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Research Note

Evaluation of Air Quality Indices of Selected Public Kitchens and Possible Health Consequences

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A B S T R A C T

Biomass use in small unit combustion systems such as for space heating or cooking could lead to ineffective mixing and potential problems arising from emissions of gaseous and particulate pollutants. We therefore conducted a study to measure pollution levels in public kitchens using biomass fuel for cooking and to ascertain their air quality indices. Markers of indoor air quality such as CO, SO2, H2S, PM2.5 and PM10 were measured in eleven (11) public kitchens of selected secondary schools over a period of four months by a set of active sampling devices. It is revealed that the mean average of CO, SO2, H2S, PM2.5 and PM10 sampled in the indoor microenvironments of the selected kitchens are 46.29 ppm, 0.36 ppm, 0.28 ppm, 74 µg/m3 and 138 µg/m3, respectively. The AQI assessed for CO for the kitchens was 36.36% very hazardous, 54.54 % hazardous and 9.09% very unhealthy while 63.64% and 36.36 % of very unhealthy and unhealthy categories, respectively for SO2. This shows that the indoor air pollution levels in selected kitchen are elevated and results in potential negative health consequences.

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INTRODUCTION

Biomass fuel is defined as any material originated from plants or animals that is burned by humans. The most common example is wood, but animal dung and crop residues are also widely used [1]. Around 2.8 billion people, or 41% of the world's population, are believed to cook and heat their houses with solid fuels (wood, charcoal, coal, dung, crop waste) on open fires or traditional stoves [2]. Inefficient cooking and heating practices result in high levels of indoor air pollution, which includes a variety of health-harming pollutants such as fine particles and carbon dioxide [3]. Solid fuels, such as wood, roots, agricultural leftovers, and animal dung, emit a lot of carbon dioxide, hydrocarbons, and particulates [4]. Williams et al. [5] in their review stated that increased biomass use in small units, such as for space heating or cooking, could result in inadequate mixing and potential difficulties due to particle emissions, notably carbonaceous smoke. Air pollution, particularly indoor air pollution, has become a public health issue.

According to a 2010 estimate of the Global Burden of Disease, household air pollution was responsible for around 3.5 million premature deaths worldwide [6]. According to WHO, 4.3 million people died each year in 2012 as a result of exposure to home air pollution, the majority of whom died of cardiovascular diseases [3]. Concerns regarding the impact of air pollution on workers' short- and long-term health are also mounting. Several studies have connected poor health outcomes among workers to workplace exposure to indoor air pollution [7, 8]. Indoor air pollution has also been linked to an increase in oxidative stress and sick building syndrome among Taiwanese office workers [7]. Indeed, the quality of the indoor air in the workplace is a

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significant indicator that is evaluated in occupational health [9, 10].

The evaluation of the air quality index in a kitchen's indoor environment could have a significant impact on workers' occupational health. In many businesses, especially commercial kitchens, indoor air quality has become a major occupational health and safety problem. Public kitchens have been found to contain higher levels of air pollutants than commercial kitchens, particularly in developing countries [11, 12]. However, it is generally difficult to evaluate the health and economic costs of air pollution; in France, the cost of mortality, morbidity (loss of life quality), and production losses due to these health effects related with indoor pollution was projected to be around €20 billion in 2004 [13]. Also, human exposure to indoor air pollutants is difficult to quantify because it is mostly affected by micro-environmental factors such as kitchen ventilation and size. This is largely due to the fact that pollution levels in one kitchen may range significantly from those in another, depending on the existence and use of pollutant sources as well as ventilation practices.

According to a number of studies, diseases caused or aggravated by exposure to air pollutants in the workplace are rather prevalent, depending on the type of industry and likely pollutants involved. Large amounts of air pollutants are produced in commercial or public kitchens. In Nigeria, kitchen ventilation in both private and public kitchens is frequently inadequate. This, combined with the low combustion efficiency of cooking devices used to burn solid fuels, results in substantial emissions of health-damaging chemicals as incomplete combustion products. This is exacerbated by the fact that in underdeveloped nations, a typical family stove for cooking uses a semi-enclosed combustion chamber composed of mud, bricks, or rocks with no flue or chimney [14].

Many kitchens servicing large number of individuals within institutions such as schools, prisons, dormitories etc use wholly or partly, biomass fuel to reduce cost of cooking. Individuals who work in such an environment are therefore prone to exposure to air pollutants with their attendant consequences on health. Unfortunately, data on human exposure to air pollutants occurring in ground-level indoor and outdoor contexts within a few meters of point sources is insufficient, according to Klepeis et al. [15]. There is paucity of data regarding the components, levels of pollution from biomass cooking from public kitchens (such as school kitchens) and its association with human health. This is the focus of this study. Meanwhile, in the wake of epidemiological research linking biomass fuel usage to detrimental health impacts, efforts to monitor air quality in homes cooking on biomass fuels in poor nations have begun, with pollution levels being reported.

However, such studies are scarce and have not been reproduced in Nigeria, particularly when it comes to analyzing indoor air pollution levels in public cooking places, where the potential consequences are greater due to the large number of individuals participating. Furthermore, it has been observed that even the few researchers who have carried out evaluation of indoor air pollution levels in Nigeria have not been able to present their findings in such a way as to give the public an opportunity to track the air quality status of the indoor microenvironments of kitchens.

In the past, government-provided air quality data was disseminated to the public in the form of annual reports, environmental evaluations, and site or subject-specific analyses/studies. These are typically available or accessible to a small number of people, and they also need time, curiosity, and the requisite background to assimilate their contents. Governments around the world have begun to use real-time access to sophisticated database management programs to provide citizens with access to site-specific air quality index/air pollution index and its likely health consequences, as large databases frequently fail to convey the air quality status to the scientific community, government officials, policymakers, and, in particular, the general public in a simple and straightforward manner. As a result, a more advanced tool has been created.

The goal of this study was to assess the levels of Indoor Air Pollution (IAP) in the microenvironments of selected public kitchens that use biomass fuel for cooking and to determine their site-specific air quality indices in order to determine the level of risk that kitchen workers face. This will aid in the refinement of the estimation of biomass burning's contribution to ambient air quality in public kitchens' indoor microenvironments.

MATERIALS AND METHODS

Study area and settings

This research was conducted in the public kitchens of selected boarding secondary schools in the Plateau State of Nigeria's Jos North Local Government Area (see Figure 1). Plateau State's capital, Jos, is located in north-central Nigeria. With an elevation of around 1238 meters, the city is located at 9°56 N 8°53 E. It has a climate that is semi-arid. Plateau State's most densely inhabited area is Jos. Between December 8, 2019 and April 19, 2020, the research was conducted. Biomass fuels were the main source of energy for cooking in most public kitchens in the city, according to observations; thus, cooking is a major source of pollution exposure to the public.

In Jos North Local Government Area, there are approximately nineteen (19) secondary schools that function on a boarding system. Of these, two are federal Government owned schools, one is Plateau State Government owned school, and seven are private while nine are mission schools. Most of these school employ biomass fuels such as charcoal and fuel wood in their kitchens for cooking due to high cost of cooking gas and

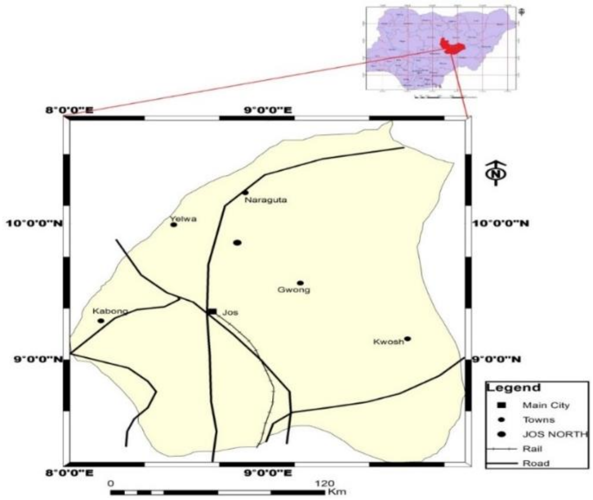

Figure 1. Map of Jos North Local Government Area of Plateau State-Nigeria

epileptic electricity supply. In each of these kitchens, there was an average of six persons directly involved in cooking and some indirectly connected but equally exposed to emissions from biomass combustion. Some of the kitchens were semi enclosed while some were with enclosed design. This study attempts to obtain real-world indoor air pollution data by undertaking on-site monitoring within the microenvironments of some randomly selected eleven (11) public kitchens in Jos metropolis in Nigeria based on the consent of the school managements after the aims of the study were explained by the Principal Investigator. No exclusion criteria were applied for the selection of the schools' kitchen.

Data collection

Exposure assessment

Exposure assessments and epidemiological research have relied on measurements of gaseous and particle air pollution [16]. In this study, hand-held active sampling devices were deployed to measure the levels of CO, SO_2, $PM_{2.5}$ and PM_{10}; Altair Multi-gas detector for CO and SO_2 and HAT 200 Particulate detector for $PM_{2.5}$ and PM_{10}. Although a few techniques have been replicated by multiple researchers, no in-kitchen field measurement protocols have been created and agreed upon internationally. [17] conducted indoor air pollution measurements in which samplers were placed in the main room of the residence at a height of roughly 1.0 m above ground level from any cooking stove. This was adopted in this work. However, these active sampling devices are placed within the kitchen space at about 2.0 m from any cooking points or mid-way between cooking points since there are often multiple cooking sources as presented in Table 1. However, since two active monitoring devices were used, they were placed within 10 cm of each other [17]. The total time of monitoring was at least 60 minutes. This monitoring was undertaking for ten sampling days for each kitchen so as to obtain data for all emissions' episodes for various meal preparations.

Air quality index evaluation

The primary goal of any air quality index is to convert the measured concentrations of distinct air pollutants into a single numerical index through the use of an appropriate aggregation method.

The monitoring concentrations of pre-determined air pollutants in the indoor environments of the selected kitchens were used for the calculation of an air quality index (AQI). The monitored data in the indoor kitchen environments are aggregated and converted into a specific pollutant index, I_p by deploying Equation (1). Pollutant concentration data and a reference concentration are included in this equation.

Meanwhile, the EPA has established breakpoint amounts based on the National Ambient Air Quality Standards (NAAQS), as shown in Table 1, as well as the findings of epidemiological studies on the effects of single pollutants on human health [18].

$$I_p = \frac{I_{HI}-I_{LO}}{BP_{HI}-BP_{LO}}(C_P - BP_{LO}) + I_{LO} \quad (1)$$

where I_P denotes the pollutant P's index,C_P is pollutant P's rounded concentration, I_{HI} is AQI value corresponding to BP_{HI}, I_{LO} is AQI value corresponding to BP_{LO}, BP_{HI} is the break point more than or equal to C_P, BP_{LO} is break point less than or equal to C_P.

The location's Air Quality Index (AQI) is represented by the highest individual pollutant index, I_P. This method does not have the flexibility to incorporate any number of air pollutants except carbon dioxide, nitrogen (IV) oxide (NO_2), ozone (O_3), particulate matter (PM_{10} and $PM_{2.5}$) and sulphur dioxide (SO_2), and can be used for determining the short term and long term air quality indices.

Questionnaire

Demographic data (age, education, smoking, habits, and marital status), as well as cooking hours per day, cooking years, kitchen design, and fuel type, were gathered through a personal interview with a standardized questionnaire. The number of respondents that consented to participating in this study was 116 across the selected eleven (11) kitchens. The respondents were kitchen staff who had spent a minimum of six months in the present kitchens and that are principally involved in cooking and not just in kitchen administration. Also, no age or sex limitations were imposed.

Statistical analysis

Using the SPSS software, we ran descriptive statistics on the data on CO, SO_2, H_2S, $PM_{2.5}$ and PM_{10} levels, as well as worker size. With this, the mean concentrations of the selected pollutants monitored were computed.

Additionally, Microsoft excel was deplored in obtaining the correlation coefficient of kitchen sizes with their respective number of kitchen staff.

Ethical approval

The Ethics Committee of Jos University Teaching Hospital gave their approval to the project (JUTH). Application for approval for this study in the selected schools' kitchen was written by the principal investigator to the respective school managements. The study commenced after approval was given by the school managements. The study's participation was entirely voluntary, and each respondent's signature was added to the consent forms once the study's goal and methodology were explained to them.

RESULTS AND DISCUSSION

Indoor air quality assessment

This paper presents evaluation Indoor Air Pollution (IAP) levels within the microenvironments of selected public kitchens that deplore biomass fuel for cooking, ascertains their specific air quality indices and assesses the probable health outcomes due to exposure by the kitchen workers. A total of eleven kitchens of schools operating a boarding system in Jos metropolis consented and participated in this study. Their indoor environments were monitored for concentration levels of CO, SO_2, $PM_{2.5}$ and PM_{10} as presented in Table 1. The mean average of CO sampled in the indoor microenvironments of the selected kitchens is 46.29 ppm (SD, 13.98); the 25th, 50th, and 75th percentiles are 37.17, 42.77, and 52.17 ppm, respectively. The mean average of SO_2 is 0.36 ppm (SD, 0.077), and the 25th, 50th, and 75th percentiles are 0.29, 0.35, and 0.44 ppm. The mean average of H_2S is 0.28 ppm (SD, 0.14), and the 25th, 50th, and 75th percentiles is 0.17, 0.25, and 0.43 ppm. The mean average of $PM_{2.5}$ is 74 µg/m^3 (SD, 46.63), and the 25th, 50th, and 75th percentiles are 55.10, 62.90, and 82.30 µg/m^3. The mean average of PM_{10} is 138 µg/m^3 (SD, 53.30), and the 25th, 50th, and 75th percentiles are 114.20, 129.60, and 176.10 µg/m^3.

Indoor pollution levels from these pollutants are primary a function of the type of appliance, emission rates, fuel moisture content, and type of wood utilized, the size distribution and chemical properties of the particles are likely to vary. According to Ugwuanyi et al. [19] the emission rates of monitored biomass combustion sources at 1.0 m downwind show charcoal burning and wood burning as having estimated emission rates of 140 mg/s and 84 mg/s for CO, 0.744 mg/s and 0.714 mg/s for SO_2 and for H_2S 1.556 mg/s and 1.176 mg/s respectively.

Table 1. Indoor air pollutants' levels in the selected public kitchens

SITES	Kitchen Sizes (m^3)	Cooking Points	No of Res.	CO (ppm)	SO_2 (ppm)	H_2S (ppm)	$PM_{2.5}$ (µg/m^3)	PM_{10} (µg/m^3)
ESS	252	2	16	42.77	0.50	0.50	82.30	176.10
RPA	364	2	13	79.46	0.40	0.21	17.10	36.20
STC	100	1	3	31.63	0.30	0.10	200.90	334.70
FGC	490	3	30	51.51	0.44	0.20	95.90	201.20
SLC	120	2	12	39.50	0.44	0.43	71.20	149.70
BHS	240	3	14	29.56	0.29	0.27	61.50	128.40
ABS	105	1	3	48.33	0.32	0.17	44.80	93.60
GCJ	150	1	9	40.10	0.35	0.25	56.10	117.70
SJC	150	2	5	52.17	0.36	0.47	67.90	140.20
CSSJ	56	1	4	57.00	0.26	0.12	62.90	129.60
MCJ	120	1	7	37.17	0.29	0.37	55.10	114.20
Min.	56		3	29.56	0.26	0.10	17.10	36.20
Max.	490		30	79.46	0.50	0.50	200.90	234.70
Mean	195.18		10.55	46.29	0.36	0.28	74.20	138.30
Std Error	39.61		2.39	4.21	0.02	0.04	14.10	16.10
Std Dev.	131.38		7.94	13.98	0.08	0.14	46.60	53.30
Percentiles25			4.00	37.17	0.29	0.17	55.10	114.20
50			9.00	42.77	0.35	0.25	62.90	129.60
75			14.00	52.17	0.44	0.43	82.30	176.10

Also, in their work, Ugwuanyi et al. [19] observed that at a downwind distance of 2.0 m from fuel wood burning sources deployed for cooking outdoor, CO, SO_2 and H_2S have concentrations of 38.57 mg/m^3 (33.67 ppm), 0.45 mg/m^3 (0.17 ppm) and 0.76 mg/m^3 (0.55 ppm), respectively; these levels compared to those sampled in this work are slightly lower except that of H_2S. Outdoor pollutants cannot be solely linked to a particular source since there could be several contributors. In fact, according to Lyon [16], pollutants generated indoors can migrate outdoors, adding to the outdoor pollution levels.

Indoor biomass burning has led to increases in many air pollutants to levels that have adverse impacts on human and environmental health. Tables 2a and 2b offer the WHO guidelines and National Ambient Air Quality Standards, respectively, for the selected pollutants monitored, allowing suitable comparative analysis and preliminary risk assessment of the sampled indoor environments. Comparing the observed IAP data with the WHO guideline values and National Ambient Air Quality Standards (NAAQS) presented in Tables 2a and 2b, show that the observed IAP data have levels within the kitchens that are much elevated than their respective allowable exposure limits; their respective minimum values obtained are higher than both WHO guideline values and the National Ambient Air Quality Standards as presented in Tables 2a and 2b. The World Health Organization (WHO) has issued recommendations for safe amounts of fine particulate matter in inspired air with an aerodynamic diameter of up to 2.5 m, based mostly on studies of environmental pollution and outdoor air.

According to these new criteria, air quality should be maintained at a maximum 24 hours average concentration of 15 mg/m^3 for $PM_{2.5}$ and 45 mg/m^3 for PM_{10} to avoid negative health consequences. The mean $PM_{2.5}$ and PM_{10} levels sampled within the indoor environment of the selected kitchens are 74.20 µg/m^3 and 138.30 µg/m^3, respectively. This depicts $PM_{2.5}$ as very hazardous since it exceeds both the recent WHO guideline values of 15 µg/m^3 and NAAQ standards of 35 µg/m^3 for a maximum 24 h average, while PM_{10} exceeds the recent WHO guideline values of 45 µg/m^3 but slightly below the NAAQS limit of 150 µg/m^3 for a maximum 24 h average. These values concentrate the majority of emissions in the repairable fraction of PM, which is important for achieving air quality regulations.

A careful assessment of the pollutants' levels reveals significant variations across the selected kitchens and with the nature of fuels used. Considering the means and the standard deviations of these pollutants in Table 1, it is clear that the particulate matters ($PM_{2.5}$ and PM_{10}) have the most significant variations while SO_2 has the least variation. Meanwhile, the mean SO_2 level is lower than the NAAQ standard of 0.075 ppm for one-hour exposure limit. This could be owing to the low sulphur content of wood, which means that SOx is unlikely to be a concern from wood combustion.

Indoor air quality indices

Air Quality Index tells how clean or unhealthy a potion of air is, and what associated health effects might be a concern. It also indicates the health effects one may experience within a few hours or days after breathing unhealthy air. Equation (1) was used to categorize the spectrum of data obtained in these selected kitchens and the findings given in Table 3 to provide people with access to site-specific air quality index/air pollution index and its likely health repercussions; the higher the AQI value, the greater the level of air pollution and the greater the health concern. From Table 3, the various categories for specific air quality indices of the selected kitchens were obtained as follows: hazardous (H), very unhealthy (VU), unhealthy (UH), unhealthy for sensitive people (UHS), moderate (MOD) and good (G). However, some of these categories were not obtained for some pollutants in some kitchens as presented in Table 4. The AQI assessed for CO for the kitchens was 36.36% very hazardous, 54.54 % hazardous and 9.09% very unhealthy while 63.64% and 36.36 % of very unhealthy and unhealthy categories, respectively for SO_2. On their part, $PM_{2.5}$ has its AQI categories as follows: 45.45 % of unhealthy category, 9.09 % of very unhealthy category, 9.09 % of moderate category and 36.36% of unhealthy for sensitive people category. PM_{10} has its AQI categories as follows: 27.27 % of unhealthy for sensitive people category, 63.64% of moderate category and 9.09 % of good category.

From the air quality indices analysis presented in Table 4, the sets of data depict CO and SO_2 as having the greatest potential negative impacts within the indoor

Table 2a. Recommended 2021 AQG levels compared to 2005 Air Quality Guidelines

Pollutants	Averaging Time	2005 AQGs	2021 AQGs
$PM_{2.5}$, µg/m^3	Annual	10	5
	24-hour^a	25	15
PM_{10}, µg/m^3	Annual	20	15
	24-hour^a	50	45
O_3, µg/m^3	Peak season^b	-	60
	8-hour^a	100	100
NO_2, µg/m^3	Annual	40	10
	24-hour^a	-	25
SO_2, µg/m^3	24-hour^a	20	40
CO, mg/m^3	24-hour^a	-	4

µg= microgram

[a] 99th percentile (i.e. 3-4 exceedance days per year)

Table 2b. National Ambient Air Quality Standards (NAAQS) (USAEPA, 2017)

S/N	Pollutants	Primary/Secondary	Average Time	Levels	Form
1	Carbon (II) Oxide, CO	Primary	8 hours	9 ppm	Not to be exceeded more than once per year
			1 hour	35 ppm	
2	Sulfur (IV) Oxide	Primary	1 hour	75 ppb	99th percentile of 1-hour daily maximum concentrations, averaged over 3 years
		Secondary	3 hours	0.5 ppm	Not to be exceeded more than once per year
3	$PM_{2.5}$	Primary and secondary	24 hours	35 μg/m^3	98th percentile, averaged over 3 years
4	PM_{10}	Primary and secondary	24 hours	150 μg/m^3	Not to be exceeded more than once per year on average over 3 years

Table 3. Breakpoint concentration of air pollutants defined by U.S. EPA

		Breakpoints						
O_3 (ppm) 8-hour	**O_3 (ppm) 8-hour**	**PM_{10} (μg/m^3)**	**$PM_{2.5}$ (μg/m^3)**	**CO (ppm)**	**SO_2 (ppm)**	**NO_2 (ppm)**	**AQI**	**CATEGORY**
0-0.064	____	0-54	0-15.4	0-4.4	0-0.034	([2])	0-50	Good
0.065-0.084	____	55-154	15.5-40.4	4.5-9.4	0.035-0.144	([2])	51-100	Moderate
0.085-0.104	0.125-0.164	155-254	40.5-65.4	9.5-12.4	0.145-0.224	([2])	101-150	Unhealthy for sensitive people
0.105-0.124	0.165-0.204	255-354	65.5-150.4	12.5-15.4	0.225-0.304	([2])	151-200	Unhealthy
0.125-0.374 (0.155-0.404)[4]	0.205-0.404	355-424	150.4-250.4	15.5-30.4	0.305-0.604	0.65-1.24	201-300	Very Unhealthy

microenvironments of the kitchens while $PM_{2.5}$ is the most harmful of the particle sizes assessed. Lyon [16] observed that temperatures of biomass burning determine the completeness of its combustion and the level of carbon dioxide emitted; the combustion of a common biomass fuel in open fires and stoves occurs at lower temperatures, resulting in reduced NOx emissions but higher CO emissions. Organic gases, as well as carbonaceous PM and contaminants in the fuel were released (e.g. potassium).

Despite the fact that these studies focused on specific pollutants like CO, SO_2, and particulates, their concentrations can be an indicator of a mixture and the existence of other substances. Field observations provide a distinct advantage over laboratory studies in conducting preliminary risk assessments of biomass fuel combustion because the investigations are conducted on-site, near to the actual burning [20-24].

Uncontrolled ventilation, variability in emissions recorded by different sampling techniques, random burning process, inevitable chemical contaminations, and ultra-low concentrations of target components due to atmospheric dilution all contribute to the challenges of indoor pollution sampling, and differences between field research and laboratory studies have also been reported [25-28]. Because the data in this investigation required in-situ measurements, they were carried out.

Kitchen designs and fuel-type use

For adequate indoor pollution exposure assessment, information on the fuel-type use and kitchens' design of the selected kitchen was sourced. From this information, 5 (45.45 %) kitchens with 36 respondents are fully enclosed while 6 (54.55%) with 80 respondents are semi-enclosed. The average kitchen size of the selected kitchens was evaluated as 195.18 m^3. Among the kitchens with semi-enclosed designs, 3 (50%) have walls with perforations. One vital factor that influences the level of pollutants' emission during biomass combustion in the kitchen is the incorporation of adequate ventilation structures in the kitchen's design. Although in this study, there was no systematic mechanical analysis of the effects of ventilation conditions of the kitchens and the nature of kitchens' design on the levels of indoor air pollutants sampled, there were some variations along obvious ventilation trends in kitchens' design from the site specific data and air quality indices presented in Tables 1 and 4. RPA, GCJ, STC, SMC and CSSJ are the only schools whose kitchens are fully enclosed with the doors and one or two windows open. SLC, ESSJ, BHS, ABS, SJC and FGCJ are kitchens with semi-enclosures. Of these kitchens, SLC, BHS and SJC are kitchens with perforations on one or two walls. A general survey shows that the semi enclosed and perforated-walled kitchens have greater number of cooking points [SLC (2 points), ESSJ (2 points), BHS (3 points), SJC (2 points) and FGCJ (3 points)] while the enclosed kitchens had fewer cooking points [CSSJ (1 point), MCJ (1 point), GCJ (1 point), RPA (2 points), ABS (1 point) and STC (1 point)]. It is observed that the higher the ventilation and kitchen dimension, the more the number of cooking points, since there are more provisions for the pollutants level to be diffused and advocated outdoor through the perforations and other openings in the walls. However, in closed kitchen structures, several cooking points will produce more indoor air pollution levels, thereby making the indoor environments more choking. This could be one of the reasons why the fully enclosed kitchens with average cooking point of 1.2 and average kitchen area of 158 m^2 have CO, SO_2, $PM_{2.5}$ and PM_{10} levels of 49.07 ppm, 0.32 ppm, 78.42 $\mu g/m^3$ and 146.20 $\mu g/m^3$, correspondingly while the semi-enclosed kitchens with average cooking point 2.5 and average kitchen area of 226.17 m^2 have CO, SO_2, $PM_{2.5}$ and PM_{10} levels of 43.97 ppm, 0.39 ppm, 70.60 $\mu g/m^3$ and 152.22 $\mu g/m^3$, correspondingly. There is no gain saying that the potential impacts of having several cooking points in the semi enclosed kitchens are being offset with their much enhanced ventilation conditions, thereby resulting to comparative Indoor Air Pollution (IAP) levels with that of the enclosed kitchen episodes.

Another key determinant of the variation in IAP levels across the selected kitchens is the nature of the fuel deployed in cooking. In this study, it is revealed that the fuels used by the selected public kitchens are mostly fuel woods followed by charcoal and gas. However, the use of gas is very rare (data not supplied). This supports the findings of [28], who found that the features of emissions are directly related to the type of burning process, the type of fuel used, and the age of the smoke.

The detected CO content is higher than the National Ambient Air Quality Standards, which are 10.00 mg/m^3 for an 8-hour exposure and 4.0 mg/m^3 for a 24-hour exposure, according to WHO Air Quality Guidelines (AQGs). The fuel-type deployed for cooking in the selected kitchens are fuel wood, charcoal, combination of fuel wood and gas and combination of charcoal and gas. There is none that use gas only. Of these kitchens, 70 (60.34%) use fuel wood only for cooking, 30 (25.86 %) use fuel wood and gas while 16 (13.79%) use charcoal and gas. Among the fuel combinations, gas is rarely used in the kitchens because of its cost implication and the convenience of using charcoal and fuel wood to cook for large number of students. It is observed that the bigger the kitchen dimensions, the more the number of kitchen workers. Correlating the dimensions of the selected kitchens with the number of kitchen workers as depicted by Figure 2 gives a correlation coefficient of 0.812. However, in this work, the number of cooking points is not controlled for, since the assessment was done under real-time situations. It is generally observed that the number of cooking points, the fuel type, and the quantity of fuel (wood fuel or charcoal) use for cooking and the combustion conditions of the kitchens are influential in the variability of these pollutants across the selected kitchen. Lyon [16] confirmed this, stating that the relative quantity of components varies depending on the fuel type and combustion conditions. It is observed that the only kitchen (RPA) where charcoal was deployed has the highest CO emission level (79.46 ppm) and the least particulate emission levels (17.10 $\mu g/m^3$ for $PM_{2.5}$ and 36.20 $\mu g/m^3$ for PM_{10}).

Demographic information

Number of respondents 91 (78.45%) out of the 116 were female, with an average age of 46.34 years, and 25 (21.55%) were male, with an average age of 43.2 years. In assessing the smoking and alcohol intake, it was obtained from interview that only 3 (2.59%) are ex-smokers and 13 (11.30%) have formally used alcohol while 113 (97.41%) respondents never smoked and 85 (73.91%) never took alcohol. However, 17 (14.78%) of the respondents were current alcohol users.

Information on exposure history and symptoms and signs was gathered by the use of questionnaire. Each kitchen has an average number of respondents of 11

Figure 2. Correlation of kitchen sizes with number of kitchen staff

whose mean age is 45.66 years ranging from 25 to 69 years. Of the 116 respondents, 69 (59.48%) suffers from joint pain, 50 (58 %) eye irritations, running nose 42 (36.21%), nasal congestion 7 (6.03%), dyspnea 17 (14.66), 52 (44.83%) dizziness, 79 (68.70%) headache, myalgia 40 (34.48%), 34 (29.31 %) joint stiffness and joint swelling 9 (7.79%).

CONCLUSION

On preliminary basis, it is clear that the sampled IAP levels of the selected pollutants within the kitchen environments pose significant potential health impacts on the kitchen workers who are directly involved in cooking within the microenvironments of these sources. The detected CO content is higher than the National Ambient Air Quality Standards, which are 10.00 mg/m^3 for an 8-hour exposure and 4.0 mg/m^3 for a 24-hour exposure, according to WHO Air Quality Guidelines (AQGs). This could be evident in the significant number of respondents who are presently grappling with some probable health consequences such as join pain, eye irritation, dizziness, headache and myalgia. This can be safely inferred because from the demographic information, it was revealed that a greater percentage of the respondents are not significantly exposed to other sources of pollution and alcohol intake. The detrimental health effects of biomass fuel combustion-related Indoor Air Pollution (IAP) are severe. This can be reduced by more enlightenment of the public kitchen workers and boarding school managements on the need to have their kitchen designed with adequate ventilation conditions reduce the number of hours spent close to the cooking sources and deploying the use of more environmental friendly fuels for cooking. Cleaner fuels, particularly liquefied petroleum gas, are likely to be the best long-term option for reducing pollution and protecting the environment, but biomass users are unlikely to be able to make the transition for many years due to the cost implications and ease of using biomass fuels for cooking for large groups of people. However, given the air quality indices found suggested that they are dangerous and likely to be harmful to health, further investigation is required.

Through well-designed kitchen structures, interventions should be undertaken to decrease exposure to concentrations that are less detrimental to health.

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Persian Abstract

چکیده

استفاده از زیست توده در سیستم‌های احتراق واحدهای کوچک مانند گرمایش فضا یا پخت و پز می‌تواند منجر به اختلاط ناکارآمد و مشکلات احتمالی ناشی از انتشار آلاینده‌های گازی و ذرات معلق شود. بنابراین ما مطالعه ای را برای اندازه گیری سطوح آلودگی در آشپزخانه های عمومی با استفاده از سوخت زیست توده برای پخت و پز و برای تعیین شاخص های کیفیت هوا انجام دادیم. نشانگرهای کیفیت هوای داخلی مانند CO، SO2، H2S، PM2.5 و PM10 در یازده (۱۱) آشپزخانه عمومی مدارس متوسطه منتخب طی یک دوره چهار ماهه توسط مجموعه‌ای از دستگاه‌های نمونه‌گیری فعال اندازه‌گیری شدند. مشخص شد که میانگین CO، SO2، H2S، PM2.5 و PM10 نمونه برداری شده در ریزمحیط های داخلی آشپزخانه های منتخب به ترتیب ۴۶,۲۹ ppm، 0.36 ppm، 0.28 ppm، 74 میکروگرم بر متر مکعب و ۱۳۸ میکروگرم بر متر مکعب است. AQI ارزیابی شده برای CO برای آشپزخانه ها ۳۶,۳۶٪ بسیار خطرناک، ۵۴,۵۴٪ خطرناک و ۹,۰۹٪ بسیار ناسالم در حالی که ۶۳,۶۴٪ و ۳۶,۳۶٪ از دسته های بسیار ناسالم و ناسالم به ترتیب برای SO بود. این نشان می‌دهد که سطوح آلودگی هوای داخلی در آشپزخانه انتخابی افزایش یافته و منجر به پیامدهای منفی بالقوه سلامتی می‌شود.