Analysis of odor nuisance emitted by Naivasha abattoir, Kenya

Philip Kiama Mbugua[1]

[1*]philip.kiama@gmail.com

[1]PhD in Environmental Planning and Management, Kenyatta University, Kenya

https://doi.org/10.51867/scimundi.5.2.10

ABSTRACT

Numerous unfit for human consumption animal byproducts are produced as a result of the ever-increasing demand for livestock production for food. As a result, the number of rendering plants that help turn animal waste into fat and protein flour is on the rise. Odors emitted from rendering processes can significantly impact air quality, causing nuisance for humans, especially when the plant is close to residential areas. The concentration of odor emission from thermal rendering operations, as determined by dynamic olfactometry, and the removal efficiency of the plant's three-stage water scrubber are the primary topics of this study. Due to their high odorant concentrations, three of the six process air stream emitters studied contributed the most to the odor. The elimination of odor nuisance by a 3-stage water scrubber revealed a removal efficiency of < 94%. This result suggested synergy between olfactory and sensorial methods of odour assessment and must be used to achieve satisfactory results.

Keywords: Nuisance, Odor Concentration, Olfactometry, Oxidation

I. INTRODUCTION

Odours emitted from abattoir are generated directly from animals, bedding and faeces (Carey et al., 2004). They are not constituted by a single compound, but rather by a complex mixture of hundreds of diluted volatile substances, which makes their identification, quantification, and abatement difficult. Indeed, the foul emissions from livestock frequently create disputes between farmers, abattoirs and their communities (National Emergency Management Agency (NEMA), 2015), owing to the offensive odor, which leads to a decrease in the local property values (Guillot, 2012). Furthermore, these smells have raised worries about the health and welfare of both animals and individuals working in or residing nearby these establishments (Van Broeck *et al*., 2021). Unpleasant livestock odors might trigger emotional tension, frustration, and physical ailments in the populations living near the abattoir (Government of Kenya, 2015). Hence, it is crucial to have dependable analytical methods for analyzing odors to establish effective abatement technologies and mitigation strategies, aimed at achieving greater environmental sustainability in meat production. Additionally, the sampling phase is pivotal and should be executed meticulously to obtain representative samples, thereby preventing erroneous conclusions and results in subsequent analyses (Wagner & Refslund, 2016). Furthermore, it should be noted that the composition and concentration of odors are influenced by various factors, including temperature, ventilation rate, relative humidity, age of the animal, season, dietary composition, litter type, and animal stocking density (Pan & Yang, 2007), which complicates odor evaluation considerably.

Exposure to low levels of this chemical can irritate the eyes, cause a cough or sore throat, shortness of breath, and fluid accumulation in the lungs. Prolonged low-level exposure may cause fatigue, pneumonia, loss of appetite, headaches, irritability, poor memory, and dizziness. Some odours may cause strong physical reactions like nausea and vomiting without being present at toxicologically significant concentrations (Victor & Barbard, 2016). A case in point is the odour associated with protein hydrolysis and the putrefaction of animal tissue. Two extremely odorous compounds, putrecine (1, 4-diaminobutane) and cadaverine (1,5-pentanediamine), are involved, the odour of which will make most people vomit; however, their toxicological significance is limited (Nicell, 2009).

Odour emissions are a complex mixture of volatile chemicals and therefore cannot be completely assessed by a stand-alone odour monitoring technique (Ubeda *et al*., 2013). The goal of the analysis is to obtain a qualitative odour assessment by scoring air samples based on their odour intensity and unpleasantness and by supplying an odour description. This study investigated the synergy between olfactometry and sensorial analysis by combining the olfactometry and sensorial method.

1.1 Research Objective

The main objective of this study was to investigate the synergy between olfactometry and sensorial analysis by combining the olfactometry and sensorial method.

II. METHODOLOGY

2.1 Research Design and Approach

The research adopted a descriptive survey research design. Descriptive research involves collecting data on a particular subject in order to determine 'what' rather than 'why' without manipulating or influencing it in any way. This research design allowed the researcher to observe and measure statistics to assess the relationship between and among variables without manipulation of the independent variables (correlational research).

2.2 Study area location

The abattoir facility is located in Naivasha East Ward, Naivasha Sub-County It is located at latitude 36^0 22'E in Nakuru District at an altitude of 1885m above sea level. The study population 2573 according to the 2019 census (KNBS, 2019). It has two distinct climatic seasons: dry and wet seasons. Although variation may occur, dry season runs from November to February, while wet season spans March to October. The choice of Naivasha was based on outcry from the residents of Naivasha town. The choice of the abattoir was based on its size and location. The abattoir is amongst the biggest in Nakuru County and slaughtering average of more than fifty animals on daily basis. The mode of operation involves slaughtering, separation meat products for consumption and dumping the wastes into pits and sometimes burning the wastes (smoke pollution) and subsequently discharge the effluents into a nearby flowing river. Apart from the average of four hundred people that patronize the abattoir on daily basis, several restaurants and food joints depend on the abattoir for meat supply.

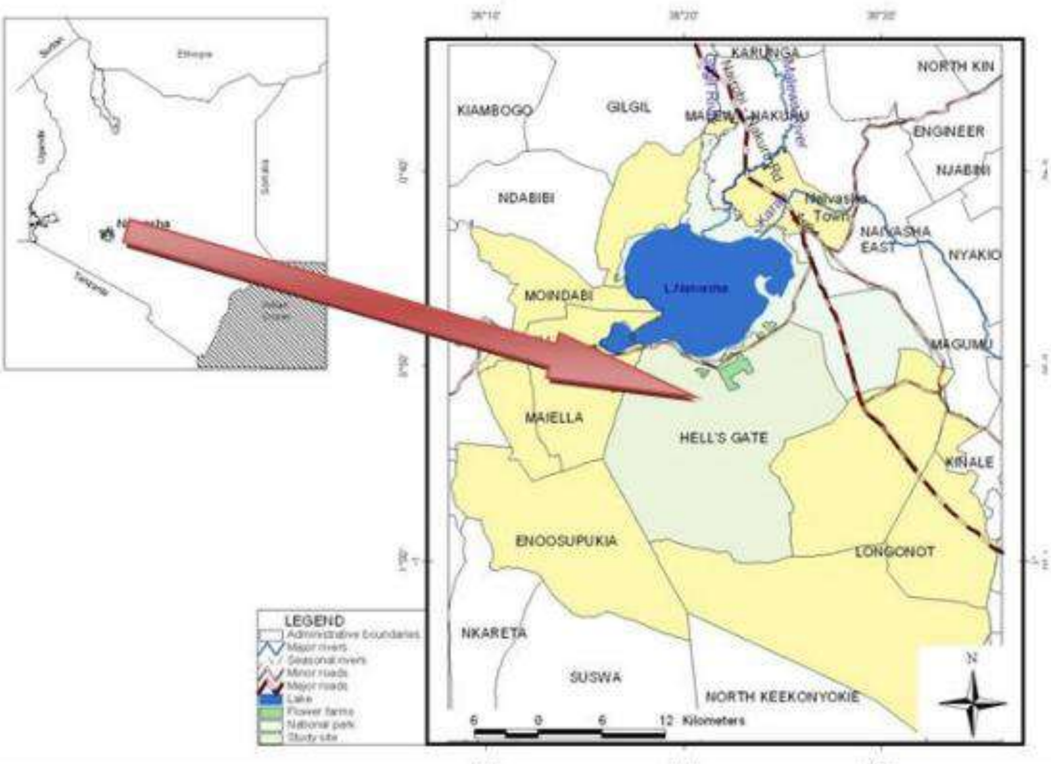

Figure 1: *Map of the Study Area*

2.3 Sampling Procedure

The experiment was setup at the slaughterhouse facility in Naivasha, Nakuru County. To treat odorous air emissions, the facility was to have two reduction techniques: (I) thermal oxidation with prior scrubbing to treat non-condensable air emissions and (II) biofiltration with prior water scrubbing to treat air emissions from the unclean unloading hall. The experiments in regard to the biofiltration technique were executed at two different moments to allow for a more deteriorated state of the biofilter material and hence a loss in efficiency reduction (i.e. insufficiently performing biofilter) (Luwumba *et al.* 2019). For the thermal oxidation technique, the experiment was executed at the same day, but once under optimal temperatures of combustion (850 °C – i.e. well performing thermal oxidation) and once under sub-optimal temperatures of combustion (600 °C – i.e. insufficiently performing thermal oxidation).

2.4 Data Collection

Air sampling focused mainly on SO_2, NO_2, PM_{10}, PM_1 and CO since these pollutants constitute large portion of emission from abattoir. Other pollutants measured include VOC, H_2S and NH_3. For comparative analysis, three air sampling locations will be chosen: The upstream (point A), the discharge station (point B) and the downstream (point C). The discharge location is the point where the animal is being processed. Upstream and downstream are 100 m before and after discharge point respectively. At the point of sampling, the devices (Aerosol Mass Monitor and Aeroqual series gas monitors) were turned on to measure the concentrations of both particulate matter and gaseous pollutants respectively.

2.5 Data Analysis

All the measurements will be done simultaneously at the three sampling points both on wet and dry days in order to assess the impact of humidity on the pollutant concentration levels. The data obtained will be statistically analyzed and mean values will be compared with standards and guideline as well as air quality index. The analysis was based on the following components;

2.5.1 Olfactometric Analysis

The analysis is carried out in accordance with the European standard EN 13725: 'Determination of odour concentration by dynamic olfactometry' (CEN, 2022). The sampled air taken for olfactometry is in duplex to address for fluctuations in the sample as shown in the figure below.

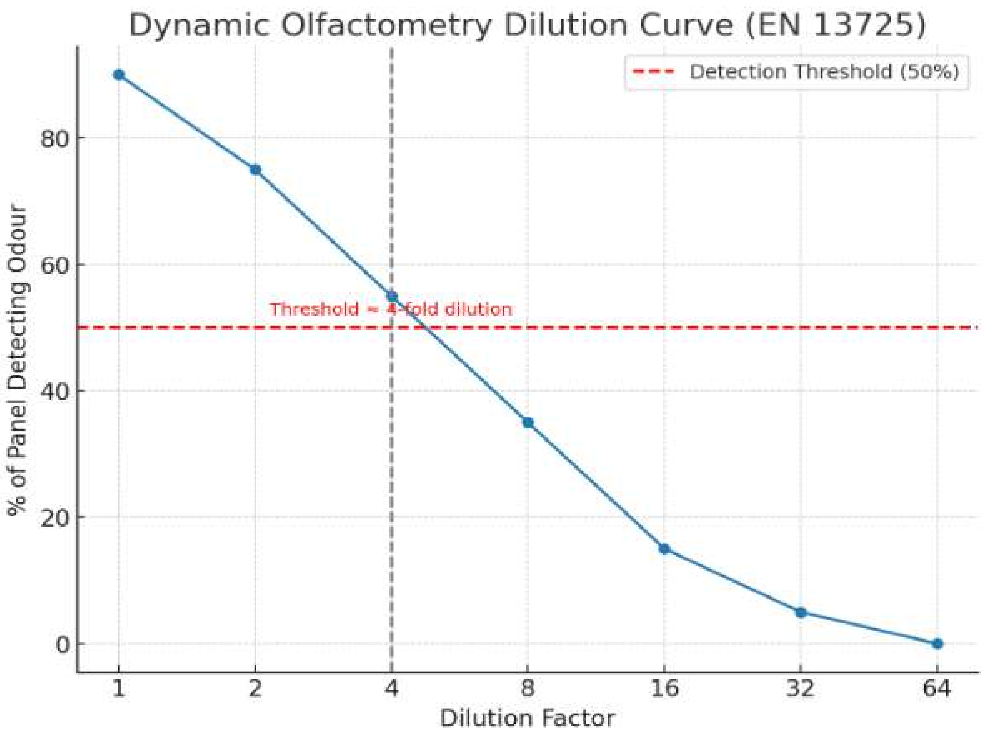

Figure 2: *Dynamic Olfactometry Dilution Curve*

The collected air samples are prior diluted and subsequently offered to a panel of selected odour calibrated assessors. The air samples are initially presented to the panel members in such a diluted state that no one can distinguish the odour from odour-free air. The sample dilution is then reduced in consecutive steps (decrement in dilution by maximal factor of 2) so that the odour becomes increasingly stronger. When 50 % of the panel members can distinguish the odour with certainty from odour-free air, there is an odour concentration of one odour unit per m3 of air (ouE.m-3). The odour concentration of an odour sample is therefore equal to the number of times the sample must be diluted to achieve an odour concentration of 1 ouE.m-3 . By definition, one odour unit per cubic meter is equal to the concentration of a compound or mixture of compounds at which 50 % of calibrated observers can just distinguish it from odour-free air. From the obtained odour concentrations of the duplex air samples, the geometric mean is calculated.

2.5.2 Sensorial Analysis

The collected air samples from the different experiments were also subjected to sensorial analysis. This analysis is conducted in an odour-free area and executed by at least six odour-calibrated panel members (odour calibration in accordance with EN 13725 (Comité Européen de Normalisation (CEN), 2022)). The panel members gently press on the air samples to release the odour and sniff directly from the sample. The purpose of this analysis is to obtain a description of the odour character and to determine two parameters, namely odour intensity and odour (un)pleasantness. The evaluation of these parameters is done using a score (Table 1).

Table 1: *Score Scaling of Odour Intensity and Odour (un)Pleasantness*

Odour intensity	odour (un)pleasantness
Undetectable (0)	Neutral to pleasant (4)
Very weak (1)	Slightly unpleasant (3)
Weak (2)	Unpleasant (2)
Clear (3)	Very unpleasant (1)
Strong (4)	Extremely unpleasant (0)
Very Strong (5)	
Extremely strong (6)	

2.6 Ethical Considerations

The researcher obtained a research permit from National commission for science, technology and innovation (NACOSTI), with the recommendation of Nakuru County government. The Naivasha Sub-County Commissioner gave consent for the research to be conducted in Naivasha Sub-County.

III. FINDINGS & DISCUSSION

3.1 Olfactometer Readings

The study used Scentroid SM100 field olfactometer which is compliant with EN 13725 European Standard. The KEBS certified SM100 field olfactometer was found to be more appropriate for its practicality for field measurement to capture odour concentration in the atmosphere. It uses compressed air for a high pressure carbon fibre tank to dilute sample air prior to presenting to the panellists (Bakhtari et al., 2020). According to European standard, nuisance odour concentration is above 30 ouE/m^3 (Brancher *et al.*, 2016). The analysis of the distribution samples is shown in Table 2.

Table 2: *Distribution of Odour Concentration near Naivasha Abattoir*

Concentration of Odour from abattoir (ouE/m^3)	Frequency	Percentage (%)
Less than or equal to 30	47	26.2
Greater than 30	133	73.8

Results show odour concentrations of above 30 (ouE/m3) were 73.8% of the 180 sampled points near the abattoir. This depicts that the area experiences high density of odour concentration.

The field survey results showed that inhabitants complained of odor-related symptoms such as nausea, weariness, headaches, dizziness, difficulties in breathing and concentration. There has been conflicting interests and shifting of responsibility between the Naivasha Sub-County Government, NAIWASCO, the traders, and National Environment Management Authority (NEMA) on the operation of the abattoir. The residents are not able to have their issues addressed since there are clashing political interests among the institutions and traders stated above on the economic viability of the abattoir.

3.2 Biofiltration

Table 3 gives an overview of the results of olfactometry in combination with odour description based on sensorial analysis of the air samples collected before the water scrubbing (i.e. untreated air – IN) and after biofiltration (i.e. treated air – OUT) and this for the optimal and deteriorated state of the biofilter (experiment ID 1 and ID 2).

Table 3: *Olfactometry Results and Odour Description of Biofilter Experiment*

Experiment identification	Sampling point	Concentration (ouE.m-3)	Efficiency (%)	Description
A	In	24148	-	Rotten, offal, rendering
	Out	1139	96,4	Bark/wood, compost
B	In	300471		Rotten, offal, rendering
	Out	4812	94,8	Woody, sulpur smell

The results show that the effective biofilter produced an odor with a concentration of approximately 1.000 $(\log_{10})$ouE.m^3 and, more importantly, an odor description free of any trace of the process odor. The residual smell was scored as mainly neutral. The bar graph below shows the odour concentration before and after biofiltration.

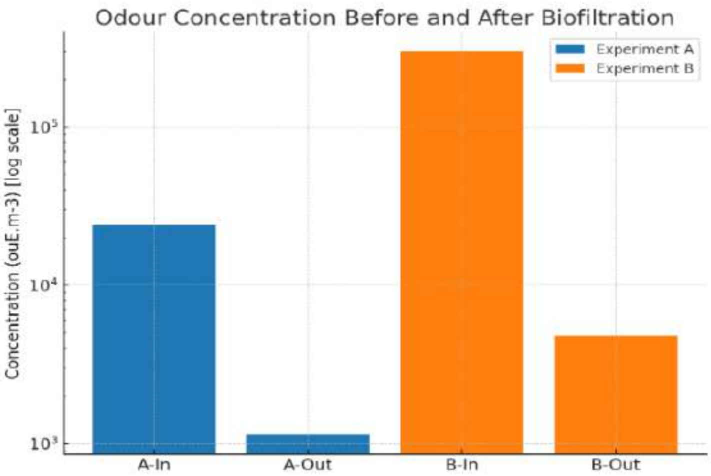

Figure 3: *Odour Concentration Before and After Biofiltration*

The residual odour concentration for the biofilter's inadequate performance was approximately 94% and the odour description included an untreated sulfur smell. Consequently, the residual smell was rated mostly as mildly unpleasant. Focusing on the removal efficiency, both the well and insufficiently performing biofilter (optimal material state vs deteriorated material state) attained a similar high removal efficiency as seen in the bar graph below.

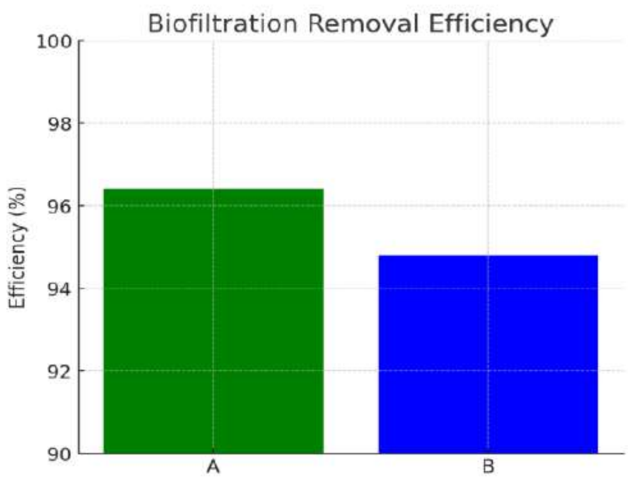

Figure 4: *Biofiltration Removal Efficiency*

Important aside: experiment B's untreated odor concentration was ten times higher than experiment A. During experiment B, the unclean unloading hall had four times as many carcasses as A, which explains the much higher concentration of odour that needed to be treated. However, the removal efficiency would indicate a functioning biofilter in both instances. By incorporating the sensorial analysis's findings, it became evident that the biofilter was partially emitting untreated process air, indicating inadequate odor reduction.

3.3 Thermal Oxidation

Table 4 gives an overview of the results of olfactometry in combination with odour description based on sensorial analysis of the air samples collected before scrubbing (i.e. untreated air – IN) and after thermal oxidation (i.e. treated air – OUT) and this for the optimal and sub-optimal combustion temperatures (experiment C and D).

Table 4: *Olfactometry Results and Odour Description of Thermal Oxidation Experiment*

Experiment identification	Sampling point	Concentration (ouE.m-3)	Efficiency (%)	Description
C	In	103724	-	Rotten, offal, non-condensable fumes (NCF)
	Out	1382	98,6	Prickling, gas
D	In	128481		Rotten, offal, rendering
	Out	45216	95,2	NCF, gas

Similar to the results of the biofilter, the olfactometry hints towards a well-performing thermal oxidation, both under optimal and suboptimal combustions temperatures, as a high removal efficiency was achieved in both cases.

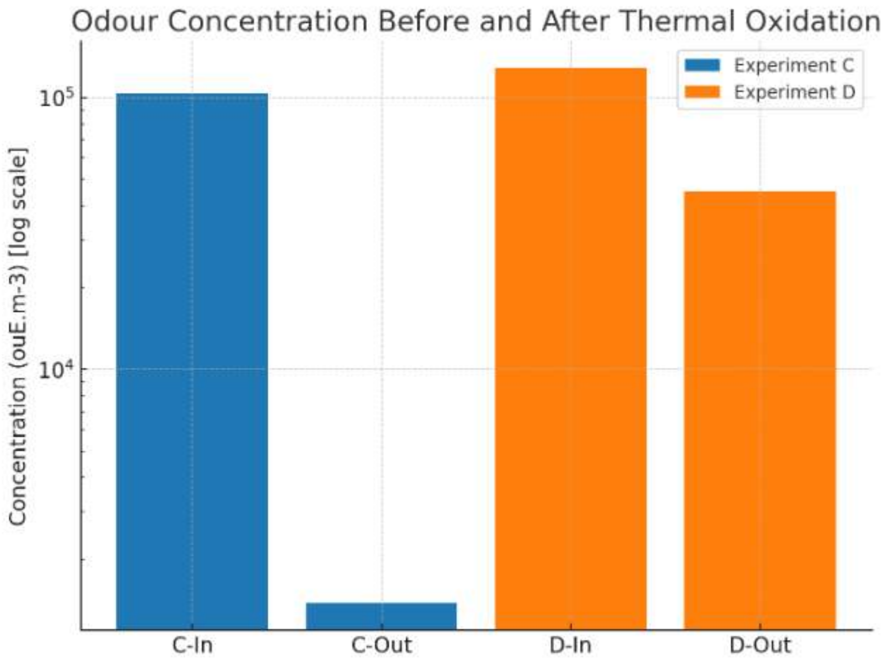

Figure 5: *Odor Concentration Before and After Thermal Oxidation*

However, the sensorial analysis revealed that even at suboptimal combustion temperatures, untreated process air (non-condensable gases) was still detectable, and that the residual odour concentration of thermal oxidation was approximately 40 times higher than at optimal combustion temperatures. Consequently, the residual smell of thermal oxidation at combustion temperatures below optimal was primarily rated as unpleasant.

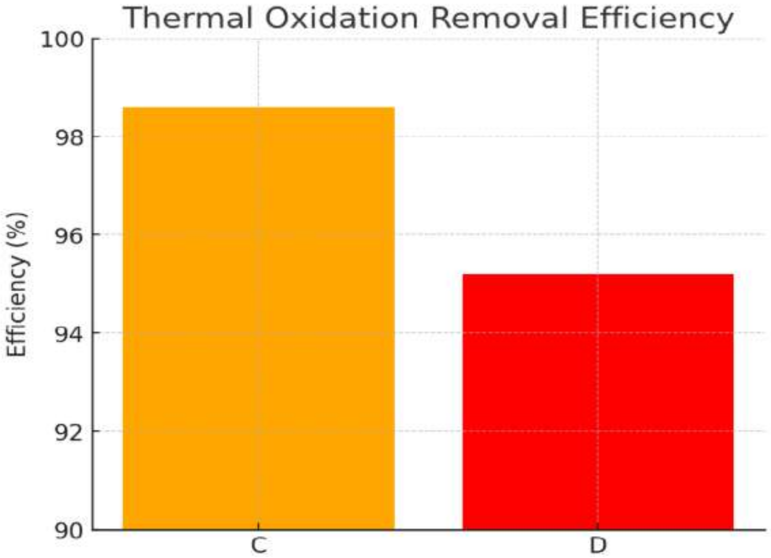

Figure 6: *Thermal Oxidation Removal Efficiency*

When olfactometry and sensorial analysis were combined, it became clear that: a high odour concentration at the outlet of the emission reduction technique is not necessarily an indication of an inadequate technique if the process odour is completely absent, and a high odour removal efficiency according to olfactometry is not necessarily an indication of a properly functioning reduction technique.

3.4 Discussion

This study is a critical examination of odor elimination processes in a slaughterhouse plant through a synergistic approach of using dynamic olfactometry in combination with sensorial analysis. The findings contradict the conventional application of sole olfactometry as a main indicator of performance in odor reduction systems, and they provide valuable insights with practical implications for environmental management (Government of Kenya, 2012).

The main finding of this research is the empirical limitation of using odor removal efficiency, as calculated based on olfactometry, as an autonomous parameter of abatement efficiency. For both the biofiltration and thermal oxidation systems, the quantitative findings showed high removal efficiencies (>94%) regardless of the operation status of the system—whether the biofilter media was deteriorated or the thermal oxidizer was running at less-than-optimum temperatures. This is consistent with traditional practice, whereby these high percentages would be interpreted to suggest good performance. The composite sensorial analysis, however, painted a more nuanced and concerning picture.

For the biofilter, sensorial measurements showed that while the "well-performing" unit (Experiment A) was giving a residual odor described as neutral ("bark/wood, compost"), the "insufficiently performing" unit (Experiment B), despite 94.8% efficiency, was emitting air with a characteristic "untreated sulphur smell" that was assessed as unpleasant. This is indicative of the biofilter likely being channeling or bypassing, with untreated process air flowing through without treatment, a failure that was totally masked by the high percentage removal efficiency.

This impact was even more pronounced in the thermal oxidation experiments. The 600°C sub-optimal system (Experiment D) achieved 95.2% removal efficiency, a result that would not generally be cause for concern. Sensorial analysis, however, detected strong, unmistakable process odors ("NCF, offal, rendering") in the treated stream, and the residual concentration was 40 times higher than when the unit was operating correctly at 850°C. This significant observation points to the reality that a thermal oxidizer operated below its design temperature, while it will still incinerate a high percentage of volatile compounds, will not completely combust some individual, highly odorous compounds that are responsible for causing the nuisance. The treated emission that results, while quantitatively reduced, is still qualitatively objectionable and a source of potential public complaint.

A limitation of this study, common in field research, is the potential variability in sampling. While the duplex sampling method helps account for process fluctuations, the immense difference in inlet concentration between the two biofilter experiments (a factor of 10) highlights how much operational factors (e.g., number of carcasses) can influence results. This is in line with the emphasis of the authors on the necessity of representative and cautious sampling, as specified in standards like EN 13725 and addressed by scholars like Capelli et al. (2013) and Guillot (2012).

1V. CONCLUSION & RECOMMENDATIONS

4.1 Conclusion

When investigating odour emission reduction techniques in the abattoir by combining olfactometry with sensorial analysis, it became clear that olfactometry as stand-alone analysis frequently lacks the necessary potential to accurately assess the method's effectiveness in removing odors. Since emissions are a complex mixture of volatile chemicals, it stands to reason that a variety of methods for monitoring odors are required to enable a more comprehensive evaluation. The sensorial analysis method makes it possible to ascertain whether untreated process odour is still present after the odour reduction technique, while the intensity and unpleasantness scaling translates to how the odour will be perceived by the surroundings. This type of information is essential for rendering facilities and slaughterhouses in order to reduce the environmental impact of odor are pivotal to their environmental license to operate. The synergy found between olfactometry and sensorial analysis highlighted the important finding that: a high odour removal efficiency according to olfactometry is not necessarily an indication of a properly working reduction technique if process odour can still be determined via sensorial analysis and; a high odour concentration at the outlet of the emission reduction technique is not necessarily an indication of an insufficient technique if the process odour is completely absent. Therefore, the integration of sensorial analysis with olfactometry should be considered a best practice. It provides a far more holistic and realistic assessment of abatement performance, ensuring that technological solutions truly mitigate the nuisance as perceived by the human nose, which is, ultimately, the final and most important arbiter of odor pollution.

4.2 Recommendations

Based on the critical conclusions of this study, the following are the recommended suggestions for abattoirs to improve odor control practices and environmental sustainability:

Put in place an Integrated Monitoring Protocol: Internal performance and regulatory compliance cannot rest solely on quantitative olfactometry (ou_E/m^3 and removal efficiency). It is strongly recommended that the addition of sensorial analysis (odor character, intensity, and hedonic tone) be made as a standard add-on tool. The double measure is an actual quantification of nuisance abatement, ensuring that objectionable process odors are eliminated, not just diluted.

Implement Real-Time Process Control Parameters: For thermal oxidation facilities, a percentage removal efficiency is a trailing indicator. Strict operation parameters, primarily combustion temperature, must be tracked and maintained at all times (e.g., at or above 850°C) as a critical Key Performance Indicator (KPI). A temperature deviation alarm system must be mandatory to prevent emissions of inadequately treated, highly odorous air.

Rank Odor Character in Environmental Impact Assessments (EIAs) and Permits: Local governments and environmental agencies must update permitting requirements to include a residual odor character determination after treatment. A condition of the permit can mandate that emissions treated not have the characteristic "rotten, offal, rendering" smell, as verified by sensorial testing, to further protect community health.

REFERENCES

Bakhtari, A., Sironi, S., & Capelli, L. (2020) How can odour be measured? An overview of methods and their applications. *Atmosphere*, *11*(1), 92.

Baran, B., Rogelberg, S., & Clausen, T. (2016). Routinized killing of animals: Going beyond dirty work and prestige to understand the well-being of slaughterhouse workers. *Organization*, *23*(3), 351-369.

Brancher, M., Franco, D., & de Melo Lisboa, H. (2016). Photocatalytic oxidation of H2S in the gas phase over TiO2-coated glass fiber filter. *Environmental technology*, *37*(22), 2852-2864.

Carey, J. B., Lacey, R. E., & Mukhtar, S. (2004). A review of literature concerning odors, ammonia, and dust from broiler production facilities: 2. Flock and house management factors. Journal of Applied Poultry Research, *13*(4), 509–513. https://doi.org/10.1093/japr/13.4.509

Capelli L., Sironi S., Del Rosso R., (2013). Odour sampling: techniques and strategies for the estimation of odour emission rates from different source types, *Sensors*, *13*, 938–955.

CEN, (2022). Stationary source emissions; Determination of odour concentration by dynamic olfactometry and odour emission rate, A Critical Review. *Waste Manag. Res. 20, 37*–58.

Government of Kenya. (2012). Meat Control Act. Revised Edition. Nairobi, Kenya: Council for Law Reporting.

Government of Kenya, GoK; (2015). Environmental Management and Coordination Act. Government Printer. Nairobi.

Guillot J., (2012). Odour measurement: Focus on main remaining limits due to sampling, *Chemical Engineering Transactions*, *30*, 295–300.

Luwumba, D., Kusiluka, L., & Shirima, G. (2019). Occupational hazards associated with human brucellosis in abattoir settings: A case study of Dodoma abattoir in Tanzania. *Journal of veterinary medicine, 11*(3), 73-80.

National Environment Management Authority (NEMA) (2015), *National Solid Waste Management Strategy*, Nairobi

Nicell, J. A. (2009). Assessment and regulation of odour impacts. *Atmospheric Environment*, *43*(1), 196-206.

Ubeda Y., Lopez-Jimenez P., Nicolas J., Calvet S., (2013). Strategies to control odours in livestock facilities: a critical review, *Spanish Journal of Agricultural Research*, *11*(4), 1004–1015.

Van Broeck G., Van Langenhove H., Nieuwejaers B., (2021). Recent odour regulation developments in Flanders: ambient odour quality standards based on dose-response relationships, *Water Science and Technology*, *44*(9), 103–110.

Victor, K., & Barnard, A. (2016). Slaughtering for a living: A hermeneutic phenomenological perspective on the well-being of slaughterhouse employees. *International journal of qualitative studies on health and wellbeing*, *11*(I), 30266.

Wagner, L., & Refslund, B. (2016). Understanding the diverging trajectories of slaughterhouse work in Denmark and Germany: A power resource approach. *European journal of industrial relations*, *22*(4), 335-351.