Assessment of hydrogen sulfide emission levels on the floors of some selected bakeries in southwestern Nigeria

O A Odunlami\textsuperscript{1*}, O G Abatan\textsuperscript{1}, A A Busari\textsuperscript{2}, G T Alao\textsuperscript{3}, F B Elehinafe\textsuperscript{1}, C O Emekwue\textsuperscript{1}

\textsuperscript{1}Department of Chemical Engineering, Covenant University, Ota, Ogun state, Nigeria
\textsuperscript{2}Department of Civil Engineering, Covenant University, Ota, Ogun state, Nigeria
\textsuperscript{3}Department of Mathematics, Covenant University, Ota, Ogun state, Nigeria
*Corresponding Author E-mail olayemi.odunlami@covenantuniversity.edu.ng

Abstract. The hydrogen sulfide (H\textsubscript{2}S) emission and oxygen (O\textsubscript{2}) level was measured within four bakeries in Ota, Ogun State. This was done to know the effect of H\textsubscript{2}S on the people working in bakeries and those walking into bakeries for business purposes. The data obtained was analyzed and the H\textsubscript{2}S emission level was around the new recommendation for airborne of 1 ppm recommended for 8 hours by ACGIH (American Conference Governmental Industrial Hygenist [1]. The highest mean concentrations of H\textsubscript{2}S were: bakery 1 (0.4 ppm), bakery 2 (0.73 ppm), bakery 3 (1.0 ppm), H\textsubscript{2}S emission was not detected by the gas analyzer in bakery 4. O\textsubscript{2} level (20.8 ppm) remained constant all through the study, which is the expected ambient O\textsubscript{2} value, this is because of the cross ventilation within the bakeries. Though literatures have shown that ovens emit some harmful gases like CO, NO\textsubscript{x}, VOC and H\textsubscript{2}S, the concentrations of these gases can be reduced if there is cross ventilation within the bakery and exhaust stacks positioned high enough towards the roof, out of the building. The stack effect happens, when warm air moves or flow upwards in the building. The warm air rises because it is lighter than cold air, when it rises, it escapes out of the upper levels of the building through ventilation openings, windows or leakages. The rising warm air reduces the pressure at the base of the building, forcing cold air to infiltrate through either open doors, windows, or other openings and leakage in lower levels of the building. The H\textsubscript{2}S emission level was higher during the heating periods than the baking periods in all the bakeries considered due to the combustion process taking place during heating. The electrically fired ovens gave lower H\textsubscript{2}S concentrations than the wood fired ovens. To ensure safety for workers and consumers in Bakeries, regular inspection of bakeries should become a priority for the various agencies involved.

Keywords: Air emissions; hydrogen sulfide; Bakeries; ventilation

1. Introduction
The demand of bakery products has increased in Nigeria over the years and this has made the setting up and operation of bakeries in Nigeria a popular business. However, some of these bakeries are not properly built and do not operate on modern designs and equipment which has increased the level of air pollution in the country. While outdoor emissions are researched on regular basis [2], indoor emissions have barely been looked into. A total of four bakeries where the baking of yeast leavened bread is done were assessed in Ota, Ogun State.

Hydrogen sulfide, a colorless gas has an offensive odor at low concentrations. The gas is toxic to humans and animals, and corrosive to many metals at high concentrations [3]. It tarnishes silver and react with heavy metals in paints to discolor the paint. It causes headache, conjunctivitis, sleeplessness, pain in the eyes, and similar symptoms in humans at low air concentrations and death at high air concentrations [4]. However, if the victim is
moved quickly to uncontaminated air and respiration initiated before heart action stops, rapid recovery can be expected [5]. Generally, hydrogen sulfide acts as a cell and enzyme poison, it can also cause irreversible changes in the nerve tissue [6]. Air pollution by hydrogen sulfide is commonly found in the vicinity of an emitter like kraft paper mills, industrial waste disposal ponds, sewage plants, refineries and coke oven plants [7].

Wood is a polymer of celluloses, polyoses and lignin with several minerals and concentrates depending on the wood species [8,9]. The heat energy from firewood (beech, oak, birch) is around 17–19 MJ kg. Subject to how the oven is run, set up and sustained, and the firewood itself, a widespread array of other combustion products are let off in addition to carbon dioxide and carbon monoxide [10, 11]. These principally consist of the normal combustion products cellulose [12], aldehyde [13] and particulate matter [14].

It has been known that fire sources in rooms can increase the level of indoor air contamination. In addition, a heat source may impact the air circulation in a room [15]. Previous work done have reported the impacts of sources, for example, gas burners [16], candles, incense sticks [17], kerosene ovens [18], pizza stoves [19] as well as open chimneys in homes [20]. Recently, Noonan and his associates have given specific consideration to the formation of particulate matter (PM2.5) in indoor air while operating wood-consuming oven [21].

This report looks into ovens in bakeries as potential sources of the predicted emissions of hydrogen sulfide. Series of tests were carried out in various sampling points of the chosen bakeries. The Hydrogen sulfide emissions measured from the Bakeries was compared with the H2S standard by ACGIH (American Conference Governmental Industrial Hygienist) [22]. The level of oxygen across the sampling points was also monitored.

2. Experimental area

2.1 Study area

The study area is Ota, Ogun state (figure 1). It is found in the southwestern region of Nigeria. It covers an approximate area of 1.46km2 (square kilometers) and runs an approximate distance of 5.08km (Google Maps, 2019). Ota is a town in Ogun State, Nigeria, and has an estimated 163,783 residents living in or around it. Ota is in Ado-Odo/Ota Local Government Area.

![Figure 1: A map of the study area [23]](image)

2.2 Materials and methods

2.2.1 Sampling points: The ALTAIR XCELL 5X Multi-gas sensor was used to measure the H2S emission concentrations and O2 level from the selected four bakeries in Ota. Four sampling points in each of the bakeries were identified based on the working sections of the bakeries. The identified
Sampling points were denoted by A, B, C and D while the bakeries were named 1, 2, 3 and 4. The hydrogen sulfide emission and oxygen level measurements were taken for one hour at 2 min intervals when the ovens were heated and during baking. The gas detector was switched on and allowed to initialize, for all internal systems to be ready. An external probe was connected to the gas detector and was placed close to the heating unit of the oven and around the baking point, then the readings were taken.

2.3 Equipment
The MSA Altair 5X Multi gas detector can monitor up to 6 gases at once and has a variety of optional MSA infrared sensors. The detector features large glove-friendly buttons, high performance cell sensors and long-lasting grip for easy operation. In potentially dangerous locations, unique features such as motion alert and instant alert provide a sense of control. The Altair 5X Multi gas detector offers matchless flexibility and versatility to meet the various needs of many of its users. The technologically advanced unit also features a bump test of less than 15 seconds, a span calibration time of 60 seconds, a run time of 20 hours, and a lengthy lifespan.

2.4 Measurement strategy
The gas analysis was carried out during the working hours of the bakery. The test samples were taken during the heating and the baking periods. The heating period was 3-5 hours while the baking period is 4 hours. To determine the concentrations of the pollutants, the MSA Altair 5X multi gas detector was employed at each of the sampling points. Measurements were taking at 2 min intervals for an hour. The measurements were taken for both the heating and baking periods.

3. Result and discussion
The results of this study are discussed here; the mean concentrations of hydrogen sulfide in the identified sampling points of the various bakeries for the two periods which include the heating period of the oven and baking period.

3.1 The identified sampling points within the four selected bakeries
The sampling points are:
1. Sampling point A: This is where the burner is situated. Workers occasionally go there to sustain the fire and heat that is being generated. Combustion takes place at this point. It is the source of the emission.
2. Sampling point B: This is the mixing zone where the pastry dough is prepared and mixed. It is situated not too far from the oven. Doughs are mixed by the workers at this point.
3. Sampling point C: This is the packing area. Finished products (bread) are allowed to cool, packaged and sealed by workers here.
4. Sampling point D: The finished products are brought here by the workers to be stored.

The bakeries include:
Bakery 1: Standard building for a bakery, which has one wood fired with its exhaust stacks positioned high enough towards the roof, out of the building.
Bakery 2: A residential apartment converted to a bakery, with its exhaust stacks positioned high enough towards the roof, out of the building. It has one wood fired oven.
Bakery 3: A residential apartment converted to a bakery, with its exhaust stacks positioned high enough towards the roof, out of the building. It has one wood fired oven.
Bakery 4: Standard building for a bakery, which it has 3 ovens powered with diesel engine and electricity. It has its exhaust stacks positioned high enough towards the roof, out of the building.
3.2 The mean concentrations of hydrogen sulfide emissions in the identified sampling points from the selected bakeries

Tables 1-4 show the mean concentrations of H$_2$S and the O$_2$ level at the sampling points in all the bakeries during the heating periods, while tables 5-8 show the mean concentrations of H$_2$S and O$_2$ level at the sampling points in all the bakeries during the baking periods.

**Table 1:** Mean concentrations of H$_2$S and O$_2$ level in the identified sampling points during the heating periods of the oven in bakery 1 (Standard bakery).

| Sampling Points | H$_2$S (ppm) | O$_2$ (ppm) | Distance from source (m) |
|-----------------|--------------|-------------|-------------------------|
| A               | 0.4          | 20.8        | 0.36                    |
| B               | 0            | 20.8        | 0.89                    |
| C               | 0            | 20.8        | 3.41                    |
| D               | 0            | 20.8        | 7.93                    |

**Table 2:** Mean concentrations of H$_2$S and O$_2$ level in the identified sampling points during the heating period of the oven in bakery 2 (Converted building).

| Sampling Points | H$_2$S (ppm) | O$_2$ (ppm) | Distance from source (m) |
|-----------------|--------------|-------------|-------------------------|
| A               | 0.73         | 20.8        | 0.33                    |
| B               | 0            | 20.8        | 0.92                    |
| C               | 0.37         | 20.8        | 0.51                    |
| D               | 0            | 20.8        | 8.93                    |

**Table 3:** Mean concentrations of H$_2$S and O$_2$ level in the identified sampling points during the heating periods of the oven in bakery 3 (Converted building).

| Sampling Points | H$_2$S (ppm) | O$_2$ (ppm) | Distance from source (m) |
|-----------------|--------------|-------------|-------------------------|
| A               | 1.0          | 20.8        | 0.36                    |
| B               | 0            | 20.8        | 0.79                    |
| C               | 0.5          | 20.8        | 5.33                    |
| D               | 0            | 20.8        | 10.1                    |

**Table 4:** Mean concentrations of H$_2$S and O$_2$ level in the identified sampling points during the heating periods of the oven in bakery 4 (Standard bakery).

| Sampling Points | H$_2$S (ppm) | O$_2$ (ppm) | Distance from source (m) |
|-----------------|--------------|-------------|-------------------------|
| A               | 0            | 20.8        | 0.97                    |
| B               | 0            | 20.8        | 2.46                    |
| C               | 0            | 20.8        | 5.32                    |
| D               | 0            | 20.8        | 9.65                    |
### Table 5: Mean concentrations of H$_2$S and O$_2$ level in the identified sampling points during the baking periods of the oven in bakery 1 (Standard bakery).

| Sampling Points | H$_2$S (ppm) | O$_2$ (ppm) | Distance from source (m) |
|-----------------|--------------|-------------|-------------------------|
| A               | 0            | 20.8        | 0.36                    |
| B               | 0            | 20.8        | 0.89                    |
| C               | 0            | 20.8        | 3.41                    |
| D               | 0            | 20.8        | 7.93                    |

### Table 6: Mean concentrations of H$_2$S and O$_2$ level in the identified sampling points during the baking period of the oven in bakery 2 (Converted building).

| Sampling Points | H$_2$S (ppm) | O$_2$ (ppm) | Distance from source (m) |
|-----------------|--------------|-------------|-------------------------|
| A               | 0            | 20.8        | 0.33                    |
| B               | 0            | 20.8        | 0.92                    |
| C               | 0            | 20.8        | 0.51                    |
| D               | 0            | 20.8        | 8.93                    |

### Table 7: Mean concentrations of H$_2$S and O$_2$ level in the identified sampling points during the baking period of the oven in bakery 3 (Converted building).

| Sampling Points | H$_2$S (ppm) | O$_2$ (ppm) | Distance from source (m) |
|-----------------|--------------|-------------|-------------------------|
| A               | 0            | 20.8        | 0.36                    |
| B               | 0            | 20.8        | 0.79                    |
| C               | 0            | 20.8        | 5.33                    |
| D               | 0            | 20.8        | 10.1                    |

### Table 8: Mean concentrations of H$_2$S and O$_2$ level in the identified sampling points during the baking period of the oven in bakery 4 (Standard bakery).

| Sampling Points | H$_2$S (ppm) | O$_2$ (ppm) | Distance from source (m) |
|-----------------|--------------|-------------|-------------------------|
| A               | 0            | 20.8        | 0.97                    |
| B               | 0            | 20.8        | 2.46                    |
| C               | 0            | 20.8        | 5.32                    |
| D               | 0            | 20.8        | 9.65                    |

#### 3.3 Discussion of results

Ovens are generally designed in way that its fire chamber is sealed off from the working place so as not to affect the indoor ambient air, but in some cases they are not properly designed and the chambers are not sealed airtight because of feeding of wood into the chambers and this allows potential emissions into the indoor air. Four bakeries were monitored and are discussed below.

Table 1 shows the mean concentrations of H$_2$S and O$_2$ level at the four sampling points in bakery 1 during the heating period. H$_2$S emission was only detected by the gas analyzer at sampling point A (0-1) ppm in this bakery. The H$_2$S mean concentration for the sampling point A was (0.4) ppm. The O$_2$ level was constant and normal at (20.8) ppm (the expected ambient O$_2$ value) which indicates a good
ventilation. The American Conference of Governmental Industrial Hygienists (ACGIH), a recognized body for standards kept the limit of H$_2$S at 1 ppm for an eight-hour time weighted average (TWA), therefore all the sampling points were well within this limit.

Table 2 shows the mean concentrations of H$_2$S and O$_2$ level at the four sampling points in bakery 2 during the heating period. H$_2$S emission was not detected by the gas analyzer at any of the sampling points in this bakery. The O$_2$ level was constant and normal at (20.8) ppm indicating a good ventilation.

Table 3 shows the mean concentrations of H$_2$S and O$_2$ level at the four sampling points in bakery 3 during the heating period. The ranges for H$_2$S concentration in the sampling points are; point A (0-3) ppm, point C (0-1) ppm. There was no H$_2$S emission detected at sampling points B and D by the gas analyzer. The H$_2$S mean concentration in the sampling point A is (1.0) ppm and (0.5) ppm in sampling point C. The O$_2$ level was constant and normal at (20.8) ppm indicating a good ventilation. H$_2$S emission levels were within the ACGIH standards which is 1 ppm for an eight-hour time weighted average (TWA).

Table 4 shows the mean concentrations of H$_2$S and O$_2$ level at the four sampling points in bakery 4 during the heating period. H$_2$S emission was not detected by the gas analyzer at any section in the bakery. The O$_2$ level was constant and normal (20.8) ppm at all the sampling points all through the monitoring process. Bakery 4 ovens operate on both electricity and diesel which gives little or no H$_2$S emission when compared with the commonly used wood fired ovens. Bakery 4 is biggest of the bakeries. It is well structured for baking and well ventilated with highly built exhaust stacks.

Table 5 shows the mean concentrations of H$_2$S and O$_2$ level at the four sampling points in bakery 1 during the baking period. H$_2$S was not detected by the gas analyzer at any sampling points in this bakery. The O$_2$ level was constant and normal (20.8) ppm at all sampling points indicating a good ventilation.

Table 6 shows the mean concentrations of H$_2$S and O$_2$ level at the four sampling points in bakery 2 during the baking period. H$_2$S was not detected by the gas analyzer at any sampling points in this bakery. The O$_2$ level was constant and normal (20.8) ppm indicating a good ventilation. The level of H$_2$S emissions within the sampling points was lower than the ACGIH standards for H$_2$S.

Table 7 shows the mean concentration of H$_2$S and O$_2$ level at the four sampling points in bakery 3 during the baking period. H$_2$S was not detected by the gas analyzer at any section in this bakery. The O$_2$ level was constant and normal (20.8) ppm because the bakery was well ventilated. The structures and operations of bakeries 2 and 3 are similar.

Table 8 shows the mean concentrations of H$_2$S and O$_2$ level at the four sampling points in bakery 4 during the baking period. H$_2$S was not detected by the gas analyzer at any of the sampling points in bakery 4 during the baking period. This implies that the H$_2$S emission was insignificant. The O$_2$ level was constant and normal (20.8 ppm) at all the sampling points.

4. Conclusion
It was concluded at the end of this study that;
• The indoor level of H$_2$S in well ventilated bakeries is relatively low.
• The construction of the fire chamber, the type of wood used and the height of the exhaust stacks play important roles in the level of emission within the bakeries.
• The mean concentrations of H$_2$S during the baking periods were relatively small when compared to the ACGIH standards.
• The mean concentrations H$_2$S at the sampling points during the heating periods did not exceed the ACGIH standards when compared.

Acknowledgement
The authors wish to acknowledge the financial support offered by Covenant University in actualization of this research work for publication.
References

[1] Threshold Limit Values for 2010-Recommended and Intended Values, of the American Conference of Governmental Industrial Hygienists, Chicago, Illinois 2010

[2] Odunlami O, Elehinafe F, Oladimeji T, Fajobi M, Okedere O and Fakinle B 2018 Implications of lack of maintenance of motorcycles on ambient air quality in IOP Conference Series: Materials Science and Engineering 1 (413) 012-055 IOP Publishing

[3] Fajobi M, Fayomi O, Akande I and Odunlami O 2019 Inhibitive Performance of Ibuprofen Drug on Mild Steel in 0.5 M of H₂SO₄ Acid Journal of Bio-and Tribo-Corrosion 5 (3) 79

[4] Permissible Emission Concentration of Hydrogen Sulfide Sub-committee on Effects of Hydrogen Sulfide of the Committee on Effects of Dust and Gas of the Verein Deutscher Ingenieur Committee on Air Purification 1960 VDI 2107

[5] Patty F, 1963 Industrial hygiene and toxicology 615 (902) 322

[6] Caponecchia C 2010 It won’t happen to me: An investigation of optimism bias in occupational health and safety Journal of Applied Social Psychology, 40 (3) 601-617

[7] Hallery P 1967 Hazards of Hydrogen Sulfide Med. Bull. 27 (3) 219

[8] Fengel D, and Wegener G 1989 wood berlin: Walter de Gruyter.

[9] Glytsos T, Ondráček J, Dzumbová L, Kopanakis I, and Lazaridis M 2010 Characterization of particulate matter concentrations during controlled indoor activities Atmos. Environ. 44, 1539-1549

[10] McDonald J, Zielinska B, Fujita E, Sagebiel J, Chow J and Watson J 2000 Fine particle and gaseous emission rates from residential wood combustion. Environmental Science and Technology 34 (11) 2080-2091

[11] Schauer J, Kleeman M, Cass G, and Simoneit B 2001 Measurement of emissions from air pollution sources. 3. C₁− C₂₉ organic compounds from fireplace combustion of wood. Environmental science & technology, 35 (9) 1716-1728

[12] Shen D, and Gu S 2009 The mechanism for thermal decomposition of cellulose and its main products. Bioresource technology, 100 (24) 6496-6504

[13] Cerqueira M, Gomes L, Tarelho Ł, and Pio C 2013 Formaldehyde and acetaldehyde emissions from residential wood combustion in Portugal, 171-176

[14] Hedberg E, Kristensson A, Ohlsson M, Johansson C, Johansson P, Swietlicki E and Westerholm R 2002 Chemical and physical characterization of emissions from birch wood combustion in a wood stove Atmospheric Environment 36 (30) 4823-4837

[15] Ardkapan S, Nielsen P, and Afshari A 2014 Studying passive ultrafine particle dispersion in a room with a heat source Building Environment 71 1–6

[16] Wallace L, Wang F, Howard-Reed C, and Persily A 2008 Contribution of gas and electric stoves to residential ultrafine particle concentrations between 2 and 64 nm: size distributions and emission and coagulation rates. Environmental Science and Technology, 42 (23) 8641-8647

[17] Wang B, Lee S, Ho K and Kang Y, 2007 Characteristics of emissions of air pollutants from burning of incense in temples, Hong Kong. Science of the total environment 377 (1) 52-60.

[18] Carteret M, Pauwels J, and Hanoune B 2012 Emission factors of gaseous pollutants from recent kerosene space heaters and fuels available in France in 2010 Indoor air 22 299-308

[19] Buonanno G, Morawska L, Stabile L, and Viola A 2010 Exposure to particle number surface area and PM concentrations in pizzerias Atmos. Environ 44 3963-3969

[20] Lahiri T, and Ray M 2010 Effects of indoor air pollution from biomass fuel use on women’s health in India Health and Environmental Impacts 135

[21] Ward T, Palmer C, Bergauff M, Hooper K, and Noonan C 2008 Results of a residential indoor PM2. 5 sampling program before and after a woodstove changeout. Indoor air 18 (5) 408-415

[22] Threshold Limit Values for 2010-Recommended and Intended Values, of the American Conference of Governmental Industrial Hygienists, Chicago, Illinois 2010

[23] Google Maps, 2019