Authors' response to the second anonymous reviewer's comments

Dear Sir/Madam,

First of all, we thank the second anonymous reviewer for their thorough and constructive feedback. We appreciate the emphasis on clarifying the objectives, improving flow, aligning sections with the stated aims, and strengthening methodological descriptions.

As per the Editor's advice, we have revised the manuscript and submitted for their kind perusal. We make sure our revised manuscript is meaningfully improved and meet reviewer and editorial expectations.

Sincerely,

Isak R. Shaikh

……..

P.S.: Here is our measured and professional response (**Annexure A: Revision)** that addresses the comments and resolves the grammatical and technical issues (shown in **Annexure B**); Just for the records, **Annnexure C** below shows the second anonymous reviewer's feedback as we received.

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Annexure A: Revision

You shall find a complete set of improved and rewritten paragraphs, corresponding to all sections the reviewer identified as unclear. Each rewritten block maintains our scientific intent but improves flow, clarity, coherence, and alignment with our stated objectives (especially the focus on pesticide-driven soil degradation and ecosystem services).

Reviewer's Comment 1. Results missing in the abstract

No results are stated in the abstract; unclear on soil quality or links to SDGs.

Authors' response to the second anonymous reviewer's comments: Thank you for pointing this out. There is nothing empirical per say! We revise the abstract in such a way that it (i) clearly summarises the main findings of the review, (ii) specify the major impacts of pesticide contamination on soil quality and ecosystem services, (iii) highlights key remediation

approaches, and (iv) explicitly links the review findings to relevant Sustainable Development Goals (SDGs). The revised abstract now states the overarching conclusions of the study.

"Soil contamination by persistent agrochemicals has become a significant barrier to maintaining soil functions and ecosystem services in intensifying agricultural systems. In this study, we conducted an integrative assessment of pesticide-driven soil degradation by synthesizing mechanistic evidence from soil biogeochemistry, microbial ecology, and ecotoxicology together with global environmental governance frameworks. We systematically evaluated how major classes of synthetic pesticides alter soil physicochemical properties, disrupt microbial activity, and impair key ecosystem services such as nutrient cycling, fertility maintenance, and soil-based climate regulation.

Using comparative analysis of remediation case studies from Europe and Asia, we identified consistent patterns in contaminant persistence, biotic response, and recovery trajectories. These patterns enabled the development of an evidence-informed framework linking specific remediation strategies—physico-chemical stabilization, bioremediation, organic amendments—to measurable improvements in soil quality indicators and reductions in contaminant risk. The synthesis further revealed how research enterprise and policy instruments jointly influence the scalability and adoption of soil restoration practices.

The resulting conceptual framework demonstrates that effective mitigation of pesticide contamination contributes directly to multiple Sustainable Development Goals, including food security (SDG 2), climate action (SDG 13), and land degradation neutrality (SDG 15). Overall, this study provides an original integrative analysis of contaminant pathways, soil-function impacts, and restorative interventions, offering actionable insights for advancing sustainable soil management in global agroecosystems."

We leave it up to the editor to decide if this new abstract is in-line with our study and the reviewer's comment.

Reviewer's Comment 2. Weak flow in introductory sentences

First three sentences do not flow well; suggestion to focus on characteristics of fertile soils.

Authors' response: We appreciate this suggestion.

We have rewritten the introductory paragraph to establish a clearer narrative: beginning with the characteristics of fertile soils and their contribution to ecosystem services, followed by the pressures leading to soil degradation. This improves readability and relevance to the

manuscript's objectives (rephrased and refined as well). And, in fact, all of the "Introduction" section is made seamless.

Reviewer's Comment 3. Scope unclear; India-specific paragraph; mixing topics

Is the review global or India-specific? Paragraph 4 mixes soil functions with Black Cotton Soil.

Authors' response: We already clarify in the "Introduction" that the review is global in scope, with illustrative examples from different regions including India. We also separated the paragraph on soil functions from the example of Black Cotton Soil, placing the latter in a separate subsection where regional examples are appropriate.

Reviewer's Comment 4. Physico-chemical/biological methods mentioned in abstract but not in introduction

Authors' response: We have mentioned in brief (in the "Introduction") and highlighted physico-chemical and biological remediation methods is a dedicated paragraph (with additional references); this we believe provide continuity between the abstract, the remediation section, and the full text.

Reviewer's Comment 5. Lines 97–99 too short for a paragraph

Author response: We agree and have merged this segment with the latter paragraph to maintain standard paragraph structure.

Reviewer's Comment 6. Introduction too broad; section 1.2 should focus on pesticide-induced soil degradation

Authors' response: We have streamlined Section 1.2 to focus specifically on pesticide contamination, mechanisms of degradation, and impacts on ecosystem services; this is in-line with the stated objectives. Broader discussions (e.g., education for sustainability) have been removed or relocated to maintain thematic focus.

Reviewer's Comment 7. Aim and objectives inconsistent

Authors' response: We have revised the aims and objectives section to ensure alignment. The aim now clearly reflects the same scope as the objectives presented earlier.

Reviewer's Comment 8. PRISMA protocol mentioned but no method description

Authors' response: We have expanded the Methods section to include:

Specific search strategy (keywords, databases); Inclusion and exclusion criteria; Screening process; Data extraction procedures.
This clarifies adherence to key PRISMA recommendations.

Reviewer's Comment 9. Unnecessary expansion on Sustainable Development explanation

Authors' response: We have substantially condensed this section, retaining only the parts needed to connect soil pollution to sustainable land management and SDGs.

Reviewer's Comment 10. Expectation for more detail on physico-chemical/biological remediation

Authors' response: We have expanded the remediation sections to include detailed descriptions of chemical, phytoremediation, and bioremediation methods; we have included appropriate citations presenting emerging technologies and environmental implications. The reference list is updated.

Reviewer's Comment 11. Reference list formatting

Authors' response: The reference list has been reformatted for consistency following journal guidelines. All missing references have been added, and incorrect citations corrected. There are additional references added while writing the section on "physico-chemical and biological remediation…"

……..

Annexure B: Responses to the line-specific technical corrections

Below we address each point in detail and describe the revisions made.

- **Line 38:** Grammar issue; Corrected wording as suggested.
  Reviewer comment: "…pollutants in each of these phases and impact thereof…" → suggest "…pollutants in each of these phases and their impact…"

- **Figure 1:** Reviewer asks, "Did you make this figure?"
  Response: Yes; The Figure 1 is original

- **Line 53:** Grammar issue

  Reviewer comment: Add comma before "carbon sequestration" and also "et cetera"

- **Figure 2:** Reviewer asks, “Can you explain the diagram?”
- Response: We have expanded caption to explain point vs. nonpoint pathways.

  Point sources refer to identifiable, localized inputs (e.g., industrial discharge, spills). Non-point sources refer to diffuse inputs across landscapes (e.g., runoff, atmospheric deposition).

- **Line 196:** Incorrect citation

  Reviewer comment: (Zhang, Y. et al 2023)

  Response: Corrected to: Zhang et al., 2023.

- **Line 201:** Typo in organization abbreviation/name in the bracket

  Response: Corrected. The World Commission on Environment on Environment and Development (WCED)

- **Line 228:** Remove “and” at the beginning

  Response: Done! The text becomes: …….data was fairly often missing in many other such instances. **Participants** of…

- **Line 234:** Reviewer commented, “Figure 5 shows some key tools…” → prefer “several key tools for sustainable soil management.”
  Response: Revised for clarity. Revised text: Figure 5 shows several key tools for sustainable soil management.

- **Lines 239–240:** Reviewer says, “Add ISO reference. ”

  Response: The reference was already there! We corrected it as per the required format, and added a website link as well.

Reference: ISO (2024). ISO/TC 190 Soil Quality – Standard Methods Catalogue. International Organization for Standardization. https://www.iso.org/committee/54328.html

- **Line 291:** Reviewer point to the missing SOCI reference.

  Response: The reference was already there! Added SOCI website to reference list. In-text reference becomes (SOCI, 2024).

  Updated reference becomes: SOCI (2024). Sustainable Soils Alliance – UK Soil Crisis Report. Soil Observatory for Climate Initiatives.

- **Line 294:** Needed citation formatting.
  Reviewer comment: (Evans, D.L et al 2020)
  Response: Corrected. Revised citation: (Evans et al., 2020)

- **Line 295 & Line 296:** Rewrote sentence; clarified on what is irresponsible and what is not! As a response, the authors' wording **becomes: "***Soil degradation can arise from poorly managed irrigation, erosion processes, and other unsustainable land-management practices, which in turn can negatively impact soil fertility. Other…***"**

- **Lines 300–301:** Reviewer comment: First and second paragraphs not connected.

  Response: Improved paragraph transition for smoother flow. A couple of transition sentences have been added. Added text: *"Thus, while soil pollution is fundamentally a chemical deterioration process, it is closely intertwined with broader environmental stressors…"*

  "Together, these processes demonstrate that soil degradation and soil pollution are interconnected challenges, setting the stage for understanding how specific contaminants further compound the problem."

- **Line 315:** EPA reference was already there! Added as USEPA reference.

- **Line 322:** Incorrect citation. Corrected as per the journal style. Fantke et al., 2012.

- **Line 330:** Removed sentence-initial “And.”

- **Line 361:** WBCSD missing

  Response: New reference added as: WBCSD (1992). Changing Course: A Global Business Perspective on Development and the Environment. World Business Council for Sustainable Development.

  Actually, this reference was already cited in my manuscript as: Schmidheiny, S. with the WBCSD: Changing Course, A global business perspective on development and the environment, The MIT Press, 1992.

- **Line 366:** Corrected grammar (“…while in sub-Saharan Africa, mining is the major contributor”).

- **Lines 366–368:** Capitalization

  Response: Capitalised all region names. Corrected: Western Europe, Northern Africa, Eastern Europe.

- **Line 431:** Reviewer comment: Clarify sentence
  "the word chemical is currently becoming synonymous with contaminant."
  Response: Sentence retained but rephrased for clarity.
  Revised text: “Nowadays, when the word agrochemical—or even just chemical—is uttered in public, the term ‘chemical’ is increasingly perceived as synonymous with ‘contaminant,’ as many assume that chemical applications inherently disregard environmental concerns…
  There is a smooth transition into the next paragraph now.

At the same time, it is important to recognize that the benefits of agrochemicals coexist with substantial environmental challenges.

- **Line 496:** Remove “and”
  Response: Corrected.

- **Lines 504–507: Reviewer:** Too much detail about book

  Response: Book details moved to reference list only.

  Evuti, M. A., Salam, K. A., & Samuel, S. S. (2022). Application of soil washing treatment method for the remediation of petroleum-polluted soil. In *Research Anthology on Emerging Techniques in Environmental Remediation* (pp. 236–261). IGI Global. https://doi.org/10.4018/978-1-6684-3714-8.ch012

- **Lines 510–514:** Need species of bacteria/fungi
  Response: Added specific examples.
  Added text: “Key degraders include Pseudomonas putida, Bacillus cereus, Phanerochaete chrysosporium (white-rot fungus), and Trametes versicolor, all documented for efficient degradation of DDT, PAHs, and organochlorines.”

- **Line 516:** Omics introduced abruptly.
  Response: Added linking sentence or reintroduced omics tools with appropriate transition and clarified relation to bioremediation.

  Added text: “These biotechnological advances are complemented by omics tools, which provide molecular insights essential for optimizing bioremediation.”

- **Line 521:** Replaced “etc” with “et cetera.”

- **Line 526:** Corrected citations.

  “…over 70% of global pesticide use (Zhang et al., 2022; Tang et al., 2022).”

- **Line 527:** Removed “And.”

- **Line 535 (two comments):** Corrected reference; removed “And.” Ensure citation style correct. Rewritten as a response:

  “370 million kilograms of pesticides were sold in the EU in 2018 (Eurostat, 2020a).”

- **Lines 536–537:** EC 2017 citation added the reference to the list.

- **Line 546:** Completed citation (Wilson & Conway, 2024).

- **Line 547:** Reviewer asks, “What is CLU-IN?” and further demands a description in the reference list. Appropriate description and a relevant text in the manuscript added.

  “CLU-IN (Contaminated Site Cleanup Information) is a U.S. EPA–maintained knowledge platform that compiles technical information, remediation technologies, and documented case studies on contaminated site cleanup. It provides practitioners with evidence-based data on technology performance, costs, monitoring methods, and lessons learned from real remediation projects. In your context, CLU-IN (2024) represents a source of validated case studies that demonstrate advancements and practical outcomes in soil and site remediation.”

- **Line 564:** Clarified citation (EEA; EU, 2024).

  Commented as: The Vemmenhög catchment area saw a drastic reduction in transport of pesticides to surface waters (EEA; EU, 2024).

  Clarified in-text citation as well as in the reference list (EU EEA, 2024).

Note: Heartfelt thanks for those who provide us comprehensive and insightful feedback. We did our best to revise the manuscript as per all the suggested revisions to improve clarity, focus, structure, and technical accuracy.

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Annexure C: Anonymous Reviewer 2 editorial/technical comments *as-they-(exactly)-appear*

Congratulations to the authors for addressing such a comprehensive topic. My suggestion for the overall draft is that the direction and objectives of the paper need to be stated more clearly, and all paragraphs should support these objectives. Additionally, the flow between and within paragraphs can be improved for better readability.

1. I do not see the result of this paper in the abstract. As a reader, I assume that I will get the general result of this research. Is there any improvement in soil quality or any recovery of ecosystem services? How does it link to Sustainable Development Goals? What are the important factors to develop sustainable land, et cetera

2. The first two sentences and the third sentence (in the first paragraph of the introduction) do not have a good flow. My suggestion is (e.g. you can describe the characteristics of fertile soils and how they benefit ecosystem services, instead of describing the soils in general).

3. Does the paper review the current state of knowledge on the degradation of soil pollution in the world or only in India? lines 60-85: The idea of the 4th paragraph is biased. The description of soil function and black cotton soil in Deccan Plateau in India should be separated into different paragraphs.

4. In the abstract, it is mentioned that researchers explore physico-chemical and biological methods to mitigate soil contamination. However, I don't see authors explain/mention those physico-chemical and chemical methods in the introduction.

5. Lines 97-99: It is too short to be one paragraph. At least, there are 3 sentences in one paragraph

6. I think the introduction's explanation is too broad and does not focus on pesticide contamination, impact and implications as mentioned in the objectives. I expect in the sub-chapter 1.2, the authors more focus on soil degradation caused by pesticide contamination,the mechanism, and its impact on ecosystem service as mentioned in the objectives, but it seems like the flow becomes broad again by mentioning "there is also a need to promote teaching and learning for a sustainable society...(lines 114-118)"

7. lines 163-167: The aim of the study is different from the objectives mentioned in the previous paragraph.

8. line 181: Authors mentioned that they used the PRISMA protocol, but did not describe search strategy, inclusion and exclusion criteria, screening and selection process, and data extraction.

9. My suggestion is no need to explain more about sustainable development (lines 205 - 215). Authors can focus on soil pollution and later relate it to sustainable land / sustainable development

10. Since the authors mentioned physico-chemical and biological methods in the abstract, I expect the authors to have more explanation on chemical, phytoremediation, and

bioremediation. The latest technology, and its impact on soil and the environment, should be explained more clearly.

10. The reference list could be formatted more neatly. Kindly revise it!

technical mistakes:

line 38: pollutants in each of these phases and impact thereof on the quality of soil, --> I suggest ...pollutants in each of these phases and their impact on the quality of soil,

Figure 1. Did you make this figure?

line 53: ...temperature regulation, carbon sequestration, et cetera.

Figure 2: Can you explain the diagram? I dont understand the point and nonpoint pathways

line 196: …the citation is incorrect, perhaps (Zhang et al., 2023).

line 201: The World Commission on Environment on Environment and Development (WCED)

line 228:...data was fairly often missing in many other such instances, and participants of … --> no "and" in the beginning of the sentence.

line 234: Figure 5 shows some key tools for sustainably managing soil/Figure 5 shows several key tools for sustainable soil management.

lines 239-240: A standard method" catalogue for collecting and analysing contaminants is available with the ISO Technical Committee 190 (Soil Quality) --> add reference for this statement.

Line 291: reference of SOCI website 2024 is not in the reference list

line 294: (Evans, D.L et al 2020) --> the citation writing is incorrect

Line 295: "Irresponsible farming practice like irrigation and erosion" --> I do not think irrigation is an irresponsible farming practice, and erosion is not a farming practice.

line 296: . And other factors --> and is not placed at the beginning of sentence

lines 300-301: " Soil pollution is nothing but a chemical deterioration and degradation. Soil is under constant threat from climate change, hydrogeological cycle, natural landscape change or land use change, loss in biodiversity, and chemical pollution (Rockström et al., 2009)." --> The first and second paragraphs are not connected smoothly

line 315: USEPA is not in the reference list

line 322: The citation is not correctly written.

line 330: remove "and" at the beginning of the sentence

line 361: WBCSD is not in the reference list

line 366: ..while in sub-Saharan Africa is mining

lines 366-368: Western Europe, Northern Africa, Eastern Europe --> the first alphabet should be capital

line 431: the word chemical is currently becoming synonymous with contaminant.

line 496: remove "and" at the beginning of the sentence

line 504-507: no need to mention the detailed book of Evuti et al (2022). Authors can write the detailed book description in the reference list

line 510-514: I expect the authors to mention the type/species of bacteria and fungi that can be used as bioremediation

line 516: The description of omic tools is introduced abruptly. Is it part of bioremediation or biotechnology advances?

line 521: etc --> et cetera

line 526: that amounts to over 70% of all the global pesticide use (Zhang et al, 2022, Tang et al., 2022).

line 527: remove "and" at the beginning of the sentence

line 535: 370 million kilograms of pesticides had been sold in the EU in 2018 (Eurostat 2020a).

line 535: remove "and" at the beginning of the sentence

lines 536-537: the ambitious target of a climate-neutral EU by year 2050 (EC, 2020; EC, 2017; FAO, 2022). (EC, 2017) is not in the reference list

line 546: ...washing projects are being taken up to respect stringent environmental regulations (Wilson and Conway, 2024)

line 547: What is CLU-IN? It was also not described in the reference list

line 564: The Vemmenhög catchment area saw a drastic reduction in transport of pesticides to surface waters (EEA; EU, 2024).