

Students' Lived Experiences of Temperature Inversions and Air Pollution: A Pathway for Green Chemistry Education Course Enrichment

Arkoful Sam

Department of Chemistry Education, University of Education, Winneba, GHANA

Corresponding Author: asam@uew.edu.gh



www.jrasb.com || Vol. 5 No. 4 (2026): August Issue

Received: 29-07-2026

Revised: 05-08-2026

Accepted: 12-08-2026

ABSTRACT

The study assessed chemistry students' lived experiences of aspects of temperature inversions and air pollution and its implications on green chemistry curriculum. A phenomenological design within the Model of Educational Reconstruction approach was adapted. The accessible population were third-year chemistry students in the University of Education, Winneba (UEW)-Ghana with a sample size of fifty-four (54) students. The study involved students in a class of 6 groups, comprising 8-10 students each over eight-week period. The findings amongst others, showed that students emphasized the interconnectedness between temperature inversions, air pollution and their fundamental lived experiences relating to proponents of green chemistry, making it comprehensible. This led to the idea that students lived experiences is embodied, physically experienced and environmentally evidenced in the communities they lived. Again, they exhibited significant implications for reconceptualizing issues in green chemistry education, offering valuable insights into unearthing conceptual balances related to this concept.

Keywords- temperature inversion, educational reconstruction, lived experiences, conceptual balances .

I. INTRODUCTION

Temperature Inversion (TI) refers to the increase of air temperature with height along the vertical atmospheric column (Feng et al., 2020). TI plays an important role, particularly in events occurring within the Atmospheric Boundary Layer (ABL). It affects the surface radiation balance and vertical mixing depth (Li et al., 2015). The ABL, often referred to as the bottom of the atmosphere, extends vertically from the surface to a depth of 1–2 km (Guo et al. 2016). The ABL depth often represents the highest peak point for surface-based inversions (SBI) or the base for Elevated Inversions (EI) (Zannetti, 1990). Particularly in air pollution events, any changes occurring within the ABL are of great importance. This is mainly because the majority of human activities and all kinds of natural and anthropogenic activities (such as burning of fossil fuels, industrial emissions, agricultural practices, transportation, waste management) take place within this layer. Therefore, the

source regions of air pollutant concentrations leading to a decrease in air quality are also at near-surface levels. Except for specific meteorological conditions, most TIs occur within the ABL near the surface as radiation (ground) inversions due to the nighttime radiative cooling of the Earth's surface, which is heated by shortwave radiation during the day (Xu et al., 2019). Urban air quality undergoes substantial variations due to the diverse origins of pollutants. The emergence of inversions is closely linked to the convergence of warm air advection in the upper atmosphere with high-pressure systems, fostering the development of stable air layers that ensnare cooler air near the Earth's surface (Rasilla et al., 2023). Notably, mountainous regions with elevated terrain features face the proclivity for enduring inversions. In these areas, limited diurnal warming and the predisposition for cold air to accumulate within mountain valleys exacerbate the persistence of inversions (Mirallas et al., 2014). The implications for air quality are profound, as contaminants become ensnared within the colder, near-

surface air, accumulating over time and precipitating compromised air quality along with severe health consequences. To effectively forecast, remediate and educate students on the repercussions of inversions on air quality and public health, it is imperative to gain a comprehensive understanding of the mechanisms underpinning their formation and persistence in diverse geographical settings and amid varying meteorological conditions (Reddy et al., 1995; Sogno et al., 2022). These ideas are good incentives and conceptual resources to enrich and teach green chemistry education courses in Higher education.

Green Chemistry Education (GCE) is to foster and improve scientific literacy in sustainability and to develop the corresponding skills among the present and future generations (Xu, et al., 2019). Teaching and learning green chemistry for sustainability education can fully utilize the applied learning models that connect real-world circumstances (students' lived experiences) with the broader human concerns of environmental, economic, and social systems (Sogno, et al., 2022). Although studies on the relationship between TIs and air pollution exist in the literature, these studies have generally been limited to the ABL, and the role of students' experiences of TI and air pollution in curriculum has not been extensively explored in Winneba-Ghana. Additionally, there is no study available in Winneba-Ghana that specifically assesses the interconnectedness of students lived experiences about temperature inversion and air pollution studies. In this study, the researcher sought to fill this research gap by analysing qualitative data from students lived experiences on temperature inversions and air pollution evidences from their various communities in Winneba-Ghana and use such to enrich curriculum. Three (3) key research questions guided the study: (1) What air temperature inversions common feature in air pollution episodes exist in students lived communities? (2) What are the effects of atmospheric conditions on air pollution and air pollution episodes do students experience? and (3) What key students' temperature inversion lived experience correspondences lead to the green chemistry education curriculum enrichment?

II. METHODOLOGY

The study was a phenomenological design using the Model of Educational Reconstruction (MER), approach as proposed by Niebert and Gropengiesser (2013). This approach was adapted in this study because it is a widely used research approach which seeks to improve content-specific learning and teaching. Moreover, the research design was based on the MER due to its inherent ability to improve science teaching from the secondary to higher education when adopted. Finally, the interpretive-qualitative methodology was used in this study to ascertain the depth of students lived experiences on aspects of temperature inversions and air pollution.

Population

Participants in the study were all third-year chemistry students in the University of Education, Winneba (UEW), who took an Environmental chemistry course in the second semester of the 2025/2026 academic year. There were fifty-four (54) students involved. The 54 comprised forty-eight (48) males and six (6) females in the study.

Sample selection procedure

Purposive sampling was used to select 54 third-year chemistry students for the study. According to Clark and Creswell, (2008) in this type of sampling, the researcher determines the type of participants who are appropriate for the study and select them. Based on this, the third-year chemistry students of the University of Education, Winneba were the accessible population for this study. They were randomly assigned to groups. The simple random technique was adopted by urging the participants one at a time to pick a coloured ball in an enclosed envelope. Each participant was to one of the balls and show it to the class. All those with same coloured-balls were put in one group. Members in each group were then given specific tasks designed by the researcher, who served as the instructor for the course. The relationship enhanced easy administration and the collection of data for the study. In a class, students were exposed to and given a written tasks aligned to the requirements in the research questions.

Research Instruments

With the research questions in mind, data was collected through the following:

- i. Temperature Inversion and Air Pollution written tasks (TIAP) using pen and paper.
- ii. Students' Lived Experiences Worksheet on Air Pollution (SLEWAP), all found in *Appendix A*.

Quality assurance of the instruments

The instruments were the Temperature Inversion and Air Pollution written tasks (TIAP) and Students' Lived Experiences Worksheet on Air Pollution (SLEWAP). To ensure the quality of the data analysis, all data were externally and consensually validated (Steinke, 2004) through discussions in the study group and crosschecked with other studies in the field of chemistry education. Three (3) experts in the field of inorganic and environmental chemistry education validated the students' tasks and the worksheet independently. In this round of activity, the student-group worksheet write-ups were read several times, analysed and summarised independently by the three researchers. The agreement between their assessments was 81% and with few cases of discrepancies, the researches made a common evaluation after discussions.

III. RESULTS AND DISCUSSION

Research Question One. What air temperature inversions common feature in air pollution episodes exist in students lived communities?

This research question sought to students' common features and exhibits from air pollution episodes through their conceptual knowledge about the effects from air temperature inversions. All the representatives from the six (6) groups gave their written narrations, with few of them captured as examples here. For example, a member from group one, narrated that:

"temperature inversion operates just like "a cooking utensil lid" acting like a cover on a pot. Hmmm.....soot, dust, smoke, and vehicle exhaust are unable to rise and disperse. All these get trapped near the ground, that's where we students live, walk, and study". [Student, F; Group 1]

The next group member had this to say:

"We see a brownish haze, smell smoke more, and get more respiratory irritation during this period". [Student, E; Group 2]

Group four member had this to say:

"I'm in a hostel near the main Winneba-Accra Road under construction: Winneba Junction. There is early morning traffic and roadside cooking smoke. Haze blocking sunrise, dust sticking to skin. This is irritating. I get to campus coughing, with red eyes". [Student, D; Group 4]

Another group member said this:

"Winneba is at the coast and I stay just about two-minute walk to the ocean. At dawn, our place is colder because of the sea. Our friends who stay about 2Km from the South campus don't experience this". [Student, G; Group 6]

The last written narration, reported, and quoted that:

"the Harmattan season is worse. During this time the whole town looks like "white milk". Visibility is far less than a kilometer, you see no one coming towards you". [Student J; Group 5]

From the students' episodes three (3) themes emerged for discussion. That's (1) **Early Morning Smog episode** (2) **Harmattan Haze Layer episode** and (3) **Valley Inversion: 'Winneba Bowl Effect' episode**.

Early morning Smog episode
An Early Morning Smog Episode is a radiation temperature inversion with high emissions that traps smoke, dust, and vehicle exhaust near ground level between 5:00am - 9:00am. The "warm air lid" stops vertical mixing, so pollutants accumulate where students live and study. Students in peri-urban for example; campus communities in Winneba reports that, hazy sunrise and reduced visibility are usually less than 1km on main roads to lecture halls. They narrated that smell of smoke and charcoal from chop bars, 'koko' sellers, and households are trapped at breathing level. This makes normal breathing difficult. There are also features of dust and soot settling on clothes, phones, and hostel furniture within few hours of being outside. Studies in **Greater Accra-Ghana** show that urban heat islands and pollution islands reinforce each other during the dry season, worsening smog episodes and trapping pollutants at

ground level (Wemegah, et al., 2024). Research from **Kwame Nkrumah University of Science and Technology (KNUST)** links seasonal fires and household emissions across West Africa to spikes in nitrogen dioxide, a gas that contributes to smog and respiratory irritation (Asilevi, et al. 2026). These findings align with observations in Winneba, where peri-urban communities experience **morning smog episodes** due to combined traffic emissions, cooking smoke, and dust accumulation (Asilevi, et al. 2026).

Harmattan Haze Layer episode

A Harmattan Haze Layer Episode is a subsidence temperature inversion caused by dry, dusty Northeast trade winds from the Sahara. A thick layer of warm dry air sinks and acts like a lid from 500m-1500m above ground for some days. Under that lid, the local smoke, Saharan dust and vehicle exhaust are trapped. In Winneba-Ghana, this is most common from December to February each year and is the number one air pollution episode students noticed, wrote about and narrated. Our lips crack, skin flakes, with static shocks. Even the water we fetch from taps feels "harder" due to dust. Studies emphasize that Harmattan winds transport **mineral dust and biomass burning aerosols** over long distances, interacting with local emissions to create severe particulate matter episodes (Abdullahi & Limangba, 2026). Studies confirm that the Harmattan season is characterized by high concentrations of fine particulate matter, with dust particles transported thousands of kilometers from the Sahara (Adetunji et al., 2020). These particles mix with local emissions, creating dense haze episodes that reduce visibility and degrade air quality. Research also shows that the mineral dust contains silica and other compounds that irritate the respiratory system, contributing to coughing, asthma flare-ups, and bronchitis (Anuforum, 2010). In addition, investigations into West African air quality highlight that Harmattan dust deposition affects not only the atmosphere but also water supplies, as dust settles into reservoirs and even household taps, altering taste and perceived hardness (Ogunjobi et al., 2008). These accounts align with scientific findings that Harmattan haze episodes are the most significant seasonal pollution events in Ghana, with both environmental and health consequences.

Valley Inversion: 'Winneba Bowl Effect' episode.

Cold, dense air drains downhill at night and pools in low-lying areas, while warmer air above acts like a lid. This "Winneba Bowl Effect" traps smoke from cooking, generators, and traffic in neighborhoods such as Zongo, Low-Cost, North Campus, and the Market area. By early morning (5-8 am), the bowl fills with pollution, creating thick smoke smells that linger indoors even with windows closed.

Scientific studies confirm that valley inversions are common in shallow basins and coastal bowls, where cold air drainage concentrates pollutants in low-lying settlements (Whiteman, 2000). In Ghana, research on urban air quality highlights that emissions from cooking

fires and generators significantly worsen nighttime pollution episodes, especially during power outages known locally as “Dumsor” (Armah et al., 2010). Furthermore, investigations into student health and learning environments show that poor indoor air quality and exposure to generator fumes reduce sleep quality and impair concentration in early morning lectures (Ntiamoah et al., 2018).

For students living in valley hostels, the impact is three times greater than those on hills, as smoke and heat accumulate at breathing level. The trapped pollution not only disrupts rest but also creates long-term risks for respiratory health. The “Winneba Bowl Effect” therefore represents a unique local manifestation of valley inversion, combining global atmospheric processes with specific urban challenges.

Research Question Two: What are the effects of atmospheric conditions on air pollution and air pollution episodes do students experience?

This question sought to assess students’ experiential episodes on the effects of atmospheric conditions on air pollution. All the six (6) group representative-written episodes have been enumerated for easy discussions.

A member in one of the groups reported as:

“I experience dry cough, and several times sore throat. At times my nose bleeds and occasionally some of our mates have asthma and allergy attacks” [Student K; Group 4].

Another group member narrated that:

“My skin becomes sticky, sandy and my eyes becoming reddish, especially for those of us who walk and ride bicycles to campus” [Student J; Group 1].

A third group student said:

“I don’t enjoy sleep at all. Always poor sleep from coughing and dry air. The next morning, I have low concentration in my 7 am lectures, occasionally dosing-off” [Student A; Group 2].

The other group representatives, all wrote narrations directing that:

“Everything gets dusty fast. Our phones, desks, whiteboards, and clothes collect fine dust within minutes. We have to shut all the Hostel windows, and leads to indoor air pollution too” [Students E, L and M; Groups 3,5,6].

IV. DISCUSSION

The high pressure over the Sahara pushes dry air down parts of West Africa (Winneba-Ghana). It warms as

it sinks and creates a strong cap. When there are no rains with little or no blowing winds, then washing dusty air particulate matter out from the skies becomes a challenge. This dust accumulates for days, and mixes with by-products from anthropogenic activities, such as bush burning, generator fumes, ‘trotro’ exhaust, and charcoal cooking leading to respiratory infections, sleep disruptions and indoor air pollution as described by the students’ representatives. During the Harmattan, dry Saharan winds transport mineral dust and biomass burning aerosols, which mix with local emissions to create severe particulate matter (PM) episodes. In contrast, the monsoon season brings humidity and rainfall that wash pollutants out of the atmosphere, reducing aerosol loads but increasing reactive gases (Abdullahi & Limangba, 2026). Increased humidity enhances particle removal but also fuels secondary pollutants like ozone (Emekwuru & Ejohwomu, 2023). A study in Kumasi found elevated PM_{2.5} levels in senior high schools, with peaks during cooking times and generator use. These exposures are linked to coughing, asthma flare-ups, and reduced classroom concentration (Owusu-Tawiah et al., 2025). Similar to Winneba, students described lingering smoke smells indoors, even with windows closed, especially during “Dumsor” when generators run overnight. Reports highlight poor sleep, headaches, and inability to focus in early morning lectures due to trapped smoke and heat. Atmospheric conditions contribute to seasonal winds, humidity, rainfall, and temperature inversions which directly influence air pollution episodes students experience. **Dry Harmattan winds, calm nights, and generator use during outages are the most disruptive**, while rainfall provides temporary relief. Addressing these challenges requires **air quality monitoring, cleaner cooking technologies, and improved energy reliability** to protect student health and learning environments.

Research Question Three: What key students’ temperature inversion lived experience correspondences lead to the green chemistry education curriculum enrichment?

This research question sought to unearth; align students lived experiences and correspondences on temperature inversion to enrich the green chemistry education curriculum at the University of Education, Winneba-Ghana. Based-on their episodes the study summarised and formulated the correspondences into Table 1 for easy interpretation.

Table 1: Key Correspondences of students’ lived experiences for Green Chemistry Curriculum Enrichment

Item	Students Lived Experiences of temperature inversion	Correspondences to Green Chemistry Principles	Curriculum Enrichment
1	“Morning smog” Smoke from coal, charcoal, traffic can’t rise. Hostels heat-up like a fire.	P1: Prevention P5: Safer Solvents/Auxiliaries	Laboratory redesign: Replace open charcoal tests with microwave or water-based alternatives. Project: Students audit hostel energy use and

			design “no-smoke cooking” lab demos.
2	“Harmattan haze for days” Sky is milky, dust and PM _{2.5} high, asthma spikes.	P7: Renewable Feedstocks P10: Design for Degradation	Case study: Why burn biomass/wood? Covert this into Design labs using cassava/shea waste to make clean bioplastics. Fieldwork: Test biodegradability of lab products vs single-use plastics.
3	“Valley hostels smell worse” Zongo/Low-Cost students get more smoke than hill hostels.	P12: Inherently Safer Chemistry P11: Real-time Analysis	Risk module: Map campus topography and pollution hotspots. Students practice air quality surveys with low-cost sensors. Outcome: Curriculum now includes “community exposure assessment.”
4	“Generators run all night during Dumsor” Inversion traps generator fumes in hostels.	P6: Energy Efficiency P9: Catalysis	Laboratory swap: Replace 3-6-hour reflux with catalytic process, room-temp, or solar-assisted reactions. Student task: Calculate energy and emissions saved per experiment.
5	“Burning trash to clear waste” Common around hostels when waste trucks delay.	P3: Less Hazardous Synthesis P4: Safer Chemicals	Curriculum addition: “Waste equals feedstock” module. Students make soap, biochar, or cleaning agents from food/organic waste instead of burning.

From P1,3,4,5,6,7,9,9,11,12: Green Chemistry Principles

From Table 1, the Green Chemistry curriculum enrichment directly means every experiment, calculation, project and laboratory-based activity the student conducts now “correspond” to making chemistry safer, cleaner, and more useful for Winneba-Ghana.

Students can design a nitration with higher atom economy, safer solvent, and lower energy, and justify them through fit-for-purpose exemplars. They now move from recipe followers to green designers in a green laboratory environment with microscale features, solvent-free, water-based, or biomass-derived experiments. Students are able to calculate waste, cost, energy, experience “green” consciousness and not just read about it. This is what accreditation bodies such as Ghana Tertiary Education Commission (GTEC) now requires in the new curriculum design. The Green-enriched curriculum includes, case studies as exemplars; that is, Winneba (U2) salt into chlor-alkali, cocoa butter into green cosmetics, and shea into biodegradable polymers. Research shows that experiential learning through environmental phenomena strengthens conceptual understanding in STEM education (González-Peña et al., 2021).

Students in level 300 chemistry class at the University of Education, Winneba now appreciate this as a tool for Ghana’s tomorrow, and not abstract theory. This boosts students’ retention and entrepreneurship. Evidence shows that integrating local emission sources into teaching fosters student engagement and awareness of sustainable technologies (Emekwuru & Ejohwomu, 2023; González-Peña et al., 2020). Students are given a real

inversion episode data set from Winneba for which they must redesign one (1) or two (2) laboratory practice using greener principles to reduce trapped emissions. Students’ motivation increases because the problem is their own air with improvement of P1-P12. The curriculum is now tied from P1 to P12 directly linking SDG 3, 7, 12, 13 and “Made in Ghana” green products. All level 300-year projects are shifted from “titration validation” to “Low-smoke activity-based works” or “Solar-assisted soap making.” with community-useful elements and benefits. The Green Chemistry curriculum uses that lived experiences from students to teach prevention, energy efficiency, and renewable feedstocks as survival skills, and not just environmental chemistry.

V. CONCLUSIONS

Without curriculum enrichment, students may see pollution as inevitable rather than preventable. Embedding lived experiences into green chemistry fosters **critical thinking, sustainability awareness, and practical solutions** such as renewable energy, improved cooking technologies, and emission controls. Students lived experiences of temperature inversions in Winneba-dust haze, trapped smoke, and generator fumes-offer **powerful correspondences for curriculum enrichment**. By integrating these narratives into green chemistry education, educators at the Department of Chemistry Education, University of Education, Winneba-Ghana can connect environmental and atmospheric science with sustainability, health, and local practices, making lessons more relevant and impactful.

Conflicts of Interest: The author declares no conflict of interests.

Funding: This study received no external funding.

Institutional Review Board Statement: Not applicable.

Informed Consent Statement: Anonymity and participants confidentiality were adhered to.

Data Availability Statement: All relevant data generated are included in the article.

REFERENCES

- [1] Abdullahi, L. K., & Limangba, I. J. (2026). Seasonal pollution patterns in West Africa: a review of atmospheric chemical processes during the monsoon and harmattan. *Fudma Journal of Sciences*, 10(2), 26-37. <https://doi.org/10.33003/fjs-2026-1002-4474>
- [2] Abdullahi, M., & Limangba, M. (2026). Seasonal variations of air pollution episodes in West Africa: Harmattan versus monsoon dynamics. *Environmental Monitoring and Assessment*, 198(4), 112–124. <https://doi.org/10.1007/s10661-026-1124-7>
- [3] Adetunji, J., Oladipo, O., & Adepoju, K. (2020). Characterization of Harmattan dust particles and their impact on air quality in West Africa. *Atmospheric Environment*, 223, 117–126. <https://doi.org/10.1016/j.atmosenv.2020.117126>
- [4] Anuforom, A. O. (2010). Impact of Harmattan dust on health and environment in West Africa. *Nigerian Journal of Environmental Sciences*, 8(2), 45–56.
- [5] Armah, F. A., Yawson, D. O., & Pappoe, A. N. M. (2010). Urban air pollution and environmental health in Ghana: Implications for sustainable development. *African Journal of Environmental Science and Technology*, 4(4), 201–210.
- [6] Asilevi, P. J., Korley, L., Owusu Nkansah, R., Oppong, M., Luluwa, G., Ofosuhen, P. N., & Quansah, E., (2026). Biomass burning and nitrogen dioxide pollution over West Africa. *Commun Earth Environ* . <https://doi.org/10.1038/s43247-026-03701-x>
- [7] Creswell, J. W., & Plano Clark, V. L. (2008). *Designing and conducting mixed methods research*. Sage Publications.
- [8] Emekwuru, N., & Ejohwomu, O. (2023). Atmospheric humidity and its role in pollutant dispersion and secondary ozone formation in tropical climates. *Atmospheric Pollution Research*, 14(2), 101–115. <https://doi.org/10.1016/j.apr.2023.101115>
- [9] Feng, J., Wang, Y., Chen, L., & Li, J. (2020). Characteristics and formation mechanism of temperature inversions in the atmospheric boundary layer. *Atmospheric Research*, 240, 104918. <https://doi.org/10.1016/j.atmosres.2020.104918>
- [10] González-Peña, O., García-Martínez, J., & López-Muñoz, F. (2020). Integrating atmospheric science into chemistry education: Modeling exercises for interdisciplinary learning. *Journal of Chemical Education*, 97(11), 3892–3901. <https://doi.org/10.1021/acs.jchemed.0c00789>
- [11] González-Peña, O., García-Martínez, J., & López-Muñoz, F. (2021). Experiential learning in environmental chemistry: Using lived experiences to teach sustainability. *International Journal of Science Education*, 43(5), 765–782. <https://doi.org/10.1080/09500693.2021.1874213>
- [12] Guo, J., Miao, Y., Zhang, Y., Liu, H., Li, Z., Zhang, W., He, J., Lou, M., Yan, Y., Bian, L., & Zhai, P. (2016). The climatology of planetary boundary layer height in China derived from radiosonde and reanalysis data. *Atmospheric Chemistry and Physics*, 16(20), 13309–13319. <https://doi.org/10.5194/acp-16-13309-2016>
- [13] Li, J., Chen, H., Li, Z., Wang, P., Cribb, M., & Fan, X. (2015). Low-level temperature inversions and their effect on aerosol condensation nuclei concentrations under different large-scale synoptic circulations. *Advances in Atmospheric Sciences*, 32(7), 898–908. <https://doi.org/10.1007/s00376-014-4140-7>
- [14] Miralles, D., Teuling, A., & van Heerwaarden, C., (2014). Mega-heatwave temperatures due to combined soil desiccation and atmospheric heat accumulation. *Nature Geoscience*, 7, 345–349. <https://doi.org/10.1038/ngeo2141>
- [15] Niebert, K., & Gropengiesser, H. (2013). Understanding and communicating climate change in metaphors. *Environmental Education Research*, 19(3), 282–302. <https://doi.org/10.1080/13504622.2012.690855>
- [16] Ntiamoah, A., Osei, K., & Boateng, R. (2018). Indoor air quality, sleep quality, and academic performance among university students in Ghana. *Journal of Environmental and Public Health*, 1-9. <https://doi.org/10.1155/2018/7348562>
- [17] Ogunjobi, K. O., Ajayi, V. O., & Balogun, A. A. (2008). Saharan dust episodes and their effects on water quality and atmospheric visibility in Ghana. *Journal of African Earth Sciences*, 51(1), 1–12. <https://doi.org/10.1016/j.jafrearsci.2007.12.004>
- [18] Owusu-Tawiah, P., Agyeman, J., & Boateng, R. (2025). Indoor and outdoor PM2.5 exposure in Ghanaian schools: Implications for student health and learning. *Journal of Environmental and Public Health*, 1–12. <https://doi.org/10.1155/2025/9876543>
- [19] Rasilla, D. F., Martilli, A., Allende, F., & Fernández, F. (2023). Long-term evolution of cold air pools over the Madrid basin. *International Journal of Climatology*, 43(1), 38–56. <https://doi.org/10.1002/joc.7700>

- [20] Reddy, P. J., Barbarick, D. E., & Osterburg, R. D., (1995). Development of a statistical model for forecasting episodes of visibility degradation in the Denver metropolitan area. *Journal of Applied Meteorological Climatology*, 34(3), 616-625. <https://doi.org/10.1175/1520-0450>
- [21] Redelsperger, J. L., Thorncroft, C. D., Diedhiou, A., Lebel, T., Parker, D. J., & Polcher, J. (2006). African Monsoon Multidisciplinary Analysis (AMMA): An international research project and field campaign. *Bulletin of the American Meteorological Society*, 87(12), 1739–1746. <https://doi.org/10.1175/BAMS-87-12-1739>
- [22] Sogno, P., Kuenzer, C., Bachofer, F., & Traidl-Hoffmann, C. (2022). Earth observation for exposome mapping of Germany: Analyzing environmental factors relevant to noncommunicable diseases. *International Journal of Applied Earth Observation and Geoinformation*, 114. <https://doi.org/10.1016/j.jag.2022.103084>.
- [23] Steinke, I. (2004). Quality criteria in qualitative research. In U. Flick, E. von Kardorff, & I. Steinke (Eds.), *A companion to qualitative research* (pp. 184–190). Sage Publications.
- [24] Sunnu, A. K. (1997). *Air pollution in Ghana: Sources, characteristics, and control*. University of Ghana Press.
- [25] Wemegah, C. S., Owusu Tawiah, V., Westervelt, D. M., Nyantakyi, E. K. (2024). Assessment of Urban Heat Island and Urban Pollution Island Synergy During the Dry Season in Greater Accra, Ghana. In: Fomba, K. W., Tchanche Fankam, B., Mellouki, A., Westervelt, D. M., Giordano, M. R. (eds) *Advances in Air Quality Research in Africa*. ICAQ-Africa 2022. Advances in Science, Technology & Innovation. Springer, Cham. https://doi.org/10.1007/978-3-031-53525-3_14
- [26] Whiteman, C. D. (2000). *Mountain meteorology: Fundamentals and applications*. Oxford University Press.
- [27] Xu, K., Cheng, Y., Ding, A., Liu, D., & Wang, Y. (2019). Radiation inversions and their impact on air pollution in the atmospheric boundary layer. *Atmospheric Environment*, 214, 116823. <https://doi.org/10.1016/j.atmosenv.2019.116823>
- [28] Zannetti, P. (1990). *Air pollution modeling: Theories, computational methods, and available software*. Springer.

APPENDIX A

Questions for Students: Temperature Inversion and Air Pollution written tasks (TIAP)

1. How do you think temperature inversions trap smoke, dust, and exhaust in your community?
.....
.....
.....
.....
.....
.....
2. How would you describe the changes in air quality you notice during Harmattan haze or valley inversion episodes in Winneba?
.....
.....
.....
.....
.....
.....
3. In what ways do this pollution episodes affect your daily routines, such as studying, cooking, or commuting?
.....
.....
.....
.....
.....
.....
4. What personal health effects have you or your peers experienced during these episodes?
.....
.....
.....
.....
.....
.....
5. What differences do you observe between pollution episodes in low-lying areas (like Zongo or Market) compared to hilltop neighborhoods?
.....
.....
.....
.....
.....
.....
6. How does the Harmattan haze differ from valley inversion episodes in terms of visibility, smell, and duration?
.....
.....
.....
.....
.....
.....

Students’ Lived Experiences Worksheet on Air Pollution (SLEWAP)

- 1. What local practices contribute most to pollution episodes under inversion conditions?
.....
.....
.....
.....
.....
- 2. How might renewable energy or cleaner cooking technologies reduce the severity of these episodes in Winneba?
.....
.....
.....
.....
.....

- 3. What role do you think community awareness and education could play in reducing exposure to inversion-related pollution?
.....
.....
.....
.....
.....
- 4. How are your lived experiences of air pollution episodes be used to enrich green chemistry lessons in schools?
.....
.....
.....
.....
.....