



International Journal of Environmental Engineering

ISSN online: 1756-8471 - ISSN print: 1756-8463

<https://www.inderscience.com/ijee>

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DOI: [10.1504/IJEE.2023.10061971](https://doi.org/10.1504/IJEE.2023.10061971)

Article History:

Received:	14 July 2023
Last revised:	11 October 2023
Accepted:	16 October 2023
Published online:	30 December 2024

Assessment of daily and seasonal concentrations of particulates matters generated by rice mills in Makurdi using cluster analysis

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Abstract: The study was carried out at four rice milling in Makurdi Markets namely Wadata, Wurukum Roundabout, High-Level, and North-Bank. Nokia C3 stopwatch, Hanhart stopwatch and Crowcon Gasman for sensing carbon monoxide, nitrogen dioxide, and sulphur dioxide were adopted for data collection at 5 minutes' interval between 8 am to 10 am and 4 pm to 6 pm for two months in rainy and dry season. The Wurukum Roundabout recorded the highest concentration of CO and NO₂ for both seasons plus highest daily SO₂ in dry season. The correlation demonstrates that CO was positively significant (0.029) for both seasons while NO₂ and SO₂ were weakly significant (0.001) at rainy season. Performing cluster evaluation by square Euclidean distance average link between locations for probable similarities that exist among the particulate and locations indicated two clusters in three stages of combination. The coefficients for these stages were 1.89, 71.85 and 245.7.

Keywords: rice processing; particulate matter; rice mill; air pollutants; Makurdi.

Reference to this paper should be made as follows: Samuel, S.A. and Shadrach, E.O. (2025) 'Assessment of daily and seasonal concentrations of particulates matters generated by rice mills in Makurdi using cluster analysis', *Int. J. Environmental Engineering*, Vol. 13, No. 1, pp.92–101.

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1 Introduction

Environmental pollution is on the increase globally, coursing serious impact on living organisms and considered as one of the greatest health risk to humans. It is the discharge into the environment (air, land and water) of substances harmful to humans and other living organisms (Manisalidis et al., 2020). Air pollution in Nigeria is increasing due to rapid urbanisation, industrialisation, agricultural production and processing, and the development of traffic and transportation systems. This development has contributed to the release of air pollutants such as nitrogen oxides, sulphur dioxide, volatile organic compounds (VOCs), dioxins and polycyclic aromatic hydrocarbons (PAHs) that are harmful to humans (Ioannis et al., 2020). Carbon monoxide can even cause direct poisoning when inhaled in high concentrations. Small-diameter particulate matter (PM) particles can enter the airways through inhalation and cause respiratory and cardiovascular diseases, reproductive and central nervous system dysfunction, and cancer (Manisalidis et al., 2020). According to Olenchock et al. (1984), the entry of undesirable components into our air network adversely alters the natural quality of the environment. In addition to metal fumes, dust, corrosive gases, excessive noise, smoke, chemical vapours, sulphur dioxide, carbon monoxide, oxides and fly ash. These are harmful to people, plants, animals and buildings. Air pollution levels vary by location and type of industrial or agricultural activity.

Asian rice (*Oryzasativa*) or African rice (*Oryzaglaberrima*) is one of the most important grains in the world, it has become a staple food for over 50% of all households; which both the rich and the poor consume, according to Godwin (2012) cited in Akinniran and Faleye (2020). According to Akinniran and Faleye (2020), only seven of the 36 states in Nigeria produce rice on a large scale. These states include: Anambra, Nassarawa, Ebonyi, Niger, Kano, Kaduna and Benue. Rice is one of the staple foods for the majority of the population in Nigeria. It is one of the largest consumed sources of calories among edible grains. Rice milling is one of the agricultural processing industries in the country and is mainly practiced in every village where rice has been produced. Typically, a large amount of dust occurs from the rice milling process. Rice milling has

both positive and negative impacts on the environment and human health, be it in terms of food, air pollution, regional and global climate change, or transboundary air pollution. Kiattisak and Thanatchai (2011) reported that dust is generated during the processing of rice. Workers in different agricultural industries are therefore exposed to different amounts of dust. Dust inhalation is a major occupational respiratory, skin and eye health hazard as reported by (Bulat et al., 2004; Latza and Baur, 2005; Mohammadien et al., 2013). Dust exposure causes pulmonary tissue inflammatory reactions, eosinophilia and asthma-related diseases from rice hulls (Dewangan and Patil, 2015). Not only workers at the rice mill, but also villagers living in the surrounding areas breathe air mixed with dust into their lungs every day. Rice husks and wood waste produced in rice mills in Makurdi, when burned without being used for energetic or non-energy purposes, lead to significant environmental hazards and health problems due to methane and other harmful emissions (Figures 1 and 2). This causes an air pollution problem in local villages that reduces the quality of life of an entire local community. However, the essence of this research work is to assess the contributions of fines to air pollutants generated by rice mills in Makurdi.

Figure 1 Burning of rice husk in Makurdi (see online version for colours)



Figure 2 Parboiling of rice in Makurdi (see online version for colours)



In a rice mill, the primary air pollutants are particulate matter emissions from the cleaning and milling process, where the particulate matter is emitted as black soot and smoke from the boiler stack. Some particles are too small (less than $10\ \mu\text{m}$) and cannot be seen by the human eye. The main components of particulate matters are organic

compound, water-soluble ions and levoglucosan. The relative abundance of some methoxyphenols (e.g., acetylsyringone), PAHs (e.g., fluoranthene and pyrene), organochlorine pesticides and PCBs can also serve as additional signatures for particulate matter emission. The presence of these toxic compounds in particulate matter from burning smoke increases the potential toxic effects of the emission (Nguyen et al., 2011).

2 Study area, sampling and data collection

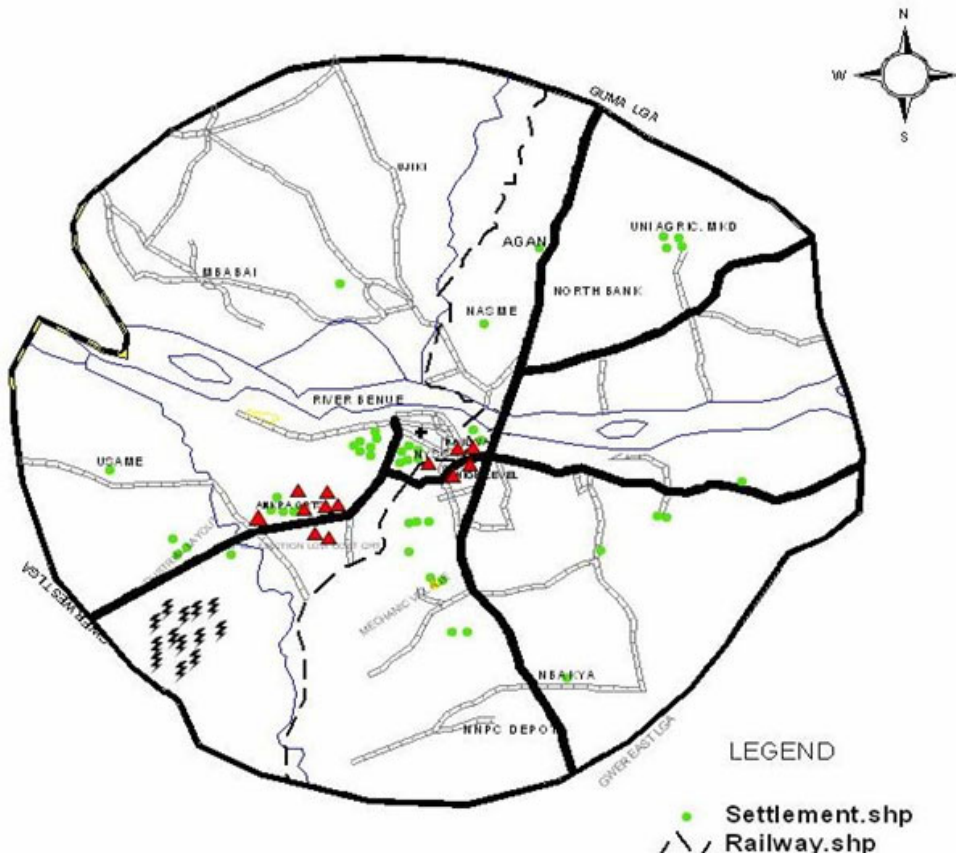
2.1 Description of study area: Makurdi

This study was conducted at four selected rice mill sites in Makurdi Metropolis, namely Wadata Market Rice Mill (WMRM), Wurukum Roundabout Rice Mill (WRRM), High-Level Market Rice Mill (HMRM) and North Bank Market Rice Mill (NMRM). Makurdi is the capital of Benue State in Nigeria West Africa. It lies on the banks of the Benue River, a major tributary of the Niger. The metropolis, located in the Benue Valley at 6°22' and 7°56' north latitude and 7°37' and 9°05' east longitude, has a total area of 325 km². Makurdi lies within the vegetation zone of the Guinea savannah with some patches of forest. The annual rainfall is between 1,500 mm and 2,000 mm, with the peak precipitation in the months of July and September. Temperatures in March and April are 38°C and 48°C respectively, while December/January temperature is 27°C. The population of residents is about 300,317 people, including 158,838 males and 141,479 females (NPC, 2007). However, the inhabitants of the Makurdi metropolis are predominantly civil servants; Fishing, trade and agriculture are the main occupations of the traditional inhabitants. Other people are involved in the production of baked bricks and irrigated agriculture (vegetables) along the Benue River. Benue State has enormous human, capital and material resource potential and is a true source of raw materials for processing plants, manufacturing industries and agricultural catchment areas specialising in cash crops, subsistence crops and raising domestic goats, ducks, chickens and pigs etc. The state is accessible via Nasarawa, Taraba, Obodu, Enugu and Ankpa roads. The area can also be accessed via the Benue River, which flows from Cameroon Mountain to the confluence of the Niger and Benue Rivers at Lokoja. A local airport is also located in Makurdi (Figure 3).

2.2 Sampling and data collection

Data for the study were collected using the Nokia C3 stopwatch, the Hanhart stopwatch and the Crowcon Gasman to detect carbon monoxide, nitrogen dioxide and sulfur dioxide. The analytical procedure involves turning the gasman into the test position until the light emitting diode (LED) flashes red continuously, followed by an audible alarm tone. The instrument was then switched to the throttle position and a green light observed on the LED. Once the liquid crystal diode (LCD) has shifted the zero value, the Hanhart stopwatch was then turned on and readings were taken at 5 minute intervals for a period of 25 minutes to ensure a constant concentration of the gas. Data were collected between 8:00 a.m. and 10:00 a.m. in the morning and between 4:00 p.m. and 6:00 p.m. in the evening as reported by Anhwange et al. (2012). The data were recorded for a period of two months (August and September for the rainy season and January and February for the dry season).

Figure 3 Makurdi map (see online version for colours)



3 Results and discussion

Table 1 presents the mean daily concentration of the three particulate gases produced from rice mills in selected location of Makurdi as compared with the National Ambient Air Quality Standards (NAAQS).

Table 1 Mean daily concentration of particulates from rice milling in Makurdi

Seasons		Locational concentration of particulate gases				NAAQS 2015 standard (ppm) (USEPA, 2015)
		WRRM	HMRM	WRRM	NMRM	
Dry	CO	6.79	13.25	19.98	7.76	0.50
	NO ₂	0.09	0.09	0.10	0.10	0.053
	SO ₂	0.09	0.09	0.09	0.09	35.0
Wet	CO	6.79	13.25	19.98	7.76	0.50
	NO ₂	0.07	0.07	0.06	0.05	0.053
	SO ₂	0.09	0.08	0.10	0.07	35.0

3.1 Carbon monoxide (CO)

The concentration of CO does not vary significantly from dry season to rainy season at each location (Figure 4) but varied among locations as attested by their standard deviation (StDev) in all the locations in Makurdi. High concentrations of the CO were recorded at WRRM for both dry and rainy season (19.98 ppm). This is attributed to the high traffic of milling activities being the largest mill in Makurdi and antecedent contribution from high vehicular traffic experienced at the Wurukum roundabout.

The WRRM is followed closely by the HMRM (13.25 ppm) in CO concentration and could also be ascribed to contribution from traffic congestion. WMRM recorded the lowest concentration of CO.

Figure 4 Seasonal concentration of CO in from rice mill in Makurdi (see online version for colours)

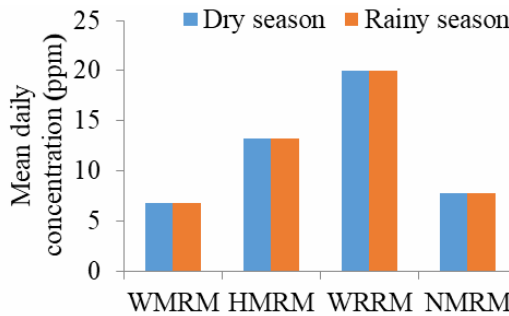
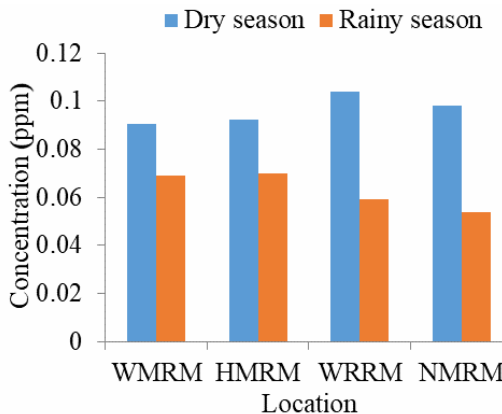


Figure 5 Seasonal concentration of NO₂ in from rice mill in Makurdi (see online version for colours)



3.2 Nitrogen dioxide (NO₂)

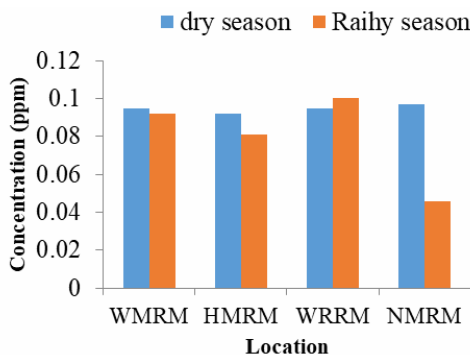
The result of NO₂ showed that the highest concentration during the dry season was measured at WRRM and NMRM (0.10 ppm), while the lowest value of 0.09 ppm was measured at HMRM and WMRM, the daily concentration was in the range of 0.14–0.05

ppm as observed during the dry season. Daily values of the gas measured during the rainy season ranged from 0.10–0.03 ppm for WMRM and HMRM. For WRRM and NMRM, the observed ranges are 0.09–0.00 ppm and 0.10–0.00 ppm, respectively. The daily NO₂ concentration measured at the four sites during the two seasons was between 0.13–0.03 ppm and 0.12–0.00 ppm respectively, with an average between 0.05 and 0.1 ppm. The highest concentration of gas observed by the WRRM and NMRM may be due to different activities in the area. There is a mechanical workshop, slaughterhouse and open waste disposal, many filling stations, many vulcanising activities and motor parks around the location. The normalised bar charts for the assessment classified WRRM as the more polluted location by air within the Makurdi (Figure 5 and 6).

3.3 Sulphur dioxide (SO₂)

The highest daily concentration of SO₂ measured during the dry season was at the WMRM (0.14 ppm), while the lowest concentration was at WMRM (0.00 ppm). A range of daily concentration measured (0.14–0.04 ppm) was observed for HMRM during the dry season, while WRRM and NMRM recorded 0.14–0.10 ppm and 0.14–0.40 ppm respectively, during the dry season. The highest mean concentrations of SO₂ during the rainy season were 0.09 ppm and 0.08 ppm for WMRM and HMRM respectively. For WRRM and NMRM, the observed daily ranges are 0.09–0.00 ppm and 0.10–0.00 ppm, respectively.

Figure 6 Seasonal concentration of SO₂ in from rice mill in Makurdi (see online version for colours)



4 Statistical analysis

The set data was statistically analysed for possible variations that may exist among locations and seasons using SPSS 20. Simple T test was performed by correlation to establish the significant differences that may exist among the particulate as well as the seasons. Table 2 indicated that CO was positively significant at 0.5 with coefficient as 0.029 both in dry and wet season of Makurdi. NO₂ and SO₂ were not significant at dry season but weakly significant with coefficient 0.001 in wet season.

Cluster analysis was also performed using the squared Euclidean distance and average association (Figure 7) between locations for possible similarities that may exist between the particles and locations. From the results in Table 3, the agglomeration plan

identified two clusters in three stages of combining sites (group), phase 1 of cluster 1 and 2 was a combination of site 1 and site 4. Phase 2 also combined sites 1 and 2, during stage 3 was a combination of location 1 and 3. The coefficients for these levels were 1.89, 71.85 and 245.7, respectively.

Table 2 One-way ANOVA

<i>Test value = 0</i>						
	<i>T</i>	<i>Df</i>	<i>Sig.</i> (2-tailed)	<i>Mean</i> <i>difference</i>	<i>95% confidence interval</i> <i>of the difference</i>	
					<i>Lower</i>	<i>Upper</i>
Cod	3.939	3	.029	11.94550	2.2955	21.5955
NO ₂ d	32.909	3	.000	.09500	.0858	.1042
SO ₂ d	38,920,602,880,793,776.000	3	.000	.09000	.0900	.0900
COw	3.939	3	.029	11.94550	2.2955	21.5955
NO ₂ w	13.056	3	.001	.06250	.0473	.0777
SO ₂ w	13.168	3	.001	.08500	.0645	.1055

Note: No statistics are computed for one or more split files

Figure 7 Dendrogram of linkages between rice mill location in Makurdi (see online version for colours)

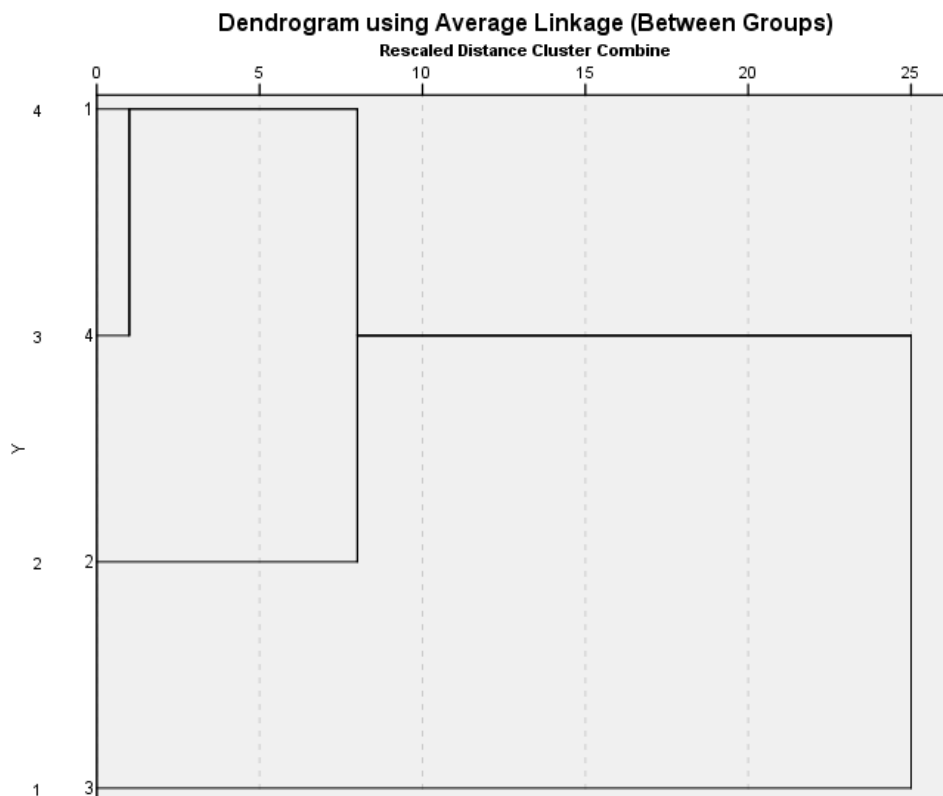


Table 3 Cluster analysis

Stage	Cluster combined		Coefficients	Stage cluster first appears		Next stage
	Cluster 1	Cluster 2		Cluster 1	Cluster 2	
1	1	4	1.890	0	0	2
2	1	2	71.850	1	0	3
3	1	3	245.700	2	0	0

5 Conclusions and recommendations

5.1 Conclusions

The results of the assessment show that the Makurdi atmosphere is polluted to some extent as was normally assumed in terms of CO and NO₂ because the particulate gases examined were above the allowable NAAQS set in 2015 both in dry and rainy seasons. However, SO₂ from the study was below the allowable NAAQS set in 2015 both in dry and rainy seasons. Therefore, unless adequate measures are taken to control the excesses, continued pollution can have cumulative effects on the health and well-being of the dweller in the future. The rice milling industries considered in this study have both positive and negative environmental impacts. The positive effects are more in the nature of social services for their host communities. The negative effect has to do with pollution. The average connections between these sites are shown in Figure 7.

5.2 Recommendations

In order to protect the environment from the adverse effects of the food processing industry (rice milling), a number of mitigation measures and management options are hereby recommended that should be implemented. An environmental awareness campaign should be conducted to sensitise people to the effects of air pollution and reduction of environmental hazards. There should be columns of smoke in burners and kitchens to disperse the particles released when burning firewood in hotplates, and adequate ventilation is required.

Government and other stakeholders should ensure enforcement and prosecution of violations of environmental laws. In addition, increases in the price of other energy sources should be controlled and kept to a minimum to divert attention from reliance on fuelwood alone. To minimise losses and also to reduce pressure on tree species and minimise air pollution. Again, research options on biofuel and other mineral resources such as coal can be supported to complement energy wood. The rice milling industry should be designed to maximise recycling potential and minimise waste generation, e.g. By burning rice husks. The government must ensure that industrial buildings are built far from residential areas and ensure proper urban planning. Funding should be made available to secure air quality measurement equipment and qualified personnel.

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