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Welding Activities and their Associated Impacts in an Urban Area: Necessity for Environmental Standards and Regulation

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Abstract
Welding is an important aspect of industrial process and a viable source of income for a vast majority. It is however characterized by occupational and environmental risks and constitutes much harm due to poor standards and regulations. This study assessed welding activities and its impact on air quality in welding workshops with a view to provide insights on environmental regulations required. Data on air pollution were obtained from 7 welding workshops in Awka town following standard procedures. Notable pollutants identified within the welding environments were: Particulate Matter ($PM_{1.0}$, PM_{10}, and $PM_{2.5}$) µg/m^3 and chemical compounds: HCHCO (Formaldehyde) mg/m^3, Total Volatile Organic Compound (TVOC) mg/m^3, Carbon Monoxide (CO) mg/m^3, and then the Air pollution level (A.P.L). Each of the pollutants contributed to the total air pollution levels without anyone significantly contributing more than others. Particulate matter ($PM_{1.0}$) and CO were much correlated to the air pollution level than others; and the risks associated with such pollutants used to show the risks and harm welding constituted in the region. With weak regulations and standards as it pertains to the workshops, work ethics and precautionary measures in the area, both welders and non-welders were seen to be prone to the risks emanating from such processes. Adherence to standard procedures and regulations were advocated for safer welding processes.

Keywords: Air pollution, environmental hazards, land use change, sustainability

Introduction

Urban areas are epicentres of economic activities and hub for much of the industrial activities and transformation experienced across the globe. Consequently, it is a ‘hotspot’ for the emission of gases (Grimm et al. 2008) and undergo continuous alteration and transformation in its land use and cover. Though the urban land use continually changes through sectors such as industries (Qiu et al. 2015), they however experience economic development and are providers of employment opportunities for a vast majority through much of such industrial activities. Processes of industrial enterprises are multifaceted and involve different aspects of design, construction and fabrication; depending on the product of choice. These are facilitated mainly through different types and allied processes of welding; which entails liquefying metals for the purpose of binding other metals together. Welding is a metal joining process wherein coalescence is produced by heating to suitable temperature. It is an important aspect of the industrial sector and plays an important role in various aspects of everyday life (Adu and Danquah, 2016). With a wide range of applications, it is used across a range of industries, to design, fabricate and actualize the creation of different products.

While welding processes are much beneficial, they however influence environmental quality and could cause harm to people. The processes are heat intensive and equally associated with fumes and particulates. The main hazards related to welding include exposures to radiation, heat, flames, fire, explosion, noise, welding fumes, fuel gases, inert gases, gas mixtures and solvents (Golbabaei and Khadem, 2015). Exposure to welding fumes is hazardous and welders are presumably the largest group occupationally exposed to airborne gases such as neurotoxin manganese (Antonini et al., 2003) and other oxides that are harmful to human health. Welding fume is a complex mixture of fine particles containing ultra-fine particles in the nanometer range (Tian et al. 2016) and constitute known health hazards to humans. Welding processes contributes significantly to air pollution, reduces the air quality of a place and could affect biological processes and general wellbeing of ecosystems. Besides the health hazards associated with fumes, fires and explosion hazards associated with it equally have adverse impacts on the welders and welding processes in totality and can constitute great tolls of losses to welding activity.

Hazards and risks associated with welding are immense and debilitates expected outputs from industrial activities. Addressing such concerns will require that baseline information on welding activities and their associated impacts are provided. Though precautionary measures on reducing risks associated with welding exists and guidelines for ensuring safety welding processes are much known, hazards emanating from welding processes still continue unabated. Such are more pronounced in developing regions unlike developed zones due to the inability of the former to follow or adopt the guidelines that will reduce the negative impacts of such processes in the environment. There is therefore the need to elucidate the processes involved with welding (industrial) activities and the extent to which they affect air quality and constitute harm to humans and the environment in general. Southeast Nigeria is a commercial and industrial hub for a broad range of firms and strategic for industrial revolution across Nigeria. Though it has a long history of welding activities due to its industrial importance, there are no baselines that could be used for designing policies that could help to promote safety standards across the region. Utilizing welding workshops in the study area, this work hence assessed welding activities and its impact on air quality. Specifically, the work identified the predominant pollutants in welding environments, impact of welding on air quality of the workshops and needed strategies to adopt in a bid to reduce the harmful impacts.

Materials and Methods

Study Area

Awka is the capital city of Anambra State (Fig 1). It is the second most densely populated state in Nigeria after Lagos State; with an estimated 1,500 to 2,000 persons living within every square kilometre (National Bureau of Statistics, 2012). The city has an estimated population of 301,657 as of the 2006 Nigerian census, and over 2.5 million as of a 2018 estimate. Awka is located midway between two major cities in Igbo land: Onitsha and Enugu, and has linkages with other locations across southern Nigeria. The town is known for craft and blacksmithing long before the colonial times and like many other towns across south east Nigeria, is characterized by different manufacturing industries. It is known for business and commerce in different sectors and has linkages with the other two well-known big markets in the state at Onitsha and Nnewi.

Awka lies below 300 meters above sea in a valley on the plains of the Mamu River. The vegetation of Awka ranges from light rainforest to Savannah and the climate is typically wet and dry according to Koppen's classification system. The climate is characterized with wet and dry season; with an average temperature of 27^0C, relative humidity ranges of 85% to 100%, during the rainy season and less than 70% during the dry season. Awka experiences two distinct seasons brought about by the two predominant winds that characterize the area. The dryness of the climate tends to be discomforting during the hot period of February to May, while the wet period, between June and September is cold. The zone is characterized by the annual double maxima rainfall with a slight drop in either July or August known as dry spell (August break).

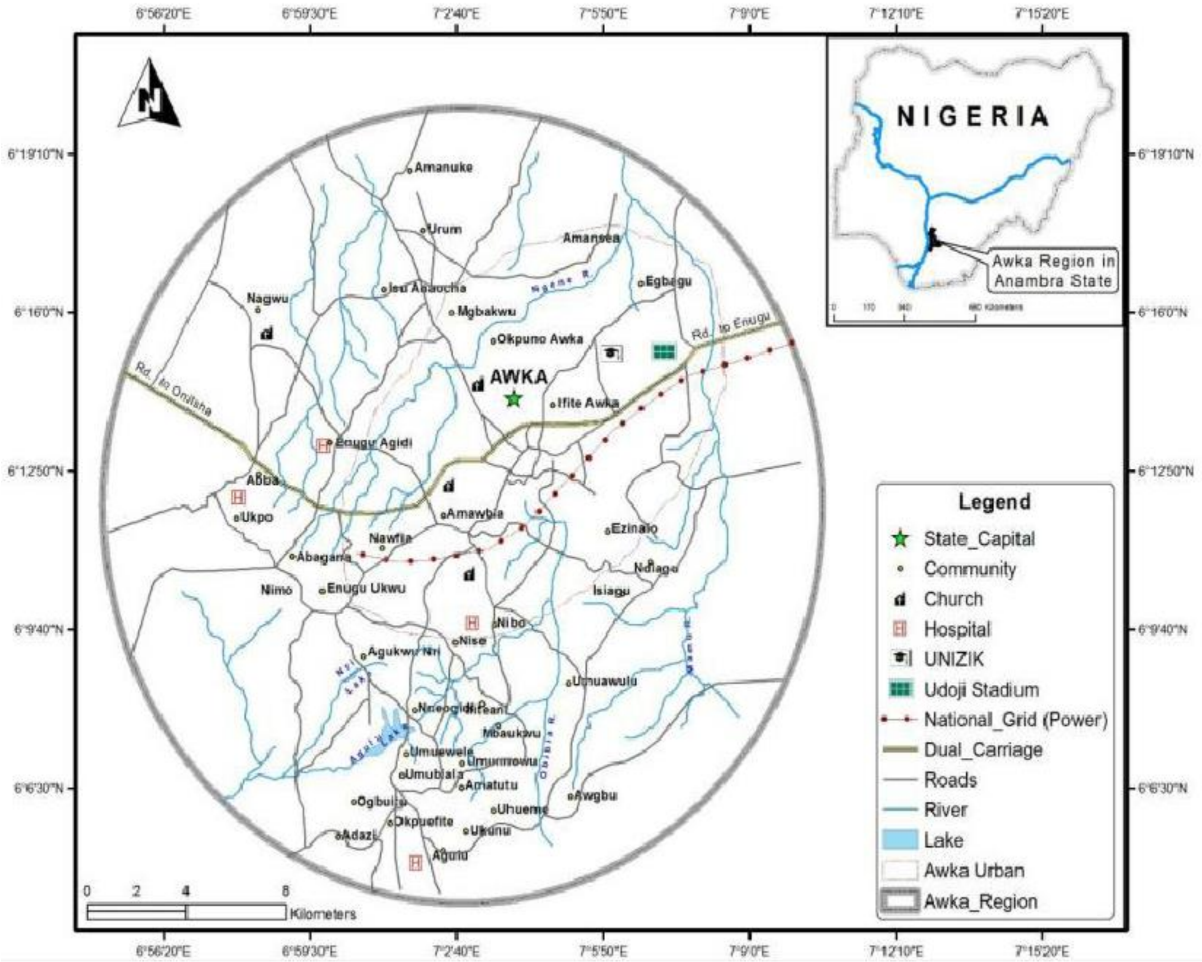

Fig 1 Map of Awka with map of Nigeria inset

Data Collection

To achieve the focus of the study, 7 different welding workshops were selected and used to detect and record in value the presence and quantity of air pollutants. Data on the predominant air pollutants and particulate matter in welding workshops were assessed. The air pollutant and pollution levels were measured using direct reading automatic in situ intelligent air quality monitor and portable gas sensor. The distance parameters were obtained through standard verification meter rule. Aeroqual gas detector was used for measurement of CO in ppm, while haze-dust particulate air monitoring equipment was used for measurement of particulate matter and other chemical compounds such as HCHO, TVOC. The particulate matter monitoring equipment is a continuous reading device in addition to being an automatic direct reading and in situ measuring meter. This device measures the ambient (Temperature, Humidity, Air Pollution Level and Status, Concentration of PM_{1}, $PM_{2.5}$, PM_{10}; CO; O_2; HCHO; TVOC in the atmosphere). The assessment of Formaldehyde (HCHO), Total Volatile Organic Compounds (TVOC), $PM_{1.0}$, $PM_{2.5}$, and PM_{10} was performed using a multifunctional air detector (Model: WP6910). To ensure consistency, data were all obtained from across the workshops between 12pm to 2pm each day for 12 days.

Pearson correlation was used to verify the association between air pollution level and the pollutants. Linear regression was used to ascertain the relationship and contribution of the other variables to air pollution level. Principal component analysis was used to summarize the variables according to the groups and verify which variables had significant loadings

Results

Notable pollutants within the welding environments include: Particulate Matter ($PM_{1.0}$, PM_{10}, and $PM_{2.5}$) µg/m^3. Chemical Compounds: HCHCO (Formaldehyde) mg/m^3, Total Volatile Organic Compound (TVOC) mg/m^3, Carbon Monoxide (CO) mg/m^3, Air pollution level (A.P.L).

Among the variables, $PM_{1.0}$ and CO were the variables that had significant correlations with APL.

Correlations

		$PM_{1.0}$	$PM_{2.5}$	PM_{10}	HCHCO	TVOC	APL	CO
PM 1.0	Pearson Correlation	1	.687*	.731**	.358	.367	.642*	.565
	Sig. (2-tailed)		.014	.007	.253	.241	.024	.055
	N	12	12	12	12	12	12	12
PM 2.5	Pearson Correlation	.687*	1	.739**	-.094	.048	.333	.319
	Sig. (2-tailed)	.014		.006	.770	.883	.291	.312
	N	12	12	12	12	12	12	12
PM 10	Pearson Correlation	.731**	.739**	1	-.332	-.128	.468	.417
	Sig. (2-tailed)	.007	.006		.292	.693	.125	.177
	N	12	12	12	12	12	12	12
HCHCO	Pearson Correlation	.358	-.094	-.332	1	.834**	.366	.206
	Sig. (2-tailed)	.253	.770	.292		.001	.242	.521
	N	12	12	12	12	12	12	12
TVOC	Pearson Correlation	.367	.048	-.128	.834**	1	.337	.078

	Sig. (2-tailed)	.241	.883	.693	.001		.283	.809
	N	12	12	12	12	12	12	12
APL	Pearson Correlation	.642*	.333	.468	.366	.337	1	.614*
	Sig. (2-tailed)	.024	.291	.125	.242	.283		.034
	N	12	12	12	12	12	12	12
CO	Pearson Correlation	.565	.319	.417	.206	.078	.614*	1
	Sig. (2-tailed)	.055	.312	.177	.521	.809	.034	
	N	12	12	12	12	12	12	12

*. Correlation is significant at the 0.05 level (2-tailed).

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

Regression to establish relationship between air pollution level and the pollutants an R value of .835, which implied that there was a good correlation between air pollution level and other pollutants. R2 value of 69.7% total variation in the dependent variable could only be explained by the independent variables.

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.835[a]	.697	.333	5.69570843

a. Predictors: (Constant), CO, TVOC, $PM_{2.5}$, PM_{10}, $PM_{1.0}$, HCHCO

Though 69.7% contribution explanation is given (which is quite ample), the regression model could not predict the dependent variable significantly. With $p = 0.246$, it meant that though the predictors contributed to the air pollution levels, none of them significantly contributed to that. This is furthermore buttressed by the presentation of the coefficients which could not show significance for any of the predictors (as none of the predictors had a significant value < 0.05).

ANOVA[a]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	372.612	6	62.102	1.914	.246[b]
	Residual	162.205	5	32.441		
	Total	534.818	11			

a. Dependent Variable: APL

b. Predictors: (Constant), CO, TVOC, $PM_{2.5}$, PM_{10}, $PM_{1.0}$, HCHCO

Coefficients[a]

Model	Unstandardized Coefficients	Standardized Coefficients	t	Sig.	95.0% Confidence Interval for B

		B	Std. Error	Beta			Lower Bound	Upper Bound
1	(Constant)	3.940	23.270		.169	.872	-55.878	63.759
	$PM_{1.0}$	-.432	.361	-1.588	-1.198	.285	-1.360	.495
	$PM_{2.5}$	-.005	.061	-.033	-.081	.939	-.161	.151
	PM_{10}	.519	.318	2.154	1.632	.164	-.298	1.336
	HCHCO	295.138	197.778	2.014	1.492	.196	-213.267	803.543
	TVOC	-62.316	78.256	-.503	-.796	.462	-263.481	138.848
	CO	.802	1.052	.248	.762	.481	-1.904	3.507

a. Dependent Variable: APL

Principal component analysis (PCA) conducted used Varimax with Kaiser Normalization and recorded 7 components. The components had high % of variance and recorded 77.268 cumulative %.

PCA Total Variance Explained

Component	Initial Eigenvalues			Extraction Sums of Squared Loadings			Rotation Sums of Squared Loadings		
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	3.339	47.705	47.705	3.339	47.705	47.705	3.199	45.706	45.706
2	2.069	29.562	77.268	2.069	29.562	77.268	2.209	31.562	77.268
3	.811	11.582	88.850						
4	.379	5.413	94.263						
5	.222	3.174	97.437						
6	.171	2.449	99.886						
7	.008	.114	100.000						

Extraction Method: Principal Component Analysis.

Results from the Rotated component matrix showed the two components that significantly defined the air pollution in the workshops. Component 1 showed the $PM_{1.0}$, $PM_{2.5}$ and PM_{10} with significant values as seen below, while component 2 showed the chemical component with HCHCO, TVOC, as its major features.

Rotated Component Matrix

	Component	
	1	2
$PM_{1.0}$	.888	.314
$PM_{2.5}$	.810	-.152
PM_{10}	.896	-.321

HCHCO	.010	.974
TVOC	.086	.899
APL	.699	.425
CO	.676	.214

Rotation Method: Varimax with Kaiser Normalization.

Discussion

Welding activities contributes to air pollution through their different workshop outlets. Pollutants from such workshops are much varied, and the major ones detected were mainly particulate matter ($PM_{1.0}$, $PM_{2.5}$, PM_{10}) and HCHCO (formaldehyde), TVC (Total Volatile Organic Compounds) and CO (Carbon Monoxide). These were found in different concentrations and were seen to contribute to the air pollution levels differently. None of the pollutants recorded a significant contribution to the air pollution level; but individually contributed to the pollution levels. Among the particulate matter, $PM_{1.0}$ and CO were found to be much correlated with the air pollution levels. PM has different ranges and is sub-classified according to particle size into (a) coarse (PM_{10}, diameter <10μm), (b) fine ($PM_{2.5}$, diameter <2.5μm), and (c) ultrafine ($PM_{0.1}$, diameter <0.1μm) (Hamanaka and Mutlu, 2018). Irrespective of the different sizes, the PMs have been accounted to present different proportions of threat to health; particularly the cardiovascular system (Brook et al. 2010; Chin, 2015). CO on the other hand is a product of incomplete combustion of carbonaceous fuel during welding. While this is so, significant amounts are often produced during some welding operations and could accumulate more in poorly ventilated spaces (Ojima, 2013). Since many of the welders do not have controlled laboratory conditions, estimating the ventilation requirements for the prevention of CO poisoning are not easily achievable (Ojima, 2013). With such scenarios being common in the study area, CO is not only seen to contribute to the air pollution levels, but puts the health of the welders (who mostly have direct contacts with it) and others at risk.

Other pollutants notably HCHCO (Formaldehyde) and Total Volatile Organic Compound (TVOC) have similar impacts on the health and well-being of people both on short-term and long-term basis. Exposures to welding fumes are associated with welding activities, but could be moderated when personal protective equipment, training, suitability of workshop/environment and necessary precautions are followed. While these seems to be common knowledge among the welders, it is however not being observed by majority of welders. Occupational health and safety were observed to be below standard among the welders in the area and for most of them, their workshops are makeshift constructions that lack the required standard as well as the equipment. With the study area being located in a tropical high temperature zone, the workshops easily heat up during welding and both debilitates the work output and increasingly makes the workers to be more susceptible to risks associated with welding.

Strategies targeted at promoting better welding practice and reducing the risks associated with it is much needed. Exposures to the pollution and risks associated with welding activities have remained across much of developing regions due to weak regulations and standards. Across the study region, the whole process of welding starting from apprenticeships to mastery and the whole chain of welding activities are known to be characterized by lack of regulations and moderations by government or requisite firms. As a result, the industry is mostly characterized by a lack of innovation, use of same (old) methods and citing of workshop to anywhere convenient for the operators. Though a good number of welders are reported to be aware of safety and precautionary measures in some parts of Nigeria (Isah and Okojie, 2006; Sabitu et al. 2009), they use (old and) basic protective equipment instead of more efficient/modern equipment and approaches. On the other hand, it is pertinent to also give attention to the safety of individuals (alongside the welders) that share the environment welders and are prone to similar risks they encounter. As environmental exposure to welding hazards are known to be as harmful as the occupational exposure for people that share neighbourhoods with some welders (Cury et al. 2017), regulations as to where the welding workshops would be cited is hence a thing of concern. Much of the workshops in the study area were cited in open spaces, and in makeshift iron/aluminium containers (used as workshops) that are pitched in available spaces. Other welders cited their workshops in portions of land that belonged to them and not necessarily ideal locations that enhanced environmental safety. Such display of weak or no regulation is quite common across many urban and peri-urban centres in south east Nigeria and requires government interventions and regulations. The concept of establishing standard welding workshops is just beginning to evolve especially within institutions, but needs to be adopted as standard practice across the region. Such initiatives would help to promote environmental safety and help in achieving the desirable standards and best practices in welding.

Conclusion

The study identified some pollutants within the welding space: particulate matter ($PM_{1.0}$, $PM_{2.5}$, PM_{10}) and HCHCO (formaldehyde), TVC (Total Volatile Organic Compounds) and CO (Carbon Monoxide). These were found to contribute differently to the total air pollution levels; with $PM_{1.0}$ and CO correlating most with the air pollution levels. Risks and hazards associated with welding were elucidated, as well as the needed precautions. Enforcing environmental standards and regulations were deemed necessary and were advocated.

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