Egyptian Journal of Occupational Medicine, 2025; 49 (2) : 67 - 81

FISH PROCESSING SMOKE FROM TRADITIONAL AND MODERN FACILITIES, AND ITS IMPACTS ON AIR QUALITY AND RESPIRATORY HEALTH OF FISH PROCESSORS

BY

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***DOI:** 10.21608/ejom.2025.360052.1360*

***Submit date:** 2025-03-10 **Revise date:** 2025-05-01 **Accept date:** 2025-05-04*

***Author's contribution:** All authors contributed equally in this work.*

Abstract

Introduction: Fish smoking is the most convenient processing method to keep the shelf life of fish before it is sold to the final consumers. A**im of Work:** This study examined air pollutant levels, including gaseous substances and particulate matter, at fish processing locations and also evaluated the respiratory health of fish processing workers through a cross-sectional, comparative analysis between traditional and modern processing kiln sites in Abeokuta, Ogun State, Nigeria. **Materials and Methods:** Forty-eight fish processors across 8 processing sites using either modern or traditional smoking kiln consented to participate in the study. Results: The majority (83.3%) of the sites had PM_{10} and $PM_{2.5}$ values five times higher than the WHO standard. The study also revealed that $PM_{2.5}$ in most locations is unhealthy to fish processors, while PM10 is hazardous in most locations. The study also revealed that the gaseous air pollutants (NO, CO, NO_2, CO_2, SO_2, and VOCs) in all locations is within the standard set by Environmental Protection Agency (EPA), except CO_2, which had high concentration in all locations. Mean forced expiratory volume in the first second (FEV_1) and forced vital capacity (FVC) were considerably lower among workers with differences of −0.22 (−0.42 to −0.05) L and −0.52 (-0.76 to −0.29) L, respectively, whereas FEV_1 /FVC ratio and peak expiratory flow rate were higher among workers with mean differences of 5.68 (3.59–8.82) % and 0.31 (-23.70 to 24.43) L/min, respectively; but the mean difference was significant only for the FEV_1/FVC ratio. **Conclusion and Recommendations:** Fish processors using modern processing facility were not suffering from serious health challenges, compared to those using local processing tools. Continuous monitoring of pollution and usage of protective gadgets are recommended.

Key words: Fish Smoking, Processing Stove, Air pollutants and Workers 'health.

Introduction

In Nigeria, one important protein source is fish consumption which its availability is been threatened due to the spoilage of between 30 – 50% of fish collected as reported by Adeyeye (2016). Hence, fish processing involves all the methods related to preservations of fish and fish product from the time fish are captured or harvested until the finished product is delivered to the consumers to prevent its quick spoilage (Saklani et al., 2024) .Fish processing contributes to the economic growth of the country by securing food, providing employment and generating income particularly in rural and coastal areas (Olaoye et al., 2024). The long-distance of distribution necessitates some processing and storage, as preservation through refrigeration is not readily available in Nigeria (Singh and Heldman, 2013). The main motive, however, is usually to reduce the water content of the fish by either smoking or drying (Mei et al., 2019).

The most popular traditional way of preserving fish in Nigeria is smoking, which combines the effects of frying the fish by producing high temperatures with the elimination of bacteria to produce products with a long shelf life. To achieve the dry state necessary for preservation and obtain a dark brown, fully dried product, smoking frequently exposes the fish to direct wood smoke (Tawari and Abowei, 2011). The oven, which can be powered by charcoal or firewood, is used in the contemporary drying procedure. However, natural energy like electricity or gas can also be used to generate heat in an oven.

Modern and traditional kilns differ significantly in design, fuel efficiency, product quality and safety, economic and labour input, and environmental impacts. Traditional kilns are made with local materials like mud, sticks and thatch with enclosures that are often opened or partially closed which leads to uneven heat distribution (Adeyeye, 2016); while the modern ones are constructed with metals, bricks, or concrete with enclosed design and chimney for smoke control (WHO, 2021). Also, traditional ovens use firewood and consume a lot of energy (Oparaku and Mgbenka, 2012), while modern kilns consume less energy by using saw dust, charcoal and/or gas (Killic et al., 2014). In addition, there is a higher risk of contamination of smoked food with ash and soot (Fakoya, 2023). Traditional kilns releases smoke and contribute to air pollution while modern kilns are built taking into consideration carbon footprint reduction (Killic et al., 2014; Okusanya et al., 2021).

Smoke produced by burning wood or charcoal is a mixture of complex chemical product gases, vapor, and volatile substances that can interact with different physiological or biochemical processes to cause negative health effects in humans and/or contribute to atmospheric pollutants (Abdel-Shafy and Mansour, 2016). These interactions can have a negative impact on the cardiovascular system (Sigsgaard et al., 2015). According to Lofuta et al. (2024), the pollutants include, formaldehyde, carbon dioxide, sulphur oxide, nitrogen oxide, particulate matter (PM), complex chemical compounds including soot, polycyclic aromatic hydrocarbons, and volatile organic compounds (Adeyeye, 2016, Oyebanji et al., 2016; Bede-Ojimadu and Orisakwe, 2020).

Apart from the environmental impacts arising from air pollutants, there are numerous occupational exposure and safety concerns. Food Agriculture Organization (FAO) (2012) categorised the fish industry as one of the riskiest industries in the world because of the multiple dangers and hazards associated with the occupation. Such hazards may be physical, chemical, and biological hazards (Uyamadu et al., 2023; Olaoye et al., 2024), which may adversely affect processors especially affecting the pulmonary system (Dienye et al., 2016; Souza et al., 2020; Adjobimey et al., 2023, Sidebang, 2023). However, studies have explored the impacts of fish processing on other functions of the processors such as haematological parameters (Purbayanti et al., 2020), and anaemic conditions (Armo-Annor, 2019),

Aim of Work

This study examined air pollutant levels, including gaseous substances and particulate matter, at fish processing locations and also evaluated the respiratory health of fish processing workers through a cross-sectional, comparative analysis between traditional and modern processing kiln sites in Abeokuta, Ogun State, Nigeria.

Materials and Methods

Study design: The study was a cross-sectional comparative study.

Place and duration of the study: The study was carried out within Abeokuta, the largest city and the capital of Ogun state in the South-West of Nigeria. The study area included Asero (Farmers' market), Eleweran, Oke Aregba, Camp, Osiele, Asero (Estate), and Itoku. The map of Abeokuta showing the sampling sites are shown on Figure 1.

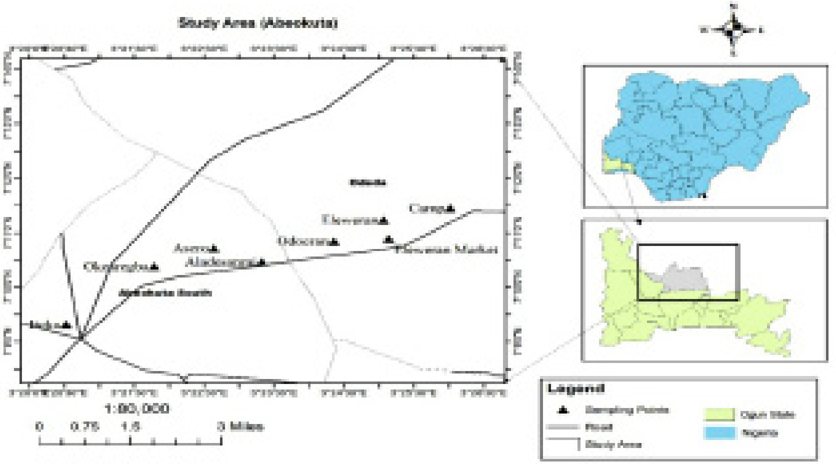

Figure 1: Map of the study area showing the sampling sites

Study Sample: The study population comprised the smoked fish marketers within Abeokuta, Ogun-state, Nigeria. A two-stage sampling procedure was adopted in selecting the sample for this study. First was the purposive selection of eight popular markets in the study area. The selected markets were Eleweran, Asero (Farmers market), Osiele, Asero (Housing estate), Oke-Aregba, Camp, Eleweran (Hausa base), and Itoku. A list of smoked fish marketers was generated from the selected markets. The second stage involved all the fish processors who consented to participate in the research at the time of data collection. The locations and number of sampled fish processors from each fish processing site is summarised in Table 1 (No). A total of forty-eight fish processors eventually consented to get involved in the research.

Study Methods:

-Sampling of the pollutants involved the use of the multiple gas detectors - ZhongAn S318 Gas Analyzer for the measurement of NO, CO, NO_2,

SO_2, CO_2 and VOCs, and ARA N-FRM Particulate Matter Sampler for $PM_{2.5}$ and PM_{10} measurements (Particulate matter of 2.5 μm and 10 μm diameter). Ambient temperature and pressure were monitored at each of the processing site using a portable weather station with the same equipment. At each sampling area, the equipment was coupled and erected/mounted at about 1m from the emission source - the smoking facility, while considering the location of the facility exhaust. The PM samplers and gas analyser were programmed to sample and measure the desired particulate matter and gases, respectively, for 1-2 hours during the smoking period/operations. The PM sampler was set to operate at an average flow rate of 16.7 LPM, both samplers automatically store the detected levels of pollutants, and upon completion the stored data was assessed through transfer using a storage USB device. The PM sampler also takes the readings of average temperature and pressure including Air Quality Index (AQI).

-**Spirometry test**: Lung function testing was obtained using a spirometer. Inhalation and exhalation through the nostrils are blocked by using the hand or placing a clip on the nose. A plastic tube was connected to the spirometer to serve as a mouthpiece. Placing the lips tightly around the mouthpiece, the participant was directed to take in a big deep breath and then blow out as hard and fast as he/she can. The test was repeated three times to ensure consistent results and the highest values from the test results were selected and stored. Lung function status was evaluated on the results of forced expiratory volume in one second (FEV_1) and peak expiratory flow rate (PEFR) as displayed on the screen of the calibrated PiKo-1 spirometer.

-**Anthropometric analysis**: For comparison with standards, anthropometric parameters such as height, age, weight and sex were obtained because the thresholds for obstructive lung disease differ by body mass index (BMI) (Sun et al, 2024). Height and weight were obtained using standard procedure which is the weighing scale and measuring tape. Gender and age of the participants were also requested to record against the spirometry data. Similarly, the blood pressure through the systolic, diastolic and pulse were done with a BP monitor.

The actual FEV_1 and PEFR were compared with predicted values based on the height and age of respondents.

The calculation of the predicted values of FEV_1 and PEFR are presented in Eqs. (1) and (2):

$$FEV_1\ (L) = 0.040H - 0.021A - 3.13 \quad (1)$$

$$PEFR\ (L\ s^{-1}) = 0.071H - 0.035A - 1.82 \quad (2)$$

where FEV_1 is forced expiratory volume in 1 second in liters (L), PEFR is peak expiratory flow rate in liters per second ($L\ s^{-1}$), H is height in cm, and A is age in years (Oyebanji et al., 2021).

Consent

Only consented fish processors participated in the study after they were all addressed at each processing plant and location.

Ethical Approval

The study was approved by the research ethical committee of the Federal University of Agriculture, Abeokuta, FUNAAB.

Data Management

The result collected were cleaned, coded, and subjected to the descriptive statistics such as frequency, percentage and mean. Similarly, means were compared using the student t-test to ascertain significant difference between modern and traditional air quality levels, and between predicted spirometry levels and calculated levels. All the measuring instruments were properly calibrated during the period of sampling. The particulate matter sampler was fitted with three cyclones specific for each particle size, namely, total suspended particles (TSP) and particulate matter (PM_{10} and $PM_{2.5}$). Each parameter was monitored after changing the filter paper to take a new reading at different sampling points.

Results

Table (1): Mean weather condition and air pollutants emitted from fish processing sites.

Locations	Stove type	No	Average temp (ºC)	Average pressure (Pa)	NO (ppm)	CO (ppm)	NO_2 (ppm)	SO_2 (ppm)	CO_2 (ppm)	VOCs (ppm)	Average $PM_{2.5}$ (µg/m³)	Average PM_{10} (µg/m³)	Average AQI
Asero Farmers Mkt	M	2	32.9	750	0.12±0.33	11.76±17.28	0	1.6±1.41	594.32±96.02	16.28±34.69	49.44	50.64	135.3
Asero (OGD Estate)	M	4	35.4	749	0.30±0.47	24.87±21.50	0	2.13±1.69	660.13±87.05	28.26±39.70	13.32	13.72	53.6
Odo-Arise, Eleweran	M	2	29.6	747	0.13±0.34	37.33±33.95	0	0.75±0.99	728.92±181.17	49.88±56.06	191.04	204.61	241.2
Camp	M	5	25.7	748	0	6.32±10.86	0	0.42±0.90	542.42±209.99	7.95±20.76	15.79	16	58.8
Osiele	M	7	27.7	750	0.05±0.22	16.81±24.04	0	7±2.72	608.14±92.53	19.90±47.51	51	58.63	139.2
Oke-Aregba	M	10	32.2	751	0±0.31	16.5±9.11	0	7.57±0.62	608.21±224.30	28.14±14.24	47.92	48.85	131.6
Itoku	T	10	31	754	0.79±0.71	27.63±21.99	0	2±1.67	726.74±130.60	27.68±23.17	791.16	1009.53	499.9
Eleweeran	T	8	29	746	2.37±1.50	106.47±111.93	0	4±1.89	1575.32±1011.97	96.84±68.51	513	605.526	499.9

M: Modern stove T: Traditional stove NO: Nitric Oxide NO_2 : Nitrogen Dioxide
SO_2 : Sulphur Dioxide CO_2 :Carbon Dioxide CO :Carbon monoxide VOCs: Volatile organic compounds
No : Number of sampled fish processors

Table 1 showed the stove type across sampled locations, mean levels of temperature and pressure, and average concentrations of gaseous and particulate pollutants. It showed that about 75% of the eight locations are already using the modern stove, while only 25% are using the C type. Also, temperature ranged from 25.7 at Camp to 35.4ºC at Asero (OGD) while pressure was 746 at Eleweeran and 754 at Itoku. Although, heat generation was higher at the modern sites, (35.4 ºC) at Asero Estate, while pressure was higher at Itoku (a traditional stove site). Gaseous pollutants differed in concentrations at various points. NO range from 0 to 2.37±1.49 ppm, CO range was highest at Eleweeran market (106.5±111.0 ppm), and NO_2 was not detected. SO_2 ranged from 0.42±0.90 to 7.63±1.92 ppm, but CO ranged with highest values at 1575±1011.9 ppm and lowest at 542.4±209.9ppm. VOCs ranged from 7.95±20.7 to 96.84±68.51 ppm. Modern processing methods provided the highest concentrations of pollutants, while traditional processing methods provided the lowest, with Camp having the lowest means and Eleweeran the highest. Mean $PM_{2.5}$ and PM_{10} (µg/m³) ranged from 13.32 and 13.72 at Asero to 791.16 and 1009.53 at Itoku. Meanwhile, AQI ranged from 53.6 – 241.5 at the locations where modern kilns were in use and 499.9 at both locations where traditional stoves were used.

Table (2): Comparative statistics among Observed and Predicted FEV1 and PEFR.

Parameters	Mean	No	Std. Deviation	Std. Error Mean	Mean Difference	Std. Deviation of difference	Std. Error Mean	95% Confidence Interval of the Difference		t-test	Significance
								Lower	Upper		
Observed FEV_1	1.0098	48	0.48676	0.07026	-1.59385	0.495922	0.071580213	-1.73785	-1.449853352	-22.267	**0.001****
Predicted FEV_1	2.603645833	48	0.347559362	0.05016587							
Observed PEFR	1.6798	48	1.31717	0.19012	-6.77341	1.213053	0.175089127	-7.12564	-6.421172359	-38.685	**0.001****
Predicted PEFR	8.453197917	48	0.608689995	0.08785683							

FEV_1: Forced Expiratory Volume in one second PEFR: Peak Expiratory Flow Rate

**: Significant differences at 0.01

Table 2 showed the observed and predicted means of Forced Expiratory Volume in one second (FEV_1) and Peak Expiratory Flow Rate (PEFR) in 48 subjects. The observed mean FEV_1 (1.0098) was less than the predicted FEV_1 (2.6036), indicating impaired lung function. Similarly, the observed PEFR (1.6798) was significantly less than the predicted PEFR (8.4532). Greater standard error and standard deviation of observed values reflect greater variability of lung function than norms would suggest. Student t-test revealed that there were 99% significant differences between observed and predicted FEV_1 ($t = -22.267$, $p<0.01$), as well as the observed and predicted PEFR ($t = -38.685$, $p<0.01$). Paired differences also showed significant declines in lung function, with mean differences of -1.5939 ($p < 0.01$) for FEV_1 and -6.7734 ($p < 0.01$) for PEFR. The 95% confidence intervals for the above differences (-1.7379 to -1.4499 for FEV_1 and -7.1256 to -6.4212 for PEFR) provide evidence of a statistically significant decline in lung function from predicted levels. These findings highlight extreme respiratory impairment in the study population.

Table (3): Comparative statistics of monitored weather and air quality parameters between modern and traditional smoking kilns.

Parameters	Smoking Kiln	Combined Mean	Std. Deviation	Std. Error Mean	t-test for Equality of Means						
					t-test	Df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
										Lower	Upper
NO (ppm)	Modern	0.1	0.11296	0.04612	-3.876	6	**0.008****	-1.48	0.38181	-2.41425	-0.54575
	Traditional	1.58	1.11723	0.79							
CO (ppm)	Modern	18.9317	10.90563	4.45221	-2.372	6	0.055	-48.11833	20.28282	-97.74862	1.51195
	Traditional	67.05	55.7483	39.42							
SO_2 (ppm)	Modern	3.245	3.19251	1.30334	0.101	6	0.923	0.245	2.4258	-5.69072	6.18072
	Traditional	3	1.41421	1							
CO_2 (ppm)	Modern	623.69	63.79666	26.04488	-2.565	6	**0.043***	-527.34	205.58699	-1030.3932	-24.28677
	Traditional	1151.03	600.03667	424.29							
VOCs (ppm)	Modern	25.0683	14.36819	5.86579	-1.907	6	0.105	-37.19167	19.50435	-84.91709	10.53376
	Traditional	62.26	48.9035	34.58							
Temperature (ºC)	Modern	32.25	6.98534	2.85175	0.43	6	0.682	2.25	5.22786	-10.54212	15.04212
	Traditional	30	1.41421	1							
Pressure (Pa)	Modern	749.167	1.47196	0.60093	-0.382	6	0.716	-0.83333	2.18157	-6.17145	4.50478
	Traditional	750	5.65685	4							
$PM_{2.5}$ (µg/m^3)	Modern	61.4183	65.77446	26.85231	-7.215	6	**0.001****	-590.6617	81.86567	-790.97974	-390.34359
	Traditional	652.08	196.68882	139.08							
PM_{10} (µg/m^3)	Modern	65.4083	70.75055	28.88379	-6.818	6	**0.001****	-742.1197	108.85149	-1008.4697	-475.76967
	Traditional	807.528	285.67397	202.002							
AQI	Modern	126.617	68.29121	27.87977	-7.333	6	**0.001****	-373.2833	50.90126	-497.83424	-248.73243
	Traditional	499.9	0	0							

M: Modern stove T: Traditional stove NO: Nitric Oxide CO: Carbon monoxide SO_2: Sulphur Dioxide
CO_2:Carbon Dioxide VOCs: Volatile organic compounds PM: Part per million
AQI: Air Quality Index * and **: Significant differences at p<0.05 and <0.01 respectively

Table 3 showed that traditional kilns emit significantly higher levels (ppm) of NO (1.58 vs. 0.10), CO (67.05 vs. 18.93), and CO2 (1151.03 vs. 623.69) than modern kilns. There is also a significant difference in particulate matter, with traditional kilns having much higher PM2.5 and PM10 (µg/m3) values compared to modern kilns (at $p < 0.01$).

Table (4): Comparative statistics of blood pressure and lung function parameters between modern and traditional smoking kilns.

					t-test for Equality of Means						
Lung Function parameters	Smoking kiln	Mean	Std. Deviation	Std. Error Mean	t-test	Df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
										Lower	Upper
Systolic (mmHg)	Modern	125.933	11.2524	2.0544	-2.572	46	**0.013***	-11.4	4.433	-20.3233	-2.4767
	Traditional	137.333	19.5508	4.6082							
Diastolic (mmHg)	Modern	80.6	10.7273	1.9585	-1.363	46	0.18	-5.4	3.9624	-13.376	2.576
	Traditional	86	16.7823	3.9556							
Pulse (bpm)	Modern	80.9	7.7653	1.4177	0.848	46	0.401	2.1778	2.5686	-2.9925	7.3481
	Traditional	78.722	9.8983	2.3331							
FVC	Modern	1.4043	0.70443	0.12861	2.756	46	**0.008****	0.49767	0.18057	0.13419	0.86114
	Traditional	0.9067	0.38222	0.09009							
FEV_1/FVC	Modern	73.6859	31.169178	5.690687	-1.726	46	0.091	-12.947433	7.50255	-28.049283	2.154416
	Traditional	86.6333	7.495724	1.766759							
FEF_{25}	Modern	1.6977	1.34385	0.24535	1.075	46	0.288	0.35767	0.33266	-0.31195	1.02728
	Traditional	1.34	0.53669	0.1265							
FEF_{50}	Modern	1.492	0.99385	0.18145	1.839	46	0.072	0.45922	0.24972	-0.04343	0.96188
	Traditional	1.0328	0.46185	0.10886							
FEF_{75}	Modern	0.906	0.64791	0.11829	2.145	46	**0.037***	0.34433	0.16051	0.02124	0.66743
	Traditional	0.5617	0.26116	0.06156							
FEF_{25-75}	Modern	1.4667	1.19426	0.21804	1.643	46	0.107	0.48389	0.29453	-0.10896	1.07674
	Traditional	0.9828	0.45565	0.1074							
Observed FEV_1	Modern	1.142	0.53368	0.09744	2.57	46	**0.013***	0.35256	0.13717	0.07644	0.62867
	Traditional	0.7894	0.29487	0.0695							
Observed PEFR	Modern	1.864	1.56564	0.28584	1.259	46	0.215	0.49122	0.39029	-0.29438	1.27683
	Traditional	1.3728	0.67485	0.15906							

FVC: Forced Vital Capacity FEV_1 : Forced Expiratory Volume in one second
FEF: Peak Expiratory Flow (measured in Liters per minute) PEFR: Peak Expiratory Flow Rate
* and ** means significant differences at p<0.05 and 0.01 respectively.

Table 4 presented the blood pressure and lung function for workers in modern and traditional smoking kilns. Traditional kiln workers have higher systolic blood pressure (137.33 vs. 125.93) and diastolic blood pressure (86.00 vs. 80.60), indicating a potentially higher cardiovascular risk in this group. Statistical tests show significant differences between modern and traditional kiln workers in terms of systolic blood pressure ($t = -2.572$, $p < 0.05$), FVC ($t = 2.756$, $p < 0.01$) and FEF75 ($t = 2.145$, $p < 0.05$). The modern kiln workers also have a significantly higher observed FEV1 ($t = 2.57$, $p < 0.05$) compared to the traditional ones.

Discussion

The study compared the air quality and respiratory health effects in fish processors using traditional and modern smoking kilns. Findings showed that traditional kilns emitted significantly higher levels of air pollutants, including nitrogen oxide (NO), carbon monoxide (CO), carbon dioxide (CO_2), and particulate matter compared to modern kilns (Table 1). This increased exposure to harmful pollutants places conventional kiln workers at greater risk of developing respiratory and cardiovascular disorders. The study is in agreement with previous research, such as Adebayo (2022), that identified that conventional kilns release greater pollutants due to incomplete combustion and poor ventilation. In addition, all the fish processors reported injuries such as burns, small cuts, and eye damage, primarily due to a lack of the use of protective devices such as gloves, aprons, and facemasks (the results were not tabulated). This finding aligns with Fapohunda et al. (2022), who also observed the same health hazards among fish processors in Ekiti State, Nigeria, where there was no protective device for smoke inhalation or contact with the eyes.

The traditional kilns were also found to release far more particulate matter which is known to be accountable for respiratory and cardiovascular diseases (Table 1). The results were consistent with studies by Obeng (2022) in Ghana, where the processors of fish through traditional means had exposure to high PM levels, leading to increased respiratory health issues. Similarly, Agyei (2022) reported elevated levels of gaseous pollutants in smokehouses in Ghana, with the findings showing possible extreme health issues for workers. The current results were also in agreement with Oyebanji et al. (2021), where the authors reported that traditional biomass burning significantly deteriorates the air quality through incomplete combustion. Bede-Ojimadu and Orisakwe (2020) also indicated that exposure to wood smoke in Sub-Saharan Africa contributes to high levels of inhalable particulates and harmful gases with long-term health effects.

Lung function impairment was evident in traditional kiln workers through spirometric tests, which showed significantly lower Forced Expiratory Volume in one second (FEV_1) and Forced Vital Capacity (FVC) values compared to predicted levels (Table 2). Employees in new kilns enjoyed better lung function indices, with higher FVC and FEV_1 levels, suggesting that work conditions in new kilns are less detrimental to respiratory health. FEV_1/FVC ratio was also lower among the traditional kiln workers (Table 2), suggesting restrictive pulmonary disorders potentially caused by long-term exposure to fine particulates and gaseous pollutants. These findings were consistent with Dienye et al. (2016), who noted impaired pulmonary functions among fish smokers who use biomass fuels, thereby predisposing them to chronic respiratory diseases.

The significant reduction in NO levels of modern kilns compared to the traditional (Table 3) agreed with Srivastava et al. (2005), which attributed reduced NO emissions from modern kilns to increased combustion efficiency and controlled airflow, preventing nitrogen oxidation, although CO levels in modern kilns were considerably lower but did not reach the significant level. Wang et al. (2023) have also reported similar trends with a retrofitted 60% reduction in CO level. Meanwhile, the 10-fold reduction in $PM_{2.5}$ is significant, considering the link between fine particulates and respiratory diseases (Wang et al., 2024) .The results of $PM_{2.5}$ and PM_{10} (Table 3) are consistent with global research attributing the use of filtration systems in modern kilns (Saidur, 2011). Khaliquzzaman et al. (2020), also established the reduction of 40–50% CO_2 in efficient kilns. Adamkiewicz et al. (2020) also reported a significant VOC reductions in closed-system kilns, which is attributable to modern kilns to be significant, and suggested that the difference might result from differences in the source of fuel or the measurement process. No significant variations were observed in pressure or temperature (Table 3), consistent with Xu et al. (2021), who found that kiln design influences primarily emissions rather than ambient thermal status. Modern kilns exhibit obvious advantages in reducing NO, CO_2, PM, and overall AQI.

Traditional kiln workers also recorded higher systolic and diastolic blood pressure (Table 4), indicating a higher risk for cardiovascular diseases. This was in agreement with the results of Sigsgaard et al. 2015 and explained that increased blood pressure has been linked to long-term exposure to pollutants like CO and PM, which result in oxidative stress and systematic inflammation, leading to vascular damage.

In conclusion, the study determines the advantage of modern kilns, which emit far fewer pollutants into the atmosphere, thereby improving air quality and reducing occupational health risks. The findings of the study demand the implementation of cleaner processing technology to avert the adverse health effects of the utilization of conventional kilns, as suggested by Bede-Ojimadu and Orisakwe (2020).

Conclusion and Recommendations

The current study indicated that traditional kilns are associated with poorer air quality and higher emissions, potentially leading to adverse respiratory outcomes for those exposed. The independent t-tests confirm significant differences between modern and traditional kilns for several pollutants. The statistical analysis supports the claim that traditional kilns generate a more hazardous environment, with notably higher pollutant levels compared to modern kilns. In terms of lung function, modern kiln workers have better results for most measures, including FVC, FEV_1, and PEFR. The differences suggest that working in modern kilns may be associated with better overall health outcomes. The results suggest that the working environment in traditional kilns may be more detrimental to both cardiovascular and respiratory health. Hence, there are indications that these variables have a meaningful influence on the lung function ratio, with males and individuals with higher diastolic pressure having better FEV_1/FVC ratios.

Conflicts of Interest

All authors hereby declared that no financial and personal relationships with other people or organizations inappropriately influenced this work.

Funding

This work was supported by the Federal University of Agriculture Abeokuta, Nigeria, FUNAAB-IBR-TETFUND in 2023.

Acknowledgement

The authors acknowledged the volunteers who participated in this study.

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