	2478	07^0 42' 291"	39^0 09' 602"
12	FB -10	Haro bilalo	Tiyo	barley	2551	$07^0$52' 624"	39^0 07' 509"
13	FB -11	Shorima sherera	Hitosa	wheat	2342	08^0 03' 056"	39^0 14' 194"
14	FB -12	Gonde shorima	Hitosa	wheat	2260	08^0 03' 558"	39^0 12' 529"
15	FB -17	Tulu jebi	Lode hitosa	barley	2473	08^0 07' 529"	39^0 26' 196"
16	FB -18	Efa lode	Lode hitosa	wheat	2689	08^0 06' 102"	39^0 29' 602"
17	FB -19	Hela wolkite	Diksis	Oat	2713	08^0 02' 502"	39^0 33' 814"
18	FB -20	Doyo gora	Arsi robe	wheat	2540	$07^0$56' 967"	39^0 34' 966"
19	FB - EAR21	A.robe on Station	Arsi robe	wheat	2437	07^0 53' 017"	39^0 37 722"
20	FB -22	Tankicha gefersa	Diksis	rapeseed	2669	08^0 07' 550"	39^0 32' 525"
21	FB -23	Banben	Siere	barley	2525	08^0 11' 457"	39^0 31' 623"
22	FB -24	Boreno Ogissa	Siere	Oat	2501	08^0 14' 378"	39^0 32' 021"
23	FB -25	Akiya tulogu	Chole	barley	2861	08^0 09' 853"	39^0 54' 196"

24	FB -26	Koro gugu	Chole	barley	3020	08^0 13' 059"	39^0 54' 970"
25	FB -27	Gado abita	Chole	barley	3047	08^0 14' 455"	39^0 55' 087"
26	FB -28	Rea amba	Abajemma	barley	2742	$08^0$19' 958"	39^0 52' 256"
27	FB -29	Jajiro	Abajemma	wheat	2498	08^0 23' 578"	39^0 54' 196"

Experimental Design and Treatments

Six native faba bean rhizobial isolates were chosen and examined at three separate Arsi zone locations: FB-24, FB-8, FB-120, FB-EAR5, FB-EAR15, and FB-EAR13 (Kulumsa, Bekoji, and Hitosa). The studies were carried out with three replications at a plot size of 4 m x 2.6 m and were done using a randomized full-block design (RCBD). To reduce cross-contamination, the distance between plots and blocks was increased by 0.5 and 1 meters, respectively. Rows and plants were 40 cm and 10 cm apart, respectively. The carrier-based rhizobial inoculants were applied at a rate of 500 g ha^{-1}. Each experimental plot received a base application of 100 kg P ha1 from TSP at planting time. Urea applied at a positive control received 18 kg N ha1. Contrarily, the negative control, does not apply any inputs (N and P). The experimental fields and experimental units were managed using the approved agronomic faba bean methods.

Preparation of Rhizobia Inoculants and Seed Dressing

At Holleta Agricultural Research Center, soil microbial laboratory rhizobia isolates were made in carrier-based inoculants. The carrier material for the investigation was 10^6 micrometer-mesh-sized powdered lignite that had been pH-adjusted and could pass through it. In white polyethylene heat-resistant bags with a partial seal, 50 grams of lignite were placed, and the bags were sterilized at 121 ^{O}C for 30 minutes. Then, using the unsealed portion, 10 ml of high-quality broth culture from each rhizobia isolate was inoculated. The broth culture contained more than 10^9 colony-forming units per milliliter, and it was homogenized in an aseptic environment before being incubated at room temperature for two weeks to cure. Viable cell counts were used to check for contamination and to determine the number of minimum-threshold rhizobia cells (Vincent, 1970). Yellow and opaque plastic bags were used to shield the inoculants from direct sunlight exposure. The recommended rate of faba bean seeds was 200 kg ha^{-1} weighed, moistened with sticker solution, and dressed carefully with the respective inoculant until all the seeds in plastic bags were uniformly coated. The whole seed dressing procedure was carried out under the shade. The fully-dressed and air-dried seeds were planted and immediately covered with soil.

Soil Sampling and Analysis

Random composite soil samples were taken at a depth of 0–20 cm from each experimental plot before planting and after harvesting. The soil samples were crushed to fit through a 2 mm filter after being air-dried. The pH of the soil was measured in a ratio of 1:2.5. The Walkley and Black (1934) wet digestion method was used to calculate soil organic carbon. The soil's accessible phosphorus content was determined using the Bray-II extraction method, and its total nitrogen content was determined using the Kjeldahl (1883) wet-digestion method.

Data Collection

Nodulation Parameters:

Five randomly chosen faba bean plants from each plot were uprooted at flowering as part of a disruptive sample technique from the border rows for the nodulation investigation. On a screen, roots were gently cleaned with tap water that was slowly flowing, and nodules were then separated and counted. An effective number of nodules: To determine the effective number of nodules, the color of the nodule inside was examined by cutting with a sharp blade; nodules that

were pink to dark red were deemed to be effective, while green nodules were considered to be ineffective. The effective nodules then underwent additional analysis, including nodule number, nodule fresh weight, and nodule dry weight. The average values of the effective nodules from the five plants were used to compute the number of nodules per plant. The collected nodules were uniformly dried in an oven for 65 hours at 75 °C to determine the nodule dry weight per plant. The average of five plants was used to compute the nodule dry weight per plant.

Agronomic Parameters:

Plant height (PH), number of pods per plant (NPPP), number of seeds per pod (NSPP), above-ground biomass yield (BY), hundred seed weight (100SW), and grain yield (Adj. GY) were all recorded for each plot. Grain yields were corrected for 10% moisture content for statistical analysis, and the yield per plot was converted to kg ha^{-1}. The average value of five representative plants per plot was used to calculate the effect of rhizobia isolates on plant height, the number of pods per plant, and the number of seeds per pod.

Statistical Analysis

Using the SAS software package, the measured data were statistically examined for analysis of variance (SAS Institute, 2010). The 5% level of significance LSD mean comparison approach was used to separate the significant treatment means.

RESULT AND DISCUSSION

Soil Analysis Results

According to the soil pH, all sites experienced somewhat acidic soil reactions (H_2O). The bulk of crops can be produced in that range (FAO 2020). The pH of the soil from the test site is almost within the range of productive soils. Tadese (1999) noted that the soil's total nitrogen content and level of organic matter were both low before planting.

Table 1: Soil chemical properties before planting of faba bean

Soil Properties	Values					
	Kulumsa (2019)	Kulumsa (2020)	Hitosa (2019)	Hitosa (2020)	Bekoji (2019)	Bekoji (2020)
pH (H2O)	5.94	6.08	6.26	6.54	5.66	5.68
Organic matter (OM) (%)	3.35	4.31	4.82	4.60	3.16	4.88
Total Nitrogen (TN) (%)	0.15	0.14	0.14	0.15	0.13	0.14
Available P (mg kg^1 soil)	17.47	11.33	8.68	14.89	15.81	9.06

The three sites' soil assessments after the faba bean harvest showed that adding strains considerably ($p \leq 0.05$) increased the soil's available P, total N, and organic matter contents (Table 2). Consequently, it is crucial to apply inoculation with effective strains in the study regions to replace any lost nitrogen that the soil was unable to deliver to the crop. Olsen *et a*l. (1954) found a high quantity of phosphorus that was readily available, and the pH of the soil varied somewhat but not significantly in the experimental sites.

Table 2: Mean soil chemical properties as influenced by application of rhizobia strains after harvesting of faba bean.

Parameters (kulumsa)					Parameters (Bekoji)				Parameters (Hitosa)			
Year	pH	TN	AvaP	OM	pH	TN	AvaP	OM	pH	TN	AvaP	OM
2019	6.6^a	0.16^b	12.29^b	2.6^b	5.70^a	0.18^b	10.98^b	3.79^a	5.96^b	0.17^b	10.77^b	4.22^a

2020	6.7[a]	0.20[a]	19.86[a]	3.6[a]	5.89[a]	0.23[a]	20.94[a]	4.86[a]	6.84[a]	0.20[a]	23.34[a]	4.47[b]
Mean	6.6	0.18	16.08	3.16	5.81	0.21	15.96	4.32	6.40	0.18	17.06	4.34
LSD	0.14	0.04	1.25	0.37	0.12	0.04	2.57	0.53	0.09	0.02	1.45	0.46
Treatment												
C-	6.5[a]	0.13[b]	14.82[a]	2.84[a]	5.71[a]	0.14[b]	14.19[a]	3.79[a]	6.68[a]	0.13[b]	15.58[b]	3.86[b]
C+	6.6[a]	0.17[ab]	15.59[a]	3.13[a]	5.74[a]	0.17[ab]	15.60[a]	4.27[a]	6.70[a]	0.19[ab]	16.54[ab]	4.18[ab]
FB-8	6.6[a]	0.17[ab]	16.26[a]	3.14[a]	5.85[a]	0.22[a]	16.37[a]	4.36[a]	6.71[a]	0.18[ab]	16.92[ab]	4.34[ab]
FB-24	6.8[a]	0.21[a]	17.24[a]	3.36[a]	5.90[a]	0.22[a]	17.04[a]	4.76[a]	6.77[a]	0.23[a]	19.43[a]	4.48[ab]
FB-120	6.8[a]	0.21[a]	17.25[a]	3.24[a]	5.82[a]	0.22[a]	16.66[a]	4.56[a]	6.74[a]	0.23[a]	17.62[ab]	5.06[a]
FB-EAR-5	6.8[a]	0.17[ab]	15.94[a]	3.22[a]	5.81[a]	0.18[ab]	16.24[a]	4.52[a]	6.72[a]	0.17[ab]	16.63[ab]	4.29[ab]
FB-EAR-15	6.7[a]	0.17[ab]	15.05[a]	3.03[a]	5.80[a]	0.17[ab]	16.03[a]	4.20[a]	6.70[a]	0.16[b]	16.37[b]	4.12[b]
FB-EAR-13	6.7[a]	0.17[ab]	16.44[a]	3.30[a]	5.79[a]	0.17[ab]	15.52[a]	4.11[a]	6.71[a]	0.18[ab]	17.37[ab]	4.41[ab]
CV	3.40	5.78	3.29	3.79	3.21	5.57	3.14	6.31	2.42	2.64	4.57	5.26
LSD	0.27	0.03	2.49	0.73	0.24	0.05	5.15	1.07	0.18	0.06	2.90	0.92

Mean values in the same column with different letter(s) are significantly different at a $p \leq 0.05$.
pH= measure of acidity or alkalinity, TN= Total Nitrogen, AvaP= Available Phosphorous, OM= Organic matter

Effects of Rhizobia Isolates on Nodulation

According to the data analysis, there was a significant interaction between Rhizobium inoculation treatments and nodule number (NN), nodule fresh weight (NFW), and nodule dry weight (NDW) at $p \leq 0.05$. Rhizobium inoculation at several experimental sites showed that there were noticeably more nodules per plant. Figure 1a shows that strain inoculation had a substantial ($p \leq 0.05$) impact on nodule number/plant. More nodules were formed overall by inoculation plants than by control plants. When these strains were inoculated alongside the native faba bean Rhizobium strains that are already present in the study area, the results suggested that they would be more competitive and suited. Inoculating the Rhizobium strain with faba bean seed produced more nodules, according to Woldekiros *et al*. (2018). Indeed, research by Gedamu *et al.* (2021), Nagwa *et a*l. (2012), and El-Khateeb *et al.* (2012) found that inoculating faba bean with a Rhizobium strain significantly increased the number of nodules. According to Desta *et al.,* (2015), the inoculation of faba bean Rhizobium strains significantly increases the number of nodules per plant. According to the results, FB-24 and FB-120 were the two samples with the most nodules overall. The inoculated rhizobia at the Kulumsa site often produced the most nodules compared to the other two sites instead of (Bekoji and Hitosa). Figure 1b illustrates how the nodule fresh weight (NFW) and nodule dry weight (NDW) increased in comparison to the control. Inoculant FB-24 produced noticeably greater mean nodule fresh and dry weights at all sites, followed by FB-120. Carter *et al.* (1995) hypothesizes that the absence of competent native rhizobia-modifying faba beans in the soil where the experiment was conducted is the reason why the control check had the lowest NN, NFW, and NDW values. The nodulation of all uninoculated faba bean plants in all study locations served as confirmation of the presence of ineffective soil resident rhizobia strain populations across the study sites.

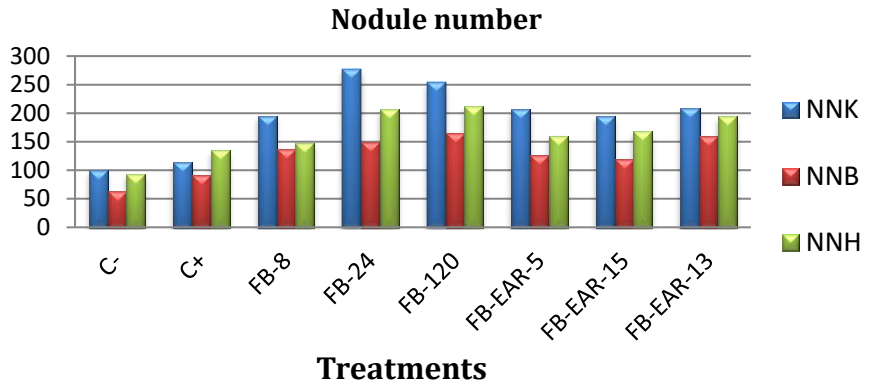

Figure1a: Effect of rhizobia inoculation on mean nodule number

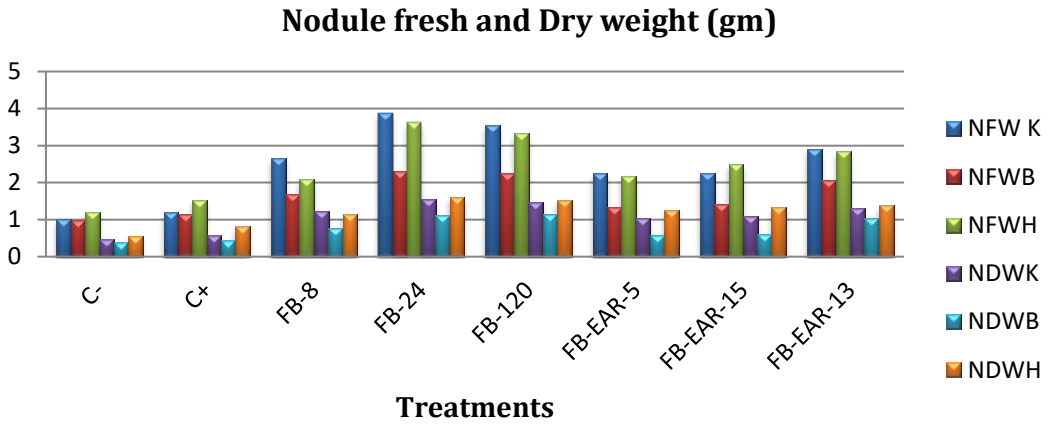

Figure 1b: Effects of rhizobia inoculation on mean nodule fresh and dry weight (gm).

NNK= nodule number Kulumsa, NNB= nodule number Bekoji, NNH= nodule number Hitosa, NFWK= nodule fresh weight Kulumsa, NFWB= nodule fresh weight Bekoji, NFWH= nodule fresh weight Hitosa, NDWK= nodule dry weight Kulumsa, NDWB= nodule dry weight Bekoji, NDWH= nodule dry weight Hitosa

Effect of Inoculation on Yield and Yield Components

The current study found that there were statistically significant differences between the treatments in terms of plant height (PH), number of pods per plant (NPPP), number of seeds per pod (NSPP), above-ground biomass yield (BY), grain yield (Adj.GY), and hundred seed weight (100 SWt) (Table 3,4 and 5). Inoculating with strain FB-24 led to the maximum plant height at the Hitosa experimental site of 160.98 cm, with FB-120 coming in second (158.47 cm). A similar pattern was seen for the quantity of pods per plant as measured by plant height. At all experimental sites, the Rhizobia isolates FB-24 and FB-120 performed best in terms of plant height and the number of pods per plant (Tables 3, 4, and 5).

Nonetheless, in terms of plant height and the quantity of pods produced per plant, there was a statistically significant difference ($p \leq 0.05$) between the treatments. According to research by Bejandi *et al*. (2012), seed inoculation significantly boosts nitrogen uptake, which enhances plant performance and growth with the potential to increase plant height. Faba bean pod production was shown to be significantly impacted by Rhizobium inoculation by Anteneh and Abere (2017), Albayrak *et al*. (2006), and Meena *et al.* (2007).

In terms of plant height, pods per plant, and seed production, the negative control showed the lowest result. At Hitosa, the rhizobia isolate FB-24 and FB-120 had superior NPPP scores of 22.95 and 20.05, respectively. Rhizobium inoculation increased the number of seeds produced per plant, as shown by Asrat and Fassil (2019) and Argaw & Tsigie (2015). In addition, isolate FB-24 was substantially greater for NSPP compared to the other treatments ($p \leq 0.05$). For 100SWt no significant difference ($p \leq 0.05$) was observed among the rest of the treatments except the negative control at all experimental sites. The negative control was the only treatment for which there was no significant change ($p \leq 0.05$) across all the experimental sites.

Table 3: Effect of inoculation on the combined mean of growth and yield parameters at Hitosa

Parameters						
Year	PH	NPPL	NSPP	100SWt (gm)	BY (kg/ha)	Adj.GY (kg/ha)
2019	141.89^{b}	16.75^{b}	3.3^{a}	93.8^{b}	6068.6^{a}	3037.9^{a}
2020	162.08^{a}	22.18^{a}	3.2^{a}	108.4^{a}	6993.7^{a}	3190.8^{a}
Mean	151.99	17.36	3.26	101.1	6531.11	3114.35
LSD	9.01	2.18	0.15	31.13	1424.4	510.09
Treatment						
C-	135.70^{b}	12.50^{b}	2.82^{b}	95.4^{b}	3866^{c}	1630.9^{c}
C+	152.18^{ab}	17.45^{ab}	3.20^{ab}	102.5^{a}	5883^{bc}	2819.7^{b}
FB-8	148.51^{ab}	18.30^{ab}	3.18^{ab}	100.1^{a}	6546^{abc}	3372.2^{ab}
FB-24	160.98^{a}	22.95^{a}	3.48^{a}	104.7^{a}	8990^{a}	4273.4^{a}
FB-120	158.47^{a}	20.05^{a}	3.25^{ab}	102.0^{a}	7490^{ab}	3929.1^{a}
FB-EAR-5	150.81^{ab}	16.43^{ab}	3.23^{ba}	100.2^{a}	5830^{bc}	2889.8^{b}
FB-EAR-15	152.85^{ab}	17.71^{ab}	3.21^{ab}	100.9^{a}	6251^{abc}	2570.3^{bc}
FB-EAR-13	149.18^{ab}	17.75^{ab}	3.15^{ab}	103.0^{a}	7391^{ab}	3429.5^{ab}
CV	15.01	10.63	10.07	12.68	18.44	13.85
LSD	18.03	4.36	0.31	62.26	2848.8	1020.2

Note. Mean values in the same column with different letter(s) are significantly different at a $p \leq 0.05$.
PH- Plant height, NPPL- Number of pods per plant; NSPP- Number of seeds per pod, 100SWt- 100 Seed weight, BY- Total biomass yield, Adj.GY- Adjusted Grain yield

Inoculating faba bean seeds with rhizobial isolates caused a significant change ($p \leq 0.05$) in above-ground biomass yield and adjusted grain yield at all study sites (Tables 3, 4, and 5). The inoculation of FB-24 and FB-120 resulted in the highest BY (9290 kg ha^{-1}) and Adj.GY (4273.4 kg ha^{-1}), which were respectively 8991.8 kg ha^{-1} and 4192.2 kg ha^{-1} at Hitosa and Kulumsa district. The negative control, however, had the lowest adjusted grain yields and above-ground biomass yields across all experimental sites. This outcome is consistent with several studies demonstrating that rhizobium inoculation considerably increases faba bean seed output (Anteneh and Abere, 2017 Habtemichial *et al.*, 2007). However, it concurs with the findings of Rugheim and Abdelgani (2012), Yohannes Desta *et al.* (2015), and Sameh *et al.* (2017), who showed that the inoculation of efficient rhizobial strains greatly boosted faba bean biomass and grain yield output. The rhizobial isolate inoculations gave the best results in the experimental year of 2020 as compared to 2019 because of the unstable rainfall conditions that occurred.

Table 4: Effect of inoculation on the combined mean of growth and yield parameters at Kulumsa

	Parameters					
Year	PH	NPPL	NSPP	100SWt (gm)	BY (kg/ha)	Adj.GY (kg/ha)
2019	152.46^{a}	20.03^{a}	2.97^{b}	96.4^{a}	7699.3^{a}	2696.05^{b}
2020	113.66^{b}	10.45^{b}	3.15^{a}	79.1^{b}	6618.1^{b}	3117.48^{a}
Mean	133.06	15.24	3.06	87.7	7158.68	2906.76
LSD	6.95	2.64	0.15	23.13	763.34	214.48
Treatment						
C-	116.01^{b}	11.38^{b}	2.88^{b}	83.8^{b}	3966.6^{d}	1739.8^{f}
C+	137.16^{a}	16.01^{ab}	3.08^{ab}	87.3^{a}	8196.2^{ab}	2868.3^{cd}
FB-8	138.50^{a}	16.18^{ab}	3.06^{ab}	88.0^{a}	7291.6^{bc}	3412.1^{b}
FB-24	141.66^{a}	19.86^{a}	3.30^{a}	88.6^{a}	8889.0^{a}	3978.6^{a}
FB-120	137.31^{a}	18.05^{a}	3.22^{a}	91.6^{a}	8991.8^{a}	4192.2^{a}
FB-EAR-5	129.51^{ab}	14.73^{ab}	2.95^{b}	85.7^{a}	6102.3^{cd}	2363.1^{e}
FB-EAR-15	132.33^{a}	15.25^{ab}	3.05^{ab}	89.3^{a}	6989.0^{bc}	2475.9^{de}
FB-EAR-13	132.00^{a}	17.50^{a}	3.06^{ab}	87.6^{a}	7545.1^{abc}	2964.3^{c}
CV	14.42	14.68	10.2	12.22	9.02	16.24
LSD	13.91	5.29	0.31	46.27	1526.7	428.95

Note. Mean values in the same column with different letter(s) are significantly different at a $p \leq 0.05$.
PH- Plant height, NPPL- Number of pods per plant; NSPP- Number of seeds per pod, 100SWt- 100 Seed weight, BY- Total biomass yield, Adj.GY- Adjusted Grain yield.

Table 5: Effect of inoculation on the combined mean of growth and yield parameters at Bekoji

	Parameters					
Year	PH	NPPL	NSPP	100SWt (gm)	BY (kg/ha)	Adj.GY (kg/ha)
2019	101.80^{a}	10.37^{b}	2.70^{b}	98.1^{a}	6853.2^{a}	2977.8^{a}
2020	120.01^{b}	13.30^{a}	3.30^{a}	102.7^{a}	6422.3^{a}	3148.5^{a}
Mean	110.98	11.83	3.00	100.4	6637.7	3063.12
LSD	7.51	1.27	0.13	45.90	648.7	160.48
Treatment						
C-	95.40^{b}	8.78^{c}	2.91^{b}	97.4^{a}	4223.3^{d}	1646.0^{e}
C+	113.50^{a}	12.36^{ab}	2.91^{b}	99.9^{a}	5803.0^{c}	2511.2^{d}
FB-8	111.35^{a}	11.35^{ab}	2.98^{b}	99.4^{a}	6914.3^{abc}	3417.3^{c}
FB-24	118.15^{a}	13.18^{ab}	3.11^{b}	103.0^{a}	7438.1^{a}	3807.2^{b}
FB-120	117.00^{a}	13.86^{a}	3.28^{a}	104.8^{a}	8029.4^{a}	4166.0^{a}
FB-EAR-5	107.35^{a}	10.88^{bc}	3.01^{b}	100.3^{a}	7188.9^{ab}	3115.6^{c}
FB-EAR-15	117.35^{a}	12.68^{ab}	2.98^{b}	99.3^{a}	6057.2^{bc}	2549.3^{d}
FB-EAR-13	109.80^{a}	11.58^{ab}	3.05^{b}	99.1^{a}	7547.8^{a}	3292.6^{c}
CV	15.7	9.10	13.72	13.86	8.27	14.43
LSD	15.02	2.54	0.26	91.803	1297.4	320.96

Note. Mean values in the same column with different letter(s) are significantly different at a $p \leq 0.05$.
PH- Plant height, NPPL- Number of pods per plant; NSPP- Number of seeds per pod, 100SWt- 100 Seed weight, BY- Total biomass yield, Adj.GY- Adjusted Grain yield.

CONCLUSION AND RECOMMENDATIONS

Eventually, at all of the experimental sites, the Rhizobium inoculation boosted the output of faba beans. Based on their performance of nodulation and yield production findings, FB-24 and FB-120 from the total of six rhizobial isolates can be candidates for producing biofertilizers for faba beans

in all experimental sites. The selected isolates must go through additional testing utilizing different agroecologies and on different soil types before being commercialized.

ACKNOWLEDGMENT

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Assessment and Characterization of Indoor and Outdoor Air Quality of Selected Facilities in a University Environment Using Different Fuel Sources

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Abstract:
This study aims to assess and characterize indoor and outdoor air quality of selected facilities in Federal University of Technology Owerri (FUTO) environs using different fuel sources. Six points in the study areas were sampled; Senate building, SOES, Old SEET Head, Female Hostel C, Market Square and Old registry designated as P1, P2, P3, P4, P5 and P6 respectively. The concentrations of PM2.5, PM10, CO, SO2, VOC, O3 and NO2 were measured using a hand-held gas analyzer. A handheld Germin-300 GPS device was used to get the coordinates of the sampling points which aided the data processing. Results showed high concentrations of CO at P5 for indoor environment, Indoor NO2 results in the P5 (0.064ppm) and P6 (0.072ppm) where Charcoal and Firewood respectively are used were above the limit set by the Federal Ministry of Environment and Department of Petroleum Resources at maximum limit of 0.06ppm. Indoor H2S at P1 and P4 with fuel sources of Diesel and Kerosene respectively had values of 0.2ppm and 0.1ppm which is above the maximum limit of 0.01ppm set by the Federal Ministry of Environment and Department of Petroleum Resources. Although, the average mean of both indoor and outdoor air quality differs, there were no statistically significant variations between the sample means of indoor and outdoor air quality parameters. The independent variables (meteorological parameters) perfectly predicted the combined indoor-outdoor air quality parameters at an adjusted R square value of 70.3% from the model summary and a statistical significance of 0.043 from the ANOVA table. Results showed that the meteorological parameters accounted for 70.3% of the air quality parameters sampled from six different facilities in FUTO utilizing varying fuel sources. Apart from the wet temperature that contributed uniquely in predicting the air qualities, the remaining meteorological parameters (dry temperature, relative humidity and wind speed) combined in predicting the air quality of FUTO environment.

Keywords: Assessment, Characterization, Indoor-Outdoor Air Quality, Fuel Sources, University Environment.

INTRODUCTION

Exposure to air pollution is globally a serious environmental issue leading to a risk factor to many diseases (Pope *et al.*, 2009; Shah *et al.*, 2013; Beelen *et al.*, 2014; Lelieveld *et al.*, 2014; Smith *et al.*, 2014; Chen *et al.*, 2017; Emeka and Chukwunyere, 2017), attracting worldwide attention (Ni *et al.*, 2018). The World Health Organization (WHO) estimates that approximately 3.7 million premature deaths worldwide result from exposure to ambient air pollution each year (WHO, 2009). Similarly, the increased burden on the use of solid fuel for cooking has resulted globally in over 4 million premature deaths from exposure to household air pollution (Shindell *et al.*, 2010: Anenberg *et al.*, 2012), with the most recent estimates from WHO reporting 4.3 million deaths for 2012 (Wilkinson *et al.*, 2009). It has been projected under socioeconomic scenarios that air

pollution will be the topmost environmental cause of premature mortality (OECD, 2012), contributing to worldwide premature mortality by 2050 (Lelieveld *et al*., 2014).

The impacts of air pollution are not limited to the public health of humans alone; Ole (2009) studies showed that air pollution has a variety of negative effects on climate and nature. Climatic effect results from the releases of particles and trace gases capable of changing a radiation balance in the atmosphere. Adverse health effects in the population are dependent on exposure level to air pollution while the effect on nature is caused by atmospheric deposition of acid gases and aerosols capable of leading to acidification of lakes and terrestrial ecosystems. Therefore, it is against this backdrop, that it becomes imperative to assess and characterize indoor and outdoor air quality of selected facilities at the Federal University of Technology Owerri environment using different fuel sources.

MATERIALS AND METHODS

Study Area

The Federal University of Technology, Owerri (F.U.T.O), prided as a premier Federal University of Technology in the South East and South West parts of Nigeria, was established in 1980. The University which operates a mono-campus structure is located in Owerri West Local Government Area, Southeast Nigeria and is bordered by Ihiagwa and Nekede communities on the North, Okolochi, Obibiezena, and Emeabiam on the East, Eziobodo community on the South and Umuoma, Avu and Obinze on the West. The campus occupies an area of about 4,048 hectares, housing eight (10) schools with over forty (40) departments, and a students' population of over 22,000. The popular Otamiri River traverses the campus from North to South adoring the site with its accompanying lush vegetation.

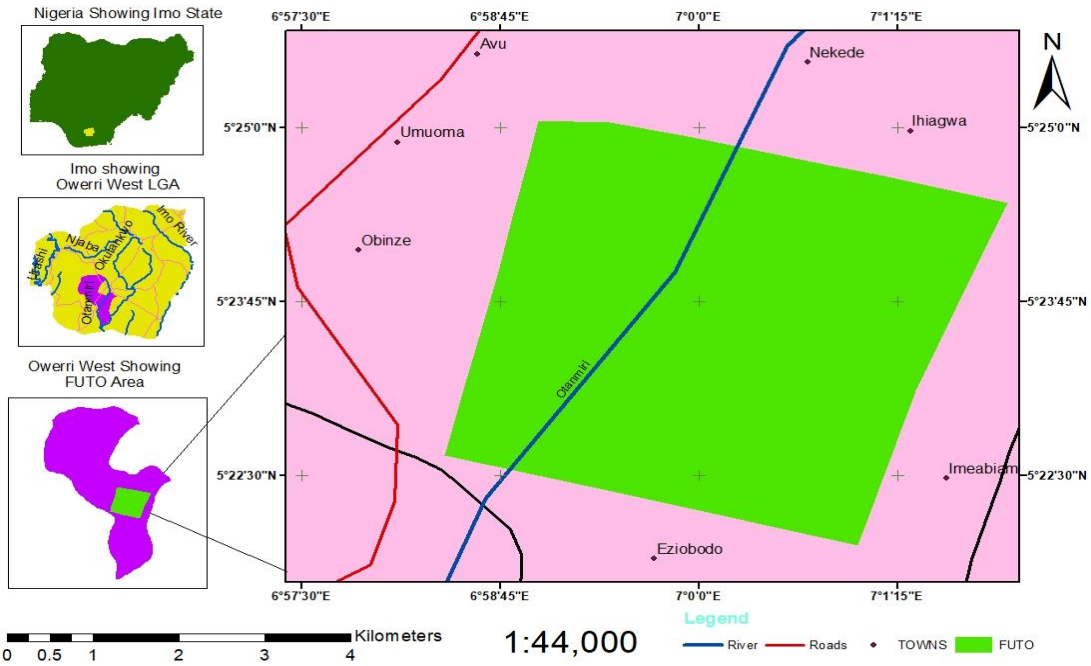


Fig. 1: Study Area

Measurement of Air Quality Parameters

A pilot study was carried out to determine the number of sites from where measurements of air quality parameters of interest were done during a regular working day and at peak hours. Gaseous

pollutants (Sulphur (IV) oxide (SO_2), Carbon Monoxide (CO), Nitrogen (IV) oxide (NO_2), Volatile Organic compounds (VOCs), particulate matter of different sizes ($PM_{2.5}$ and PM_{10}) and Ozone (O_3) and meteorological parameters (Temperature, Relative humidity, and Wind speed) were monitored for both indoor and outdoor in the study location (P1 to P6). Six (6) different fuel sources (charcoal, diesel, petrol, firewood, kerosene and gas) were identified for sampling to assess the variation in the concentration of gaseous pollutants emitted in both indoor and outdoor environments. The locations were randomly selected to spatially represent the university environment. Where each fuel source of interest is limited, selection is based on its availability irrespective of the proximity to another fuel source of interest.

Table 1: Sampled facilities from varying fuel sources

S/N	Name	Fuel Source Type	Longitude	Latitude
1	Female Hostel C	kerosene	6.99713	5.37874
2	Old Seat Head	Gas	6.99609	5.3835
3	Senate	Diesel	6.9933	5.38499
4	Behind Old Registry	firewood	6.99623	5.37924
5	SOES	Petrol	6.99955	5.38924
6	Market Square behind Catholic church	Charcoal	7.00015	5.39005

In-situ measurement was deployed to collect data of indoor-outdoor air quality parameters within the study area. This method involves air quality monitoring using a hand-held Gas analyzer (Aeroqual gas monitor). HT9600 Detector was used for Temperature, Relative humidity, $PM_{2.5}$, PM_{10}. Wind speed was measured using a Digital Handheld Anemometer. The remaining gaseous pollutants were measured using an Aeroqual 500 model instrument. A portable Samsung Android phone was used to take snapshots of the facility while Etrax GPS was used to record the coordinates of the sampling points in each facility. The portable air quality meter was raised to varying heights of 1.5 to 3 meters in the direction of the prevailing wind at each sampling location to avoid obstructions.

RESULT AND DISCUSSIONS

Table 1: Outdoor air quality result

Parameter	POINT 1	POINT 2	POINT 3	POINT 4	POINT 5	POINT 6	FMEnv STD/DPR Limit
	N: 5.3932^0	N: $5{\cdot}3851^0$	N: 5.38357084^0	N: 5.3876782^0	N: 5.39007217^0	N:5.37875216^0	
	E:6.9860^0	E: 6.9931^0	E: 6.99606351^0	E: 6.999397^0	E: 6.999709^0	E: 6.99701288^0	
	TIME: 10:05 AM	TIME: 12:17 PM	TIME: 1:49 PM	TIME: 3:09 PM	TIME: 4:35 PM	TIME: 5:54 PM	
	ELEVATION: 54.5 m	ELEVATION: 57.9 m	ELEVATION: 59 m	ELEVATION: 59 m	ELEVATION: 59 m	ELEVATION: 60 m	
CO, ppm	1.1	ND	ND	2.7	3.6	5.8	10.00 – 20.00
CO2, ppm	478	470	490	516	488	495	NS
O_3, ppm	ND	ND	ND	ND	ND	ND	0.15
NO2, ppm	0.039	0.055	0.034	0.049	0.058	0.064	0.075 - 0.11– 1 hour
CH_4, ppm	21	4	4	4	7	1	NS
H_2S, ppm	ND	ND	ND	ND	ND	ND	0.042
VOC, ppm	1	ND	ND	ND	ND	ND	NS
SO_2, ppm	ND	ND	ND	ND	ND	ND	0.026 – 24 hrs.;

							0.26– 1 hr.;
PM_{10}, ppm	0.016	0.009	0.011	0.018	0.1	0.025	0.15 - 24 hours;
$PM_{2.5}$, ppm	0.005	0.004	0.005	0.006	0.04	0.021	0.23 - 1 hours;
AIR TEMP. ^{0}C	30.1	31.9	33.7	33.5	30.3	29.6	NS
WIND SPEED, m/s	0.6	1.6	0.9	0.7	0.8	0.5	NS
Relative Humidity, %	72.2	64.3	64.7	75.8	74.6	72.8	NS
Wet Bulb Temperature, ^{0} C	27	27.6	28.5	28.9	39	25.6	NS

POINT 1	**DIESEL**	**Senate Building**
POINT2	**FUEL**	**School of Environmental Sciences (SOES)**
POINT3	**GAS**	**Old SEET Head**
POINT4	**KEROSEENE**	**Female Hostel C**
POINT5	**CHARCOAL**	**Market Square**
POINT6	**FIREWOOD**	**Commercial Building behind Old Registry**

Table 2: Indoor air quality result

PARAMETER	POINT 1	POINT 2	POINT 3	POINT 4	POINT 5	POINT 6	FMEnv STD/DPR Limit
	N: 5.3927^0	N: 5·3819^0	N: 5.38367782^0	N: 5.3877084^0	N: 5.38976121^0	N:5.37863721SS^0	
	E:6.9859^0	E: 6.9951^0	E: 6.99593321^0	E: 6.99925983^0	E: 7.00008279^0	E: 6.9969437^0	
	TIME: 10:46 AM	TIME: 11:38 AM	TIME: 1:11 PM	TIME: 2:34 PM	TIME: 3:58 PM	TIME: 5:19 PM ELEVATION: 60 m	
	ELEVATION: 54.1m	ELEVATION : 59.2 m	ELEVATION: 59 m	ELEVATION: 59 m	ELEVATION: 59 m		
CO, ppm	8.3	4.4	5.3	8.2	8.2	9.1	10.00 – 20.00
CO_2, ppm	513	523	708	541	450	498	NS
O_3, ppm	ND	ND	ND	ND	ND	0.02	0.08
NO_2, ppm	0.057	0.053	0.056	0.05	0.064	0.072	0.04 - 0.06– 1 hour
CH_4, ppm	6	4	4	4	1	7	NS
H_2S, ppm	0.2	ND	ND	0.1	ND	ND	0.01
VOC, ppm	ND	ND	ND	ND	ND	ND	0.0001
SO_2, ppm	ND	ND	ND	ND	ND	ND	0.01 – 24 hours; 0.1– 1 hour;
PM_{10}, ppm	0.012	0.01	0.012	0.011	0.013	0.008	0.37- 24 hours;
$PM_{2.5}$, ppm	0.004	0.004	0.005	0.006	0.005	0.003	0.34 - 24 hours;
AIR TEMP. ^{0}C	35.7	31.7	34.2	35.5	30.2	30	NS
WIND SPEED, m/s	0.6	0.7	0.25	0.5	1.3	0.3	NS
Relative Humidity, %	62.4	72.6	69.9	63.9	66.9	74.2	NS
Wet Bulb Temperature, ^{0} C	28.3	27.6	29.4	30.1	24.7	25.8	NS

POINT 1	DISEL	Senate Building
POINT2	FUEL	School of Environmental sciences (SOES)
POINT3	GAS	Old SEET Head
POINT4	KEROSEENE	Female Hostel C
POINT5	CHARCOAL	Market Square
POINT6	FIREWOOD	Commercial Building behind Old Registry

Meteorological Parameters

Dry-Bulb Temperature:

Mean dry bulb temperature of the fuel sources ranged from 29.6 to 35.7°C (Fig. 2). The highest dry bulb temperature was found at indoor measurement (35.7°C) in P1 utilizing diesel as fuel source while the least indoor temperature value was gotten at P5 utilizing firewood at 30°C. Similarly, the highest outdoor dry-bulb temperature was gotten at P3 using gas as fuel source while the least was at P5 utilizing firewood. Mean indoor dry bulb temperature ranged from 30 to 35.7°C with an average of 32.9°C while that of outdoor ranged from 29.6 to 33.7 with an average of 31.5°C

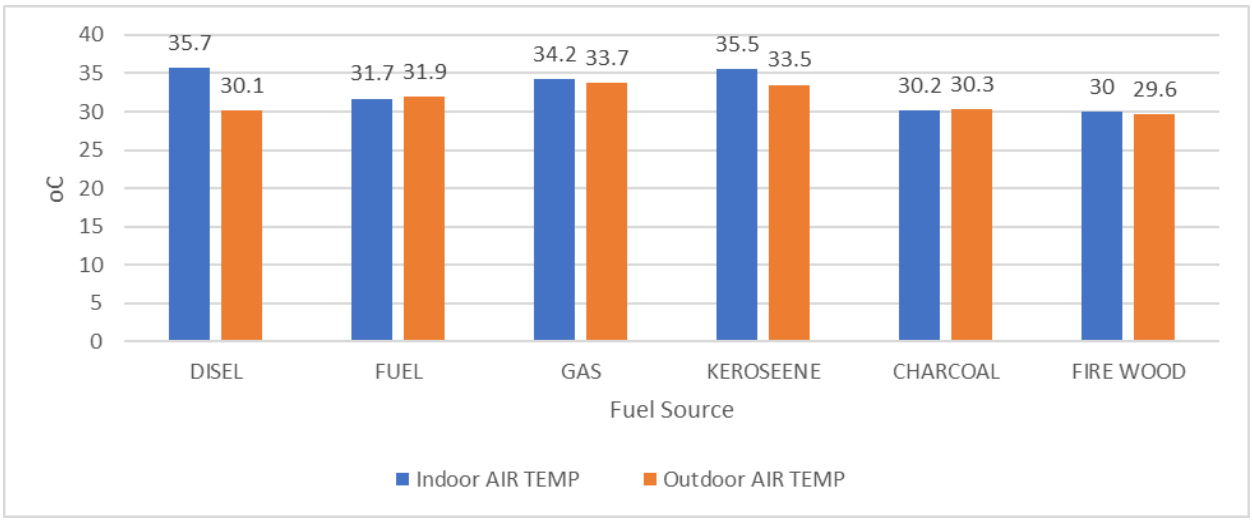


Fig. 2: mean dry bulb temperature for indoor and outdoor fuel sources

Wet Bulb Temperature:

Mean wet bulb temperature of the fuel sources ranged from 24.7 to 39°C (Fig. 3). The highest and lowest mean wet bulb temperature was found at outdoor measurement (39°C) and (24.7°C) respectively in P5 utilizing Charcoal as fuel source for both outdoor and indoor. Mean outdoor wet-bulb temperature ranged from 25.6°C to 39°C with an average of 29.4°C while that of indoor ranged from 24.7 to 30.1°C with an average of 27.7°C.

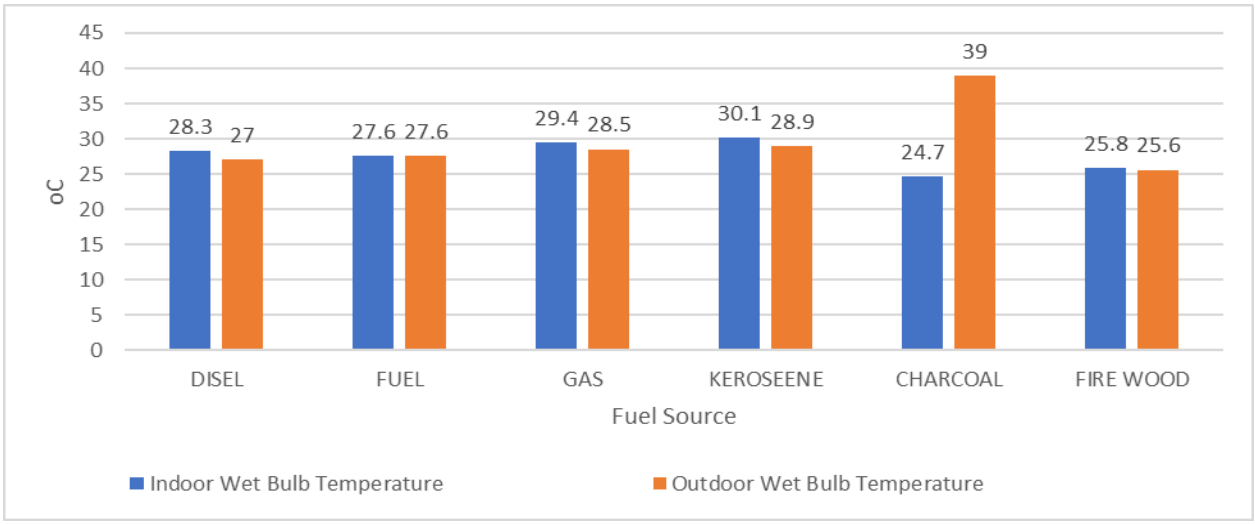


Fig. 3: mean wet bulb temperature for indoor and outdoor fuel sources

Relative Humidity:

Relative humidity readings were higher in outdoor fuel sources with an average of 70.7% compared to that of the indoor at an average of 68.3% (Fig. 4). The highest relative humidity wasfound at outdoor P_4 utilizing Kerosene as fuel source at 75.8% while the least relative humidity was found at indoor P_3 utilizing Diesel as fuel source.

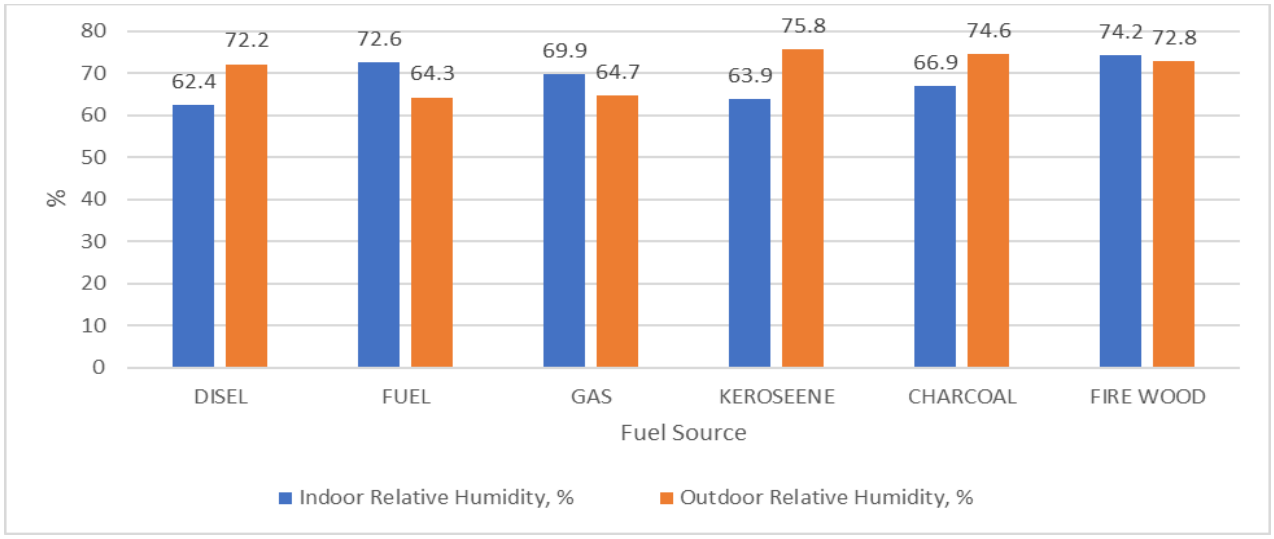
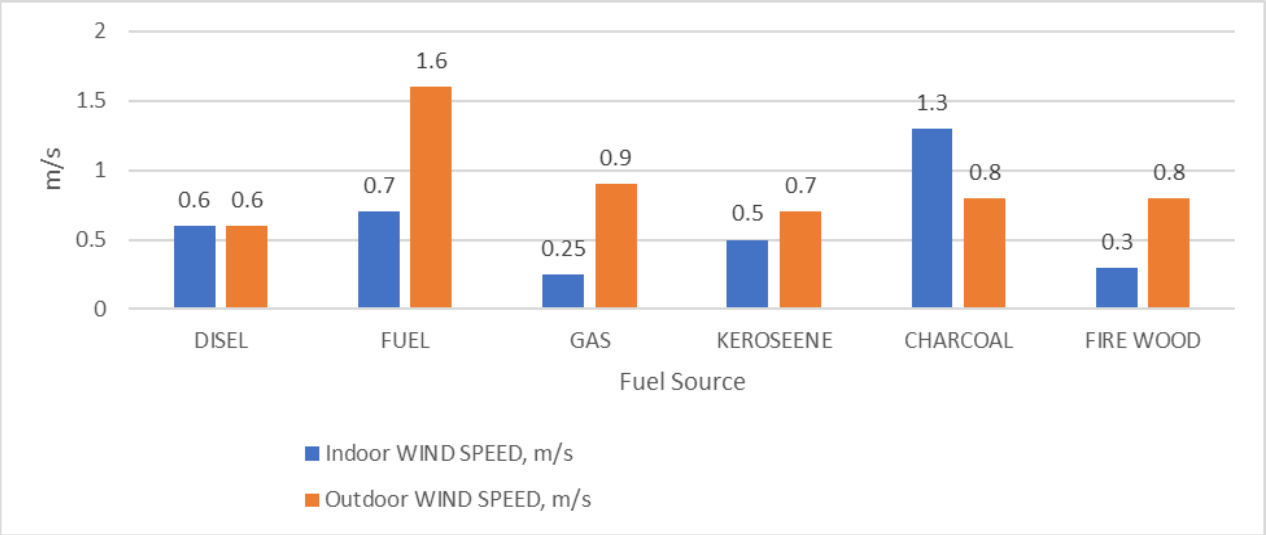


Fig 4: mean dry Relative humidity for indoor and outdoor fuel sources

Wind Speed:

Figure 5 presents the mean wind speed for both outdoor and indoor fuel sources. Outdoor fuel source had the highest and lowest wind speed at P_2 (1.6m/s) and P_1 (0.6m/s) respectively with an average of 0.9m/s. Indoor fuel source had the highest and lowest at P_5 (1.3m/s) and P_3 (0.25m/s) respectively with an average of 0.6m/s



Figs 5: mean wind speed for indoor and outdoor fuel sources

Physiochemical Parameters

Carbon Monoxide (CO):

There are observable variations between indoor and outdoor CO across six sampled building (Fig 6). Mean indoor CO concentration varies from 4.4 to 9.1ppm with an average of 7.3ppm whereas; mean outdoor CO varies between 0.000 to 5.8ppm with an average of 2.3ppm. Mean Indoor concentration at P6 where firewood is used for cooking was observed to be 9.1ppm. This result is above limit set for 8 hours indoor concentrations of less than 8.7ppm. WHO (2010) has identified cooking, heating, and smoking as common indoor sources of CO. Observed high concentrations of CO at P5 for indoor environment have been associated with burning of anthropogenic activities that include the firewood that emit CO and other gases as by-products in the university environments, there were no CO concentrations observed at location P2 and P3 where Petrol and Gas were fuel type utilized.

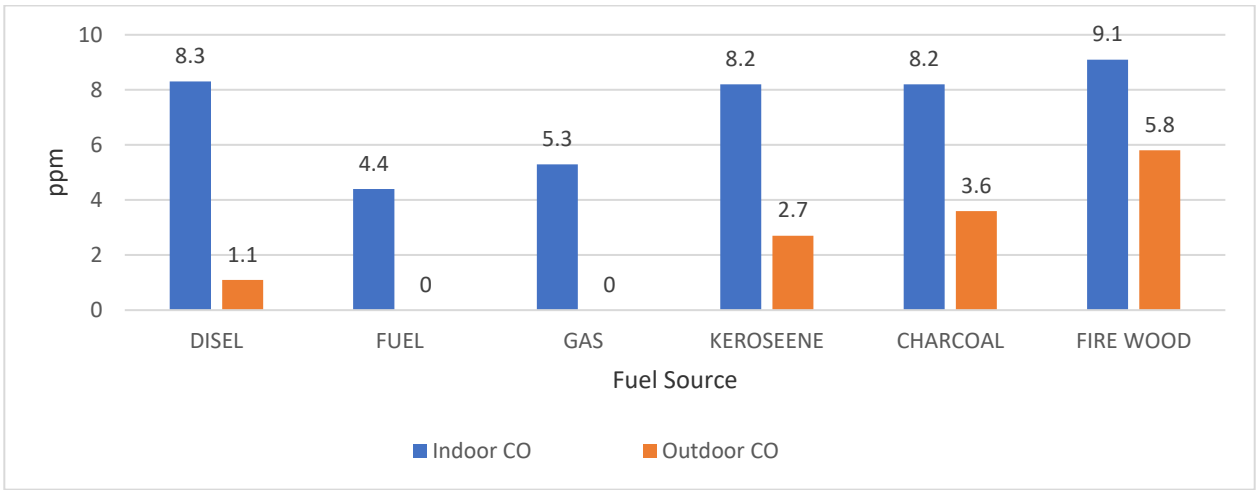


Fig 6: Mean CO concentration for indoor and outdoor fuel sources

Carbon Dioxide (CO_2):

Figure 7 presents CO_2 concentrations of different fuel sources from indoor and outdoor ranging from 450 to 708ppm. The mean values for outdoor concentrations ranged from 470 to 495ppm with an average of 489.5ppm while the indoor with the least and highest observed CO_2 concentration maintained an average of 538.8ppm. High indoor value was observed at P3 at

708ppm utilizing gas as fuel source. Meanwhile the highest outdoor value was observed at P6 where charcoal was used as fuel source. Indoor CO_2 concentrations were observed to be higher than outdoor cocentrations in four of the six sampled buildings in FUTO environment. Observed higher indoor CO_2 concentrations in comparison to the outdoor CO_2 concentrations found in this study can be attributed to the high occupant densities within the buildings which might have contributed to the high CO_2 concentrations through breathing.

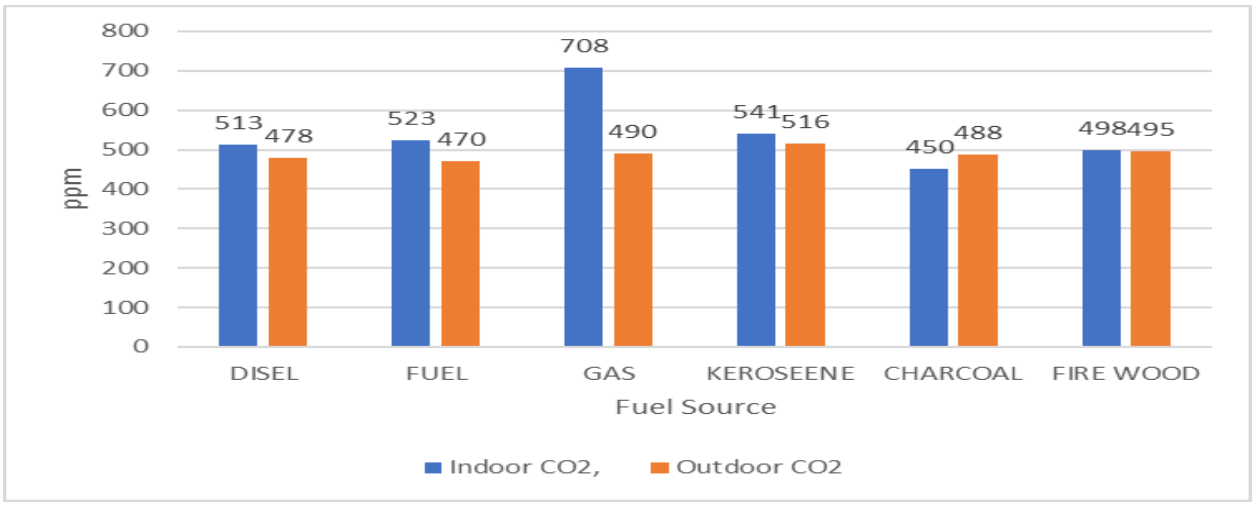


Fig 7: Mean CO concentration for indoor and outdoor fuel sources

Nitrogen Dioxide (NO_2):

Higher values of NO_2 were observed in indoor fuel source building compared to outdoor buildings (Fig .8). The mean values for indoor concentrations ranged from 0.05 to 0.072ppm with an average of 0.059ppm while the outdoor value ranged from 0.034 to 0.064ppm with an average of 0.049ppm. Highest indoor and outdoor values were observed at P6 at 0.072 and 0.064ppm respectively utilizing firewood as fuel source. These results are above the limit of 0.05ppm set by Federal Ministry of Environment for NO_2. Indoor NO_2 results at P_5 location (0.064ppm) and P6 (0.072ppm) where Charcoal and Firewood respectively are used were above the limit set by the Federal Ministry of Environment and Department of Petroleum Resources at maximum limit of 0.06ppm. Outdoor NO_2 concentration for the six buildings were within the limit of 0.075-0.11ppm set by the Federal Ministry of Environment. The lowest values for outdoor and indoor NO_2 concentration were at P_3 (0.034ppm) and P_4 (0.05ppm) representing Gas and Kerosene fuel sources respectively.

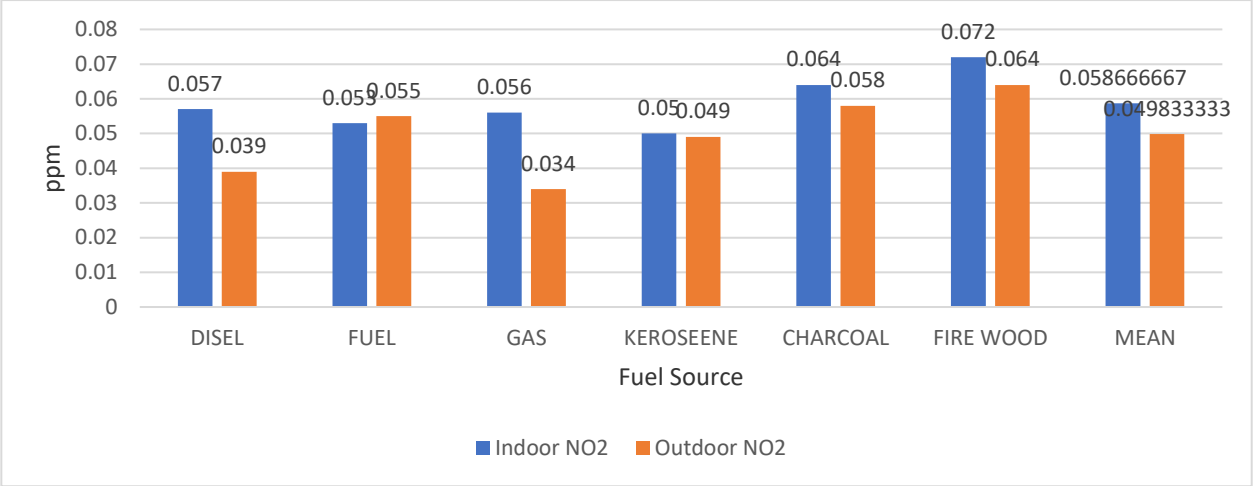


Fig 8: Mean NO_2 concentration for indoor and outdoor fuel sources

Methane (CH_4):

Indoor and Outdoor CH_4 maintained the same values at 3 fuel sources (Fuel, Gas and Kerosene) representing P2, P3 and P4 respectively (Fig. 9). Higher values of CH_4 were observed in outdoor fuel source of P1 (21ppm against 6) and P5 at (7ppm against 1). Mean values for indoor concentrations ranged from 1 to 7ppm with an average of 4.3ppm compared to outdoor value ranged from 1 to 21ppm with an average of 6.8ppm.

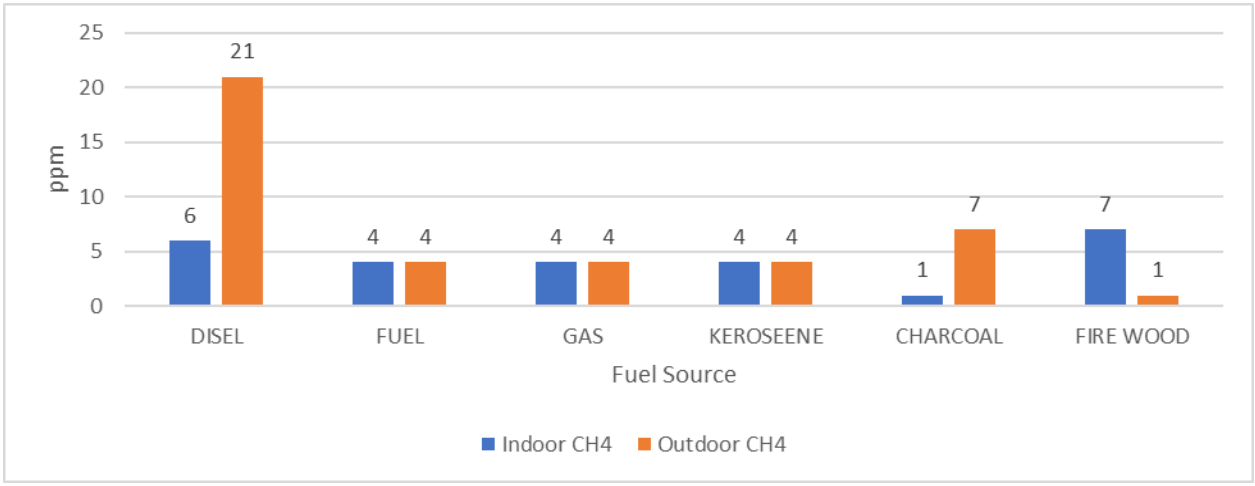


Fig. 9: Mean CH_4 concentration for indoor and outdoor fuel sources

Hydrogen Sulphide (H_2S):

There were no outdoor observations for hydrogen sulphide across the six fuel sources sampled (Fig. 10). P1 and P4 with fuel sources of Diesel and Kerosene respectively have 0.2ppm and 0.1ppm values for hydrogen sulphide out of the six sampled indoor air quality. The observed results for the two buildings were above the limit set by both Federal Ministry of Environment and Department of Petroleum Resources.

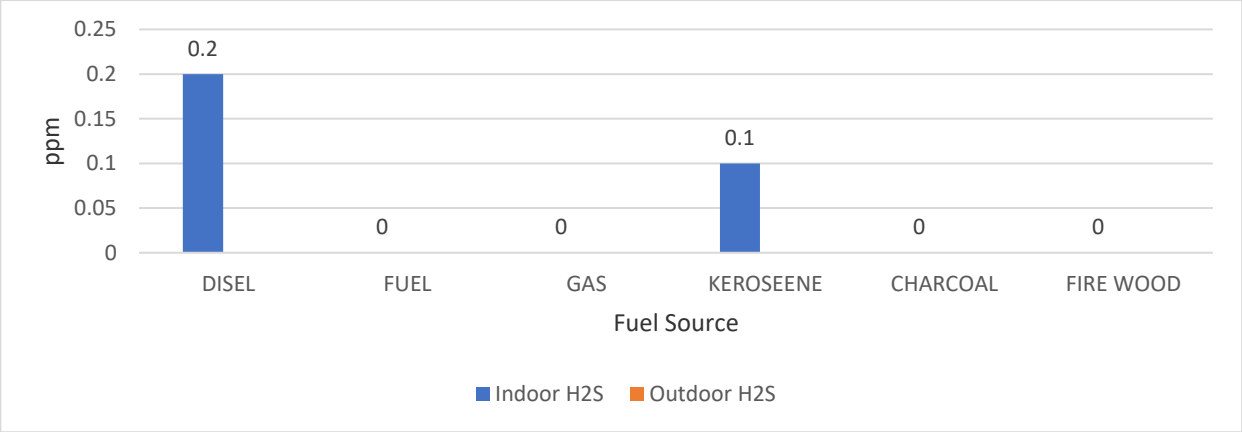


Fig. 10: Mean H_2S concentration for indoor and outdoor fuel sources

Volatile Organic Compound (VOC):

Out of the six sampled fuel sources for both indoor and outdoor air quality parameters (Fig. 11), outdoor location for P1 utilizing diesel was the only fuel source observed to have emitted VOC at 1ppm.

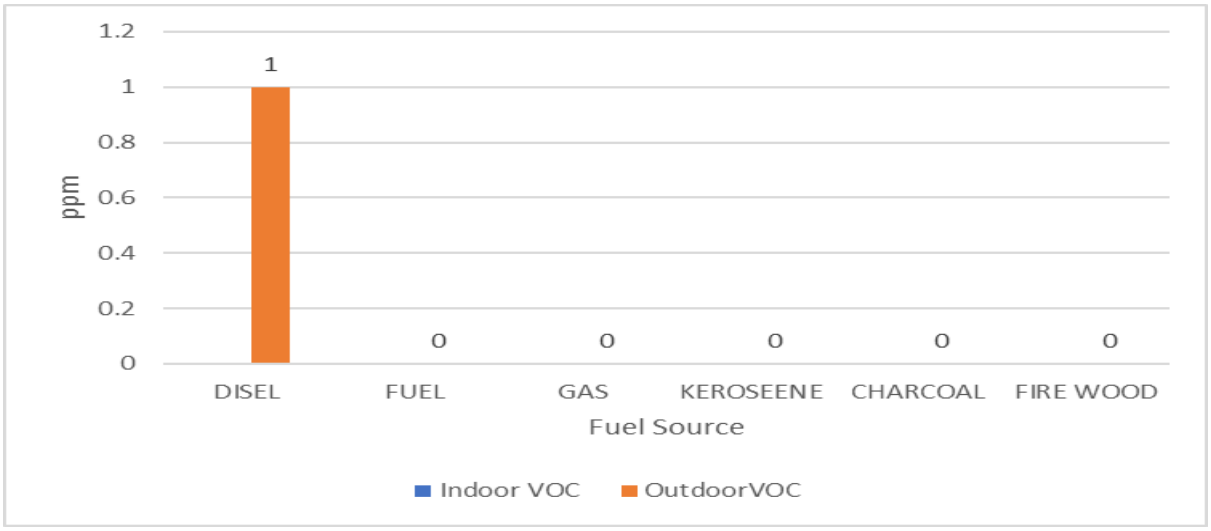


Fig 11: Mean VOC concentration for indoor and outdoor fuel sources

Particulate Matter PM_{10}:

Figure 12 presents the mean outdoor and indoor concentration of PM_{10} across six fuel sources in FUTO environs. The mean value of outdoor PM_{10} ranges from 0.008 to 0.13ppm compared to the outdoor concentration that ranged from 0.09 to 0.1ppm. The highest values of PM_{10} for both indoor and outdoor were observed at 0.13 and 0.1ppm respectively location P5 where charcoal was used as fuel source.

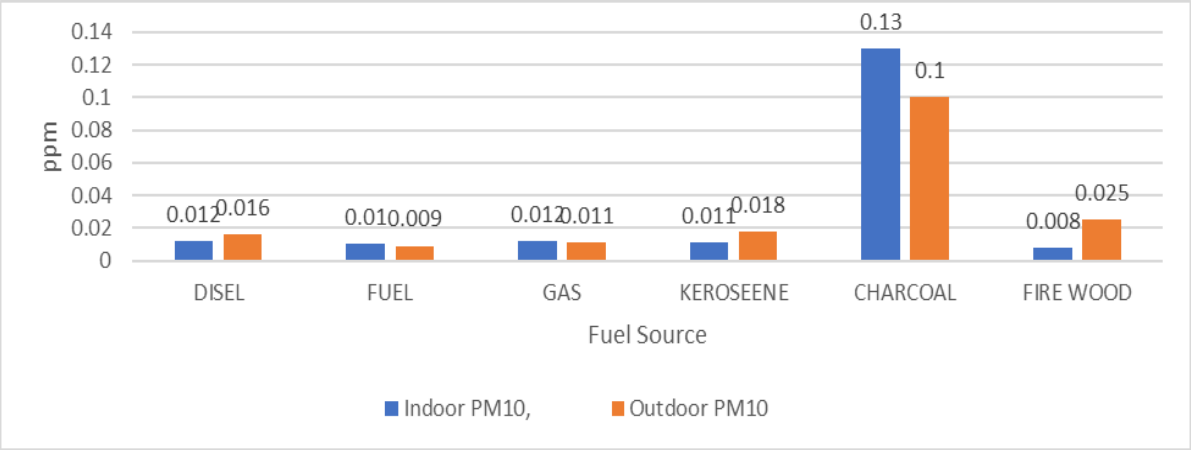


Fig 12: Mean PM_{10} concentration for indoor and outdoor fuel sources

Particulate Matter ($PM_{2.5}$):

Unlike PM_{10} Observation, outdoor air quality had more $PM_{2.5}$ than indoor air quality (Fig. 13). More significant variation was observed at P5 at 0.04ppm against 0.005ppm and at P6 (0.021ppm) against 0.003ppm. Mean range of indoor air quality ranged from 0.003 to 0.005ppm with an average of 0.0045 while the outdoor air quality ranged from 0.004 to 0.04ppm with an average of 0.012ppm.

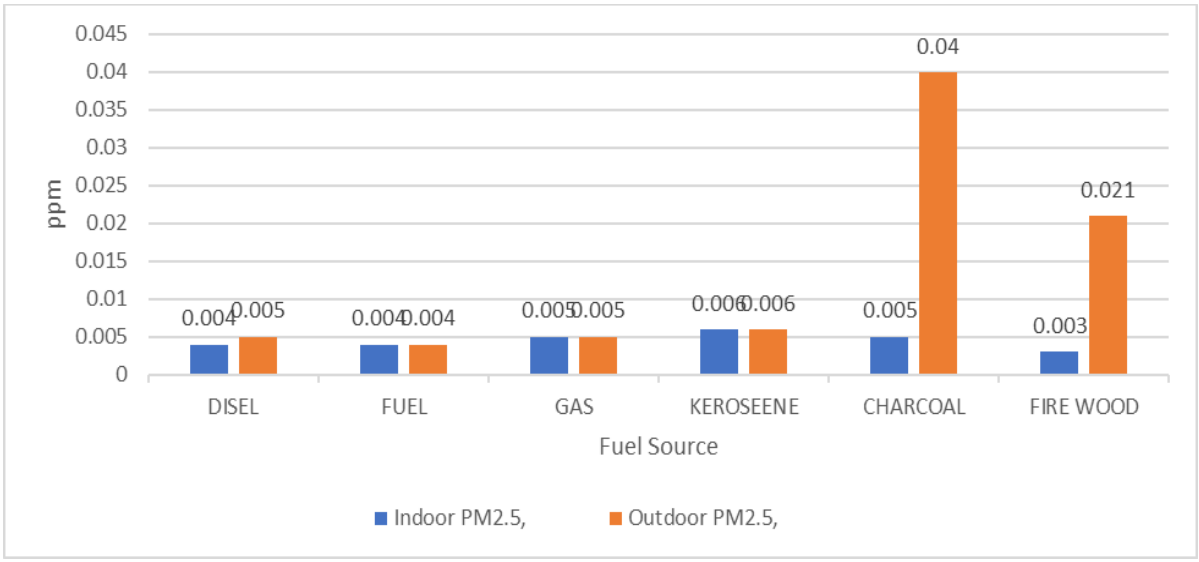


Fig 13: Mean $PM_{2.5}$ concentration for indoor and outdoor fuel sources

Ozone (O_3):

Ozone was only observed at indoor air quality sample at P6 where firewood is utilized as fuel source at 0.02ppm (Fig. 14). It remains the only observations made on both indoor and outdoor air quality sampling for ozone concentrations across the six fuel sources in the study.

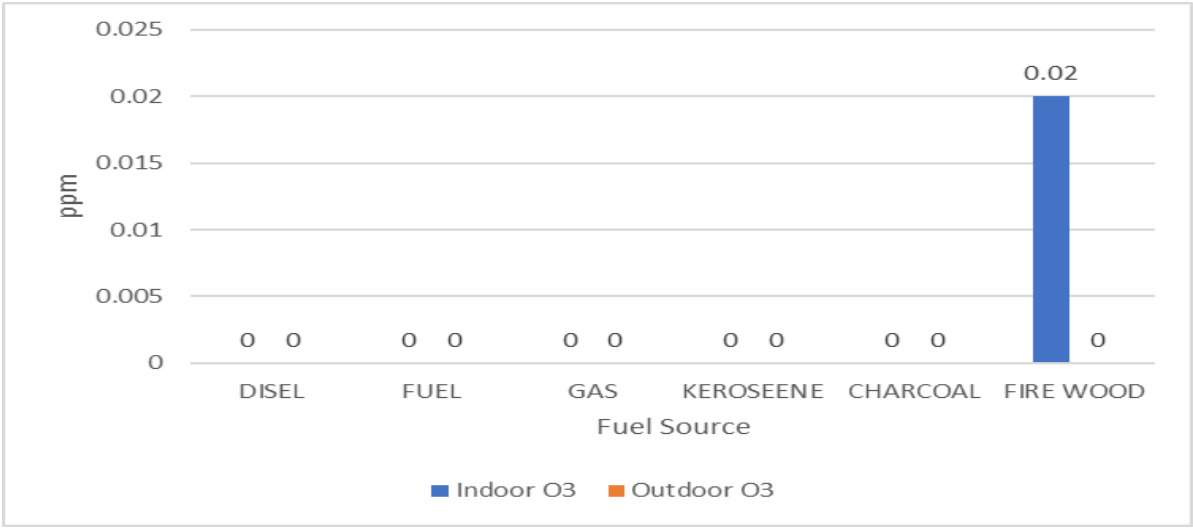


Fig 14: Mean O3 concentration for indoor and outdoor fuel sources

Table 3: Correlation of indoor-outdoor meteorological parameters

		Indoor TEMP	Outdoor TEMP	Indoor WIND SPEED	Outdoor WIND SPEED	Indoor Relative Humidity	Outdoor Relative Humidity	Indoor Wet Temp	Outdoor Wet Temp
Indoor TEMP	Pearson Correlation	1	.537	-.377	-.355	-.725	.011	.887*	-.351
	Sig. (2-tailed)		.272	.461	.490	.103	.983	.018	.495
	N	6	6	6	6	6	6	6	6
Outdoor TEMP	Pearson Correlation	.537	1	-.353	.191	-.114	-.365	.800	-.107
	Sig. (2-tailed)	.272		.492	.718	.830	.476	.056	.839
	N	6	6	6	6	6	6	6	6
Indoor WIND SPEED	Pearson Correlation	-.377	-.353	1	.074	-.271	.321	-.601	.876*
	Sig. (2-tailed)	.461	.492		.890	.603	.535	.207	.022
	N	6	6	6	6	6	6	6	6
Outdoor WIND SPEED	Pearson Correlation	-.355	.191	.074	1	.615	-.733	-.065	-.118
	Sig. (2-tailed)	.490	.718	.890		.193	.098	.903	.824
	N	6	6	6	6	6	6	6	6
Indoor Relative Humidity	Pearson Correlation	-.725	-.114	-.271	.615	1	-.520	-.382	-.251
	Sig. (2-tailed)	.103	.830	.603	.193		.290	.454	.631
	N	6	6	6	6	6	6	6	6
Outdoor Relative Humidity, %	Pearson Correlation	.011	-.365	.321	-.733	-.520	1	-.233	.333
	Sig. (2-tailed)	.983	.476	.535	.098	.290		.657	.519
	N	6	6	6	6	6	6	6	6
Indoor Wet Temp	Pearson Correlation	.887*	.800	-.601	-.065	-.382	-.233	1	-.509
	Sig. (2-tailed)	.018	.056	.207	.903	.454	.657		.302
	N	6	6	6	6	6	6	6	6
Outdoor Wet Temp	Pearson Correlation	-.351	-.107	.876*	-.118	-.251	.333	-.509	1

	Sig. (2-tailed)	.495	.839	.022	.824	.631	.519	.302	
	N	6	6	6	6	6	6	6	6
*. Correlation is significant at the 0.05 level (2-tailed).									

Table 4: Paired Samples t Test for meteorological parameters

		Paired Differences					t	df	Sig. (2-tailed)
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference				
					Lower	Upper			
Pair 1	Indoor TEMP - Oudoor TEMP	1.3667	2.2187	.9058	-.9617	3.6951	1.509	5	.192
Pair 2	Indoor WIND SPEED - Outdoor WIND SPEED	-.2917	.5024	.2051	-.8189	.2356	-1.422	5	.214
Pair 3	Indoor Relative Humidity - Outdoor Relative Humidity, %	-2.4167	8.4828	3.4631	-11.3188	6.4855	-.698	5	.516
Pair 4	Indoor Wet Temp - Outdoor Wet Temp	-1.7833	6.1545	2.5126	-8.2421	4.6754	-.710	5	.510

Indoor-Outdoor Physiochemical Characteristics

Table 5 shows result of correlation of Indoor-outdoor air quality parameters, strong correlations were observed between Indoor and outdoor CO, NO_2, PM_{10} at 81.9%, 58.5% and 98.3% respectively. CO and PM_{10} maintained strong significant correlation at .045 and .000 respectively. Weak correlations were observed between indoor and outdoor CO_2, CH_4 and $PM_{2.5}$ at 9.4%, 13.9% and 5.9% respectively.

Across parameters, indoor NO_2 maintained strong positive correlation with indoor CO, outdoor CO at 53.5% and 77.7% respectively while outdoor NO_2 had strong correlations with outdoor CO and indoor CO_2 at 74.1% and 74.4% respectively.

The mean correlation between indoor and outdoor air quality physiochemical characteristics were tested for significance using the paired t-Test method to determine if there are significant variations between the sample means of the indoor and outdoor air quality measurements. Result showed only significant value on CO at 0.000. Thus, justifying that there is no major significance variation of the sample mean of the indoor-outdoor air quality parameters.

Table 5: Indoor-outdoor air quality Correlation result

		Indoor CO	Outdoor CO	Indoor CO2,	Outdoor CO2	Indoor NO2	Outdoor NO2	Indoor CH4	Outdoor CH4	Indoor PM10,	Outdoor PM10	Indoor PM2.5,	Outdoor PM2.5,
Indoor CO	Pearson Correlation	1	.819*	-.556	.507	.535	.345	.243	.220	.235	.385	-.095	.482
	Sig. (2-tailed)		.046	.252	.305	.274	.503	.642	.675	.654	.451	.858	.334
	N	6	6	6	6	6	6	6	6	6	6	6	6
Outdoor CO	Pearson Correlation	.819*	1	-.574	.474	.777	.741	.187	-.308	.278	.446	-.284	.661
	Sig. (2-tailed)	.046		.234	.343	.069	.092	.723	.553	.594	.375	.585	.153
	N	6	6	6	6	6	6	6	6	6	6	6	6

Indoor CO_2,	Pearson Correlation	-.556	-.574	1	.094	-.381	-.744	.101	-.183	-.477	-.556	.271	-.585
	Sig. (2-tailed)	.252	.234		.859	.456	.090	.849	.728	.339	.252	.604	.223
	N	6	6	6	6	6	6	6	6	6	6	6	6
Outdoor CO_2	Pearson Correlation	.507	.474	.094	1	-.057	.065	-.012	-.381	-.048	.040	.561	.071
	Sig. (2-tailed)	.305	.343	.859		.915	.902	.982	.456	.927	.940	.246	.893
	N	6	6	6	6	6	6	6	6	6	6	6	6
Indoor NO_2	Pearson Correlation	.535	.777	-.381	-.057	1	.585	.249	-.181	.304	.431	-.664	.682
	Sig. (2-tailed)	.274	.069	.456	.915		.223	.634	.732	.558	.394	.150	.136
	N	6	6	6	6	6	6	6	6	6	6	6	6
Outdoor NO_2	Pearson Correlation	.345	.741	-.744	.065	.585	1	-.031	-.488	.320	.426	-.389	.607
	Sig. (2-tailed)	.503	.092	.090	.902	.223		.954	.326	.537	.399	.446	.201
	N	6	6	6	6	6	6	6	6	6	6	6	6
Indoor CH_4	Pearson Correlation	.243	.187	.101	-.012	.249	-.031	1	.139	-.800	-.702	-.646	-.495
	Sig. (2-tailed)	.642	.723	.849	.982	.634	.954		.793	.056	.120	.166	.319
	N	6	6	6	6	6	6	6	6	6	6	6	6
Outdoor CH_4	Pearson Correlation	.220	-.308	-.183	-.381	-.181	-.488	.139	1	.029	-.008	-.066	-.168
	Sig. (2-tailed)	.675	.553	.728	.456	.732	.326	.793		.956	.988	.901	.751
	N	6	6	6	6	6	6	6	6	6	6	6	6
Indoor PM_{10},	Pearson Correlation	.235	.278	-.477	-.048	.304	.320	-.800	.029	1	.983**	.252	.884*
	Sig. (2-tailed)	.654	.594	.339	.927	.558	.537	.056	.956		.000	.630	.019
	N	6	6	6	6	6	6	6	6	6	6	6	6
Outdoor PM_{10}	Pearson Correlation	.385	.446	-.556	.040	.431	.426	-.702	-.008	.983**	1	.178	.946**
	Sig. (2-tailed)	.451	.375	.252	.940	.394	.399	.120	.988	.000		.736	.004
	N	6	6	6	6	6	6	6	6	6	6	6	6
Indoor $PM_{2.5}$,	Pearson Correlation	-.095	-.284	.271	.561	-.664	-.389	-.646	-.066	.252	.178	1	-.059
	Sig. (2-tailed)	.858	.585	.604	.246	.150	.446	.166	.901	.630	.736		.911
	N	6	6	6	6	6	6	6	6	6	6	6	6
Outdoor $PM_{2.5}$,	Pearson Correlation	.482	.661	-.585	.071	.682	.607	-.495	-.168	.884*	.946**	-.059	1
	Sig. (2-tailed)	.334	.153	.223	.893	.136	.201	.319	.751	.019	.004	.911	
	N	6	6	6	6	6	6	6	6	6	6	6	6
. *Correlation is significant at the 0.05 level (2-tailed).													

**. Correlation is significant at the 0.01 level (2-tailed).										

DISCUSSION OF RESULTS

Temperature has been documented widely in several studies as a major parameter that affects the chemistry and behaviour of air pollutants (Budiakova, 2017; Anthony, 2020). Mean indoor dry bulb temperature ranged from 30.2 to 35.7°C with an average of 32.9°C compared to that of outdoor which ranged from 29.6 to 33.7 °C with an average of 31.5°C. Studies by Budiakova, 2017; Choo *et al*., 2015; Fadeyi *et al*., 2014, have reported an indoor temperature range of 13.0 to 26.0 °C for school classrooms and university lecture halls in Europe and Asia. This differs from the result obtained from this study and can be explained that most of these studies were carried out in cold regions where temperature values hardly reach the values obtainable in West African Countries. Similarly, outdoor temperature range observed differs from the range of 1 to 28°C recommended by Wangchuk *et al*., 2015 and Mohammadyan *et al*., 2017 in Universities and Home environments. Relative Humidity ranged from 64.3 to 75.8% for outdoor buildings against a range of 62.4 to 74.2% for indoor. Relative humidity results were higher in outdoor compared to indoor. Similar results were obtained from several studies carried out of indoor and outdoor of university buildings (Jovanovic *et al*., 2014; Wangchuk *et al*., 2015; Lu *et al*., 2016; Mohammadyan *et al*., 2017 and Anthony, 2020).

However, on the buildings where Gas, fuel and firewood were utilized, relative humidity was higher at indoor than outdoor, this observation can be justified by the inverse relationship of relative humidity with temperature because warm air tends to hold more moisture than cold air reported by Anthony (2020) in few of the buildings sampled in the University environment. Variances in the results of relative humidity of sampled buildings for indoor and outdoor occur as a result of differences in terms of activities going on in the various buildings which may be contributing to indoor moisture levels as well as the building structure.

Mean values of indoor wind speed ranged from 0.25 to 1.3m/s with an average of 0.6m/s while the outdoor ranged from 0.6 to 1.6m/s with an average of 0.9m/s. The higher values for outdoor wind speed against indoor obtained in this study were consistent with studies by Choo *et al*., 2015; 2016; Budiakova, 2017; Mohammadyan *et al*., 2017; and Anthony 2020 for indoor and outdoor wind speed.

The result of indoor-outdoor air quality parameters for of six buildings in FUTO where different fuel sources are utilized were within the Federal Ministry of Environment and Department of Petroleum Resources standards, except for indoor CO from P6 where firewood is utilized. An indoor CO concentration of 9.1ppm against indoor air quality value of either 8.7ppm or <10000ug/m3 for an 8-hour average testing period of Indoor Air Quality Management Quality Group. The overall trend was higher indoor CO concentrations compared to outdoor CO concentrations across the six buildings (Figure 6), Observed high value of CO concentration is attributed to the fuel type associated with high smoke as a result of incomplete combustion of firewood (WHO, 2010). A similar observation was made by Anthony, (2020) that high concentrations of CO in the indoor environment have been associated with burning of firewood and other fuels that emit CO gas as by-products.

DEH, (2005) opined that under natural and unpolluted atmospheric conditions, the mean CO concentrations are around 0.20 ppm. Carbon monoxide being a product of incomplete

combustion of carbon-containing material was strongly reported in the works of Choo *et al*, 2015 as a major pollutant released into the environment through sources of vehicular traffic emissions, domestic fuel burning (gas, fuel, firewood, or coal appliances), tobacco smoking or industrial sources. This report agrees with findings from this research as a higher concentration of indoor CO was observed in areas where appliances of the fuel types (Charcoal, Firewood, Gas, Kerosene, Diesel, and fuel) were used at FUTO.

Indoor CO_2 concentration across the six buildings followed the pattern of Gas > Kerosene>Fuel> Diesel > Charcoal > Firewood whereas that of outdoor followed the order of Kerosene > Firewood > Gas > Charcoal > Diesel >Fuel (Fig. 6). In comparison, the average mean of indoor CO_2 concentration across the six buildings is 538.8ppm while that of outdoor CO_2 concentration is 489.5ppm. Several studies (Budiakova, 2017; Peng *et al*., 2017; Choo *et al*., 2015; Fadeyi *et al*., 2014) have reported an indoor CO_2 concentration range of 408 to 2739ppm. However, an upper limit range of 708ppm was reported for Indoor in this research which is lower than observed findings from earlier researchers.

In comparison, higher CO_2 concentrations were observed in indoor environments than outdoor, this observation is similar to the findings from Knížatová *et al*., (2010); Widder and Haselbach, (2017) and Anthony (2020), which was attributed to mainly human respiration and the burning of different types of fossil fuels. In addition to the contributions of the fuel sources in the observed values of Indoor CO_2 concentrations, higher indoor CO_2 concentrations can be explained by the combined operation of different fuel sources serving mostly for commercial purposes coupled with high occupant densities within the buildings which might have contributed to the high CO_2 concentrations through breathing. Budiakova (2017) and OSHA (2011) also found a positive correlation between CO_2 concentrations and occupant density within a given environment.

In a similar pattern, higher values of NO_2 were observed in indoor compared to outdoor results (Fig. 8). Highest values for indoor and outdoor concentrations were observed at P6 at 0.072 and 0.064ppm respectively utilizing firewood as the fuel source. Four out of five of the six facilities had indoor NO2 concentrations above the limit set by the Federal Ministry of Environment compared to outdoor concentrations above the limit of three out of the six facilities. This can be attributed to complex human activities in the university environment involving the burning of biomas fossil fuels (gas, oil, diesel wood burning etc) and vehicular emissions. A similar observation was reported on WHO (2009) guidelines for indoor air quality of selected pollutants and EPA (2011) report on air quality guide for nitrogen. WHO 2009 outlined factors with complex interactions contributing to the variations in indoor-outdoor concentrations of nitrogen to be; the level of buildings, building designs for ventilations classroom distances to the road and sources of NO_2 emissions to the environment.

There were significant variations in the Indoor and Outdoor CH_4 concentration at P1 (Fig. 9) where diesel is the major fuel source at 21ppm against 6. A similar obervation was seen at P5 (7ppm against 1) where charcoal was used as the fuel source. Among other sources of methane emission in the environment, observed variations on the two buildings can be attributed to the fuel sources sampled because methane is a natural gas originating mainly from fossil fuel among other sources with little to rare reactivity apart from combustion, steam reforming to syngas, and halogenation which results to carbon monoxide and H_2O.

Hydrogen sulphide was not found in the outdoor ambient environment across the six facilities sampled. However, H_2S was found at only two buildings (P1 and P4) where diesel and kerosene were used as the fuel source for indoor air quality. Results obtained 0.2ppm for P1 and 0.1ppm for P4 was by far above the limit set by both the Federal Ministry of Environment and the Department of Petroleum Resources (Table 2 and Fig .10). Anthony (2020) observed that only very few studies so far have looked at H_2S concentrations across indoor and outdoor environments. Hence, indoor and outdoor H_2S concentration mean values and ranges are not common in literature.

There was no result for indoor VOCs on the entire six buildings sampled. Similarly, outdoor had 1ppm only at P1 among the six buildings sampled. The observed result at P1 (Fig. 11) can be attributed to diesel combustion and some renovation activities that were ongoing during the entire sampling period. Paints usually comprise alcohols, esters, texanol, cellosolve, and glycols, which are all primary VOCs (Chang *et al*., 2011). Other sources of VOCs especially indoor are floors, ceilings, walls, renovated environments (stripping painting and construction which release formaldehyde. Consumer products such as nail polish and remover, perfumes and detergents, floor wax and polish, solvents (adhesives, welding, inks, chlorinated tap water), other building materials (plastics, coatings, foam insulators, varnish, paint remover, plywood, phenolic resins, furniture polish), moth repellents, cigarette smoke and burning of fossil fuels are inclusive sources of VOC (Anthony, 2020).

Outdoor-indoor particulate matter (PM_{10} and $PM_{2.5}$) were presented in Figs. 12 and 13 respectively. The highest outdoor PM_{10} and $PM_{2.5}$ were recorded in P5 where charcoal is used as the fuel source at 0.1 and 0.04 ppm respectively. The lowest mean concentrations of indoor PM_{10} and $PM_{2.5}$ were obtained at P5 and P4 where Charcoal and Kerosene were used at 0.13ppm and 0.006ppm respectively. Result for both indoor and outdoor PM_{10} and $PM_{2.5}$ were within the provided limit by the Federal Ministry of Environment and The Department of Petroleum Resources. The finding from this research is in agreement with the report from Jelili *et al* (2020) in indoor and outdoor particulate matter having higher values of PM_{10} and $PM_{2.5}$ observed on facilities where Kerosene and Charcoal were used among other fuel types sampled. Jelili *et al*., (2020) justified the result by stating that Kerosene and charcoal were the dominant forms of cooking fuels, used by 92.5% and 66.0% of the population, respectively in Ogbomoso, Nigeria, followed by firewood (20.5%), while the least used was sawdust.

The mean concentration for Ozone (O_3) was only found at P6 at 0.02ppm (Fig. 14). Indoor O_3 concentrations in this study were with the limit provided by Federal Ministry of Environment and the Department of Petroleum Resources. In comparison was within the limit found in literature for university classrooms (Fadeyi *et al*., 2014; Jovanovic *et al*., 2014; Kalimeri *et al*., 2016) and above the result obtained by Anthony (2020) in the University of Limpopo, South Africa.

CONCLUSION

In pursuance of the main and specific objectives of the study, assessment of the indoor-outdoor air quality and meteorological parameters captured most of the air pollutants associated with different fuel sources (Diesel, Kerosene, Fuel, Gas, Charcoal and Firewood) in FUTO buildings (P1-P6). Result showed high concentrations of CO at Market Square for indoor environment, Indoor NO_2 results in the Market Square (0.064ppm) and Commercial building behind Old Registry (0.072ppm) where Charcoal and Firewood respectively is used were above the limit set by the Federal Ministry of Environment and Department of Petroleum Resources at maximum limit of 0.06ppm. Similarly, indoor H_2S at P1 and P4 with fuel sources of Diesel and Kerosene respectively

have 0.2ppm and 0.1ppm values which is above the maximum limit of 0.01ppm set by the Federal Ministry of Environment and Department of Petroleum Resources.

Although, the average means of both indoor and outdoor air quality differ, there are no statistical significant variations between the sample means of indoor and outdoor air quality parameters. The independent variables (meteorological parameters) perfectly predicted the combined indoor and outdoor air quality parameters at an adjusted R square value of 70.3% from the model summary and a statistical significance of 0.043 from the ANOVA table. The result showed that the meteorological parameters were able to account for 70.3% of the air quality parameters sampled from six different buildings in FUTO utilizing varying fuel sources. Apart from the wet temperature that contributed uniquely to predicting the air qualities, the remaining meteorological parameters (dry temperature, relative humidity and wind speed) combined in predicting the air quality of FUTO environment.

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