

REVIEWER'S REPORT

Manuscript No.: **IJAR- 59258**

Title: Refrigeration and Air-Conditioning Equipment Users in Togo: A Cross-Sectional Assessment of Refrigerant Knowledge, Traceability, and Composition-Based Environmental Indicators.

Recommendation:

Accept as it is

Accept after Minor revision.....

Accept after Major revision

Do not accept (*Reasons below*)

Rating	Excel.	Good	Fair	Poor
Originality		✓		
Techn. Quality		✓		
Clarity			✓	
Significance			✓	

Reviewer Name: **Dr. ANAPANA GOPAL**

Reviewer's Comment for Publication.

1. General Comments

This manuscript addresses an important environmental and occupational-health issue in Togo by assessing **refrigerant knowledge, refrigerant identification, professional/training factors, and composition-based environmental indicators** among refrigeration and air-conditioning equipment users. The study includes **634 participants across 10 cities**, uses a spatial-grid sampling approach, and combines questionnaire data with statistical and composition-based analyses.

The manuscript has several strengths, including a relatively large multicity sample, an explicitly described sampling strategy, use of HC3-robust regression, reporting of confidence intervals, and an attempt to distinguish knowledge from refrigerant traceability and environmental indicators.

However, **substantial methodological, conceptual, statistical, and presentation issues need to be addressed before publication**. In particular, the manuscript needs clearer definitions of “knowledge” and “traceability,” stronger justification for the PCA and regression approaches, clarification of the denominators used for refrigerator and air-conditioner analyses, and a more rigorous interpretation of the Environmental Pressure Index (EPI).

2. Minor Comments

2.1 Clarify the study population and denominators

A minor issue is that the manuscript repeatedly presents **N = 634** for both refrigerator and air-conditioner analyses. For example, 67.4% of 634 air-conditioner users could not identify the refrigerant, while 74.0% of 634 refrigerator users could not identify the refrigerant.

The authors need to clearly explain:

- How many respondents actually owned/used refrigerators?
- How many actually owned/used air conditioners?

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- Could participants report both types of equipment?
- Were all 634 respondents included in both analyses?
- Were some respondents non-users of one equipment category?
- How was missing/not-applicable information handled?

The statement later that unidentified air-conditioning refrigerants were observed among both participants who used air-conditioning equipment and those who did not is particularly confusing.

The sampling unit and analytical denominator must be completely transparent.

3. The Concept of "Traceability" Needs Minor Clarification

The manuscript defines:

$$T = 1 - pNS$$

where pNS is the proportion of unspecified refrigerants.

However, this measure appears to represent **the proportion of equipment for which the respondent could identify the refrigerant**, rather than actual refrigerant traceability.

True traceability generally involves the ability to identify and document refrigerant:

- type;
- quantity;
- installation;
- servicing;
- recovery;
- recycling/reclamation;
- disposal;
- and movement through the equipment life cycle.

The manuscript itself later recognizes that traceability depends on reliable information throughout the equipment life cycle.

Therefore, calling 32.6% identification a **"Traceability Index"** may overstate what was actually measured.

Recommendation

Consider renaming this measure as:

"Refrigerant Identification Index"

or

"User-Level Refrigerant Identification/Information Index."

Alternatively, retain "Traceability Index" but explicitly state that it represents **user-level identification rather than full lifecycle traceability**.

4. Knowledge Assessment Requires Stronger Validation

Knowledge is assessed using a six-level ordinal scale adapted from Bloom's taxonomy and subsequently transformed to:

0, 20, 40, 60, 80, and 100.

This approach requires further justification.

The manuscript does not sufficiently explain:

- how individual questionnaire questions were converted into Levels 0–5;
- who assigned each participant's knowledge level;
- whether the classification was based on predefined scoring criteria;
- whether multiple questions were combined;
- whether the questionnaire was validated;

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- whether inter-rater reliability was assessed;
- whether content validity was evaluated.

Most importantly, **Bloom's taxonomy is an educational classification framework, not automatically a validated instrument for measuring refrigerant knowledge.**

The authors should provide the complete scoring algorithm, preferably as supplementary material.

5. Treating the Ordinal Knowledge Score as a Continuous Outcome Requires Justification

The knowledge variable originates from an ordinal six-level scale. The authors convert it into a 0–100 score and then apply multiple linear regression.

Although this transformation can be used descriptively, the authors should justify the assumption that the difference between:

- 0 → 20,
- 20 → 40,
- 40 → 60,
- 60 → 80,
- 80 → 100

represents equal intervals.

An **ordinal logistic/ordinal regression model** may be more appropriate if the underlying outcome remains ordinal.

At minimum, the authors should conduct a sensitivity analysis comparing the OLS results with an appropriate ordinal model.

6. The PCA Approach Is Problematic and Needs Substantial Revision

The PCA uses only four variables:

- age;
- technical profession;
- training level;
- non-technical profession.

This is a relatively unusual application of PCA.

The variables are also of mixed measurement types:

- continuous;
- binary;
- ordinal.

The authors acknowledge this and call the PCA exploratory.

Nevertheless, conventional PCA assumes continuous variables and is not generally the preferred approach for mixed binary/ordinal variables.

The authors should consider an alternative such as:

- multiple correspondence analysis;
- factor analysis based on an appropriate correlation matrix;
- polychoric/tetrachoric correlation approaches;
- or simply remove the PCA if it does not provide substantive information beyond descriptive and regression analyses.

Furthermore, “technical profession” and “non-technical profession” appear conceptually complementary. Their simultaneous inclusion needs careful justification.

7. PCA Does Not Demonstrate “Determinants” of Knowledge

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The manuscript uses PCA to describe participant characteristics and then regression to identify factors associated with knowledge.

This is acceptable if clearly separated.

However, the manuscript should avoid implying that PCA establishes determinants or causal structure. The PCA only identifies statistical dimensions in the coded variables. The authors appropriately state that the components are exploratory rather than validated latent constructs.

This cautious interpretation should be maintained throughout the manuscript.

8. The Regression Model Needs More Complete Reporting

The HC3 regression reports:

- OLS $R^2 = 0.412$;
- age;
- technical profession;
- training level;
- coefficients;
- HC3 standard errors;
- t-values;
- p-values.

However, important information is missing.

The authors should provide:

- 95% confidence intervals for coefficients;
- adjusted R^2 ;
- overall model F-statistic;
- sample size after missing-value exclusions;
- VIF values;
- residual diagnostics;
- influence/outlier diagnostics;
- exact coding of categorical predictors.

The Methods mention VIF only indirectly through the broader statistical framework in the manuscript, but the actual VIF results are not presented.

9. The Relationship Between Knowledge and Actual Refrigerant Identification Is Not Tested

The central narrative of the paper links:

low knowledge → poor refrigerant identification → poor traceability.

However, the authors explicitly acknowledge that the individual association between knowledge and refrigerant identification was not directly tested.

This is an important limitation.

A useful additional analysis would be:

Outcome: refrigerant identified vs. not identified

Predictors: knowledge level, profession, training, age, sex, equipment type, etc.

A logistic regression could directly determine whether knowledge level is associated with the probability of refrigerant identification.

Without this analysis, the relationship remains largely descriptive.

10. The Environmental Pressure Index Requires Stronger Methodological Justification

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The EPI is defined as:

$EPI = \sum p_i \times (GWPI_i / GWP_{max})$.

The resulting EPI is 0.164377.

However, the interpretation of this index needs considerable clarification.

Because **67.4% of air-conditioner cases are unspecified**, the EPI calculation appears to use the identified refrigerants while retaining their proportions relative to the entire sample.

Consequently, the EPI is influenced simultaneously by:

1. refrigerant composition;
2. prevalence of identified refrigerants;
3. the large proportion of unspecified cases.

Therefore, a low EPI does **not necessarily mean low environmental pressure**.

The authors should report a sensitivity analysis, for example:

- EPI based on the full population;
- EPI conditional on identified refrigerants only;
- potentially lower/upper bounds for unidentified units.

This would make the indicator much more interpretable.

11. EPI Should Not Be Interpreted as Actual Environmental Impact

The manuscript correctly states in its limitations that the EPI and ODP index are **composition-based population indicators rather than estimates of atmospheric emissions or absolute environmental impacts**, because charge sizes, leakage rates, service history and atmospheric concentrations were unavailable.

This is an important strength.

However, this distinction should be emphasized much earlier—in the Abstract, Results and Discussion.

For example, statements such as:

“environmental pressure”

could be interpreted as actual environmental burden.

A clearer terminology would be:

“composition-based climate-pressure indicator”

or

“GWP-weighted composition indicator.”

12. Refrigerant Charge Size Is Missing

The study reports refrigerant identity but apparently does not report:

- charge quantity;
- equipment capacity;
- equipment age;
- annual refrigerant refill;
- leakage frequency;
- service history.

These are essential if the goal is to understand environmental significance.

For example, two air conditioners containing the same refrigerant can have very different potential climate impacts depending on refrigerant charge size and leakage.

The authors acknowledge this limitation, but it substantially limits the environmental interpretation.

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13. Identification by Users Should Be Distinguished From Physical Verification

The manuscript describes refrigerants as “identified” or “unspecified,” but it is not sufficiently clear whether identification was based on:

- participant verbal response;
- equipment label;
- manufacturer's plate;
- service record;
- technician documentation;
- physical inspection.

This distinction is critical.

If the participant simply reported the refrigerant from memory, this is **reported identification**, not verified refrigerant composition.

The Methods should explicitly describe how refrigerant identity was established.

14. The Sampling Strategy Limits Generalizability

The manuscript uses a spatial-grid approach in which 60 cells were generated, 45 selected/retained and 34 effectively surveyed.

The authors correctly state that this should not be interpreted as simple random sampling of individuals.

However, the statistical analyses subsequently appear to treat participants as independent observations.

The authors should discuss:

- clustering within grid cells;
- unequal numbers of participants per cell;
- whether sampling weights were used;
- whether design effects were considered;
- whether robust/clustered standard errors were considered.

If the sample is spatially clustered, ordinary confidence intervals and p-values may not fully account for the sampling design.

15. Sample-Size Calculation Needs Better Justification

The authors calculate a theoretical sample size of 600.25 using:

- 95% confidence;
- $p = 0.5$;
- 4% margin of error;

then use a population of **8,095,498** and arrive at 600.2 after finite-population correction, eventually targeting 652 and obtaining 634 responses.

The calculation is presented clearly, but using the **entire population of Togo** as the finite population may not necessarily correspond to the actual target population of refrigeration/air-conditioning equipment users.

The authors should explain why the national population was used rather than:

- number of households;
- number of refrigeration/AC users;
- number of equipment units;
- or another relevant sampling-frame population.

16. Non-response Bias Should Be Discussed More Explicitly

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The response rate is high at **97.2%**, which is a positive feature. However, 18 participants were excluded, including nine refusals and nine incomplete responses, and no formal non-response bias analysis was performed.

The authors should report whether the 18 non-respondents differed systematically by:

- sampling location;
- profession;
- sex;
- equipment type;
- or other available characteristics.

If this information is unavailable, the limitation should be explicitly acknowledged.

17. Multiple Testing Requires Attention

The manuscript conducts numerous statistical tests:

- Mann–Whitney U;
- Kruskal–Wallis;
- chi-square;
- ANOVA;
- PCA;
- multiple regression;
- several environmental calculations.

A 0.05 significance level is used throughout.

Given the large number of hypothesis tests, the probability of chance findings increases.

The authors should identify primary versus exploratory analyses and consider appropriate multiplicity control where multiple pairwise or related hypotheses are tested.

18. Post-Hoc Testing Is Missing for Significant Omnibus Tests

The manuscript reports significant Kruskal–Wallis results across professional groups but does not identify which groups differ.

Likewise, the ANOVA reports significant differences in equipment-use duration across professional groups but no post-hoc comparisons are provided.

The authors should provide appropriate post-hoc tests, such as:

- Dunn's test with multiplicity adjustment after Kruskal–Wallis;
- Tukey HSD after ANOVA if assumptions are satisfied.

Alternatively, clearly state that these are omnibus findings only.

19. Sex-Based Comparisons Need Effect Sizes

The manuscript reports significant sex differences in knowledge and equipment-use duration.

However, statistical significance alone does not indicate the magnitude or practical importance of the difference.

The authors should provide:

- group medians/means;
- confidence intervals;
- appropriate effect size;
- group sample sizes.

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The female sample is considerably smaller than the male sample, so the comparison should be interpreted carefully.

20. Occupational-Risk Claims Need Greater Caution

The Discussion states that refrigeration technicians with limited training may handle refrigerants without adequate PPE and identifies several groups as vulnerable.

However, the manuscript explicitly states that it did **not directly measure**:

- refrigerant concentrations;
- leakage;
- individual exposure;
- PPE use;
- thermal-decomposition products.

Therefore, the manuscript should avoid describing these groups as demonstrably “exposed” or at increased toxicological risk.

The authors partially address this issue later, stating that these are groups for future risk assessment.

This cautious wording should be applied consistently throughout.

21. The Introduction Contains Some Broad Claims That Need Better Linking to the Study

The Introduction discusses:

- occupational exposure;
- greenhouse-gas emissions;
- obsolete refrigerants;
- informal markets;
- public-health consequences.

These are relevant, but the manuscript should make a clearer distinction between:

documented background evidence

and

variables actually measured in the present survey.

For example, the study does not measure greenhouse-gas emissions or occupational exposure directly.

22. Kigali Amendment Discussion Should Be Presented Carefully

The Introduction provides detailed statements about HFC phase-down schedules and Montreal Protocol requirements.

Because these are regulatory claims, the authors should ensure that:

- the relevant Togo obligations are correctly represented;
- the applicable Article 5 grouping is accurate;
- the cited regulatory source supports the exact percentage and timeline stated.

The manuscript should distinguish general international provisions from **Togo-specific implementation and enforcement.**

23. The Choice of GWP Basis Needs Explicit Justification

The manuscript states that all GWP100 values use the **IPCC AR4 basis** consistently.

This is methodologically acceptable if applied consistently, but the authors should explain why AR4 was selected instead of a more recent assessment basis.

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More importantly, the manuscript should avoid comparing values from different GWP assessment bases.

A supplementary table showing the source and assessment basis for every refrigerant would improve reproducibility.

24. Refrigerant Composition Tables Need Careful Verification

Tables 7 and 8 report the refrigerant frequencies and environmental characteristics.

These tables should be checked carefully for:

- refrigerant classification;
- GWP values;
- ODP values;
- refrigerant naming;
- consistency with the cited source;
- rounding;
- consistency between percentages and frequencies.

In particular, the manuscript should explain whether the reported refrigerant identity was self-reported or physically verified.

25. The Shannon Entropy Analysis Is Interesting but Its Contribution Should Be Better Justified

The manuscript calculates normalized Shannon entropy:

$$HN = 0.5886$$

and interprets this as moderate distributional heterogeneity.

This is mathematically reasonable as a description of categorical composition, but the manuscript needs to explain more clearly **why entropy adds substantive value** to the research question.

At present, the central finding is already evident from the refrigerant distribution.

The authors should explain whether entropy is intended to measure:

- diversity;
- heterogeneity;
- uncertainty;
- composition complexity;
- or information deficiency.

These are not interchangeable concepts.

26. The “Environmental Indicators” Are Not Independent of the Identification Problem

The EPI and ODP index can only be calculated for identified refrigerants. Therefore, the indicators are structurally dependent on the traceability/identification process.

The manuscript should explicitly explain this relationship.

A useful conceptual diagram could show:

Equipment → Refrigerant identification → Composition distribution → GWP/ODP weighting → Environmental indicator

This would make the methodological framework much easier to understand.

27. The Discussion Is Generally Strong but Some Statements Remain Too Causal

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The manuscript generally handles causality responsibly. For example, it explicitly states that regression coefficients represent adjusted associations rather than causal effects.

This is good.

Nevertheless, phrases such as:

- “training factors determine knowledge”;
- “these groups are exposed”;
- “traceability has direct consequences”;

should be reviewed carefully.

A cross-sectional survey can identify **associations and information gaps**, but cannot establish temporal causality or actual emission/exposure consequences.

28. Structure and Organization Need Improvement

The manuscript has a relatively clear overall structure, but some sections combine **Results and Discussion**, while later sections contain another extensive Discussion.

For example:

- 3.1–3.8 present results;
- Section 4 provides detailed discussion.

This is mostly appropriate, but some interpretive statements appear within Results.

The Results section should primarily report the findings, while explanations and comparisons with previous literature should be concentrated in the Discussion.

29. Figures and Tables

The figures and tables are useful, particularly Figure 1 showing knowledge distributions for refrigerator and air-conditioner users.

However, the presentation should be improved.

Figure 1

The figure clearly shows the large “Unknown” category for both equipment types, but the legend and category presentation could be simplified. The figure should also explicitly state whether percentages are based on all 634 participants.

Tables 7–10

The environmental-indicator tables contain useful information but are somewhat repetitive.

Tables 9 and 10 largely reproduce the same EPI contribution information. These could potentially be consolidated.

30. Language and Formatting Require Professional Editing

Several formatting issues are evident throughout the manuscript, including:

- missing spaces: “Myhreet al.”, “Velderset al.”;
- inconsistent spacing after punctuation;
- “Table 7.Refrigerants”;
- “Table 9.Refrigerant”;
- “The composition-based analysisprovides”;
- inconsistent use of hyphens;
- inconsistent capitalization;
- occasional awkward sentence construction.

For example:

“The rapid expansion of refrigeration and air-conditioning equipment...”

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is clear, but some later sentences are overly long and would benefit from editing. A thorough English-language and formatting revision is recommended.

31. References Need Careful Checking

The reference list is reasonably extensive and includes several relevant sources, including literature on:

- refrigerant toxicity;
- refrigerant emissions;
- knowledge;
- PCA;
- sampling;
- statistical methods;
- refrigerant management.

However, the references should undergo a complete consistency check for:

- author formatting;
- spaces between author names;
- journal titles;
- volume/issue;
- DOI formatting;
- institutional-author formatting;
- consistency between in-text citations and reference list.

The authors should also ensure that all regulatory claims are supported by the most appropriate authoritative sources.

32. Important Strengths of the Manuscript

The manuscript has several notable strengths:

1. **Multicity coverage:** data were collected across 10 cities in Togo.
2. **Large sample:** 634 completed questionnaires with a reported 97.2% response rate.
3. **Clear sampling description:** the grid-based spatial approach is explicitly described.
4. **Transparent statistical methods:** the authors report their tests and assumptions.
5. **HC3 correction:** heteroskedasticity was formally assessed and HC3 standard errors were applied.
6. **Useful environmental framework:** the attempt to combine identification, GWP, ODP and entropy provides a potentially interesting analytical contribution.
7. **Cautious limitations:** the manuscript correctly acknowledges that the EPI and ODP index are not estimates of actual emissions.
8. **Practical relevance:** equipment labelling, training and refrigerant-management systems are directly relevant to the findings.

33. Minor Comments

1. Define all abbreviations at first use: GWP, ODP, EPI, ODP_I, PCA, HC3, etc.
2. Use one terminology consistently: **air conditioner**, **air-conditioning equipment**, or **AC unit**.
3. Avoid using “environmental pressure” without defining exactly what the index measures.

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4. Explain whether "user" refers to owner, operator, household member, technician, merchant or any respondent using the equipment.
5. Provide the questionnaire as supplementary material.
6. Provide the exact coding scheme for the six knowledge levels.
7. Provide the complete PCA loading matrix, preferably including all four components.
8. Report confidence intervals for regression coefficients.
9. Report effect sizes where group comparisons are made.
10. Clarify whether missing responses were excluded listwise or handled otherwise.
11. Consider a flow diagram showing the sampling process from 60 grids to 45 selected/retained grids and finally 34 surveyed grids.
12. Ensure that all percentages sum correctly after rounding.

34. Recommended Revision of the Main Analytical Framework

A stronger analytical framework would be:

Step 1

Describe the respondents and equipment ownership/use.

Step 2

Assess knowledge using the validated scoring system.

Step 3

Model knowledge using an appropriate ordinal or continuous approach, with justification.

Step 4

Model the probability of refrigerant identification separately.

Step 5

Describe refrigerant composition among **identified units**.

Step 6

Calculate environmental indicators separately for:

- all equipment;
- identified equipment only;
- sensitivity/bound scenarios for unidentified equipment.

Step 7

Clearly distinguish:
knowledge → **identification** → **composition** → **potential environmental relevance**.

This would make the manuscript much more coherent.

35. Final Recommendation

Decision: MINOR REVISION

The manuscript presents a **relevant and potentially valuable multicity assessment of refrigerant knowledge and identification in Togo**. The sample size is relatively strong, the topic has clear environmental and occupational relevance, and the attempt to quantify refrigerant composition using GWP, ODP and entropy is potentially interesting.

However, **minor revision is required** before the manuscript can be considered for publication.

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Priority revisions should include:

1. Clarify the actual study population and denominators for refrigerator and air-conditioner analyses.
2. Provide the complete knowledge-scoring and questionnaire methodology.
3. Reconsider or justify the use of Bloom's taxonomy for refrigerant knowledge assessment.
4. Reassess the use of conventional PCA for mixed binary, ordinal and continuous variables.
5. Justify treating the ordinal knowledge score as a continuous outcome or perform ordinal-regression sensitivity analysis.
6. Directly analyse the association between knowledge and refrigerant identification.
7. Redefine or more carefully qualify the "Traceability Index."
8. Clarify the mathematical and conceptual interpretation of the EPI and ODP index.
9. Provide sensitivity analyses accounting for the 67.4% of unidentified air-conditioner refrigerants.
10. Clarify how refrigerant identities were established—self-report, equipment labels, records, or physical verification.
11. Address possible clustering resulting from the grid-based sampling design.
12. Provide post-hoc tests for significant omnibus ANOVA/Kruskal-Wallis findings where appropriate.
13. Strengthen regression reporting with confidence intervals and diagnostic information.
14. Avoid causal or exposure claims that were not directly measured.
15. Improve figures, tables, language, formatting and reference consistency.

Final Decision: Minor Revision

The manuscript has a worthwhile research question and a substantial dataset, but the **measurement framework and statistical interpretation need significant strengthening** to support the conclusions reliably.