

Review of the doctoral (PhD) dissertation titled

“Survey of Naturally Occurring Radionuclides in Soils, Water, and Rice from Artisanal and Small-Scale Gold Mining Affected Areas in Ghana”

by Lordford Tettey-Larbi

The topic of the dissertation is important, because artisanal and small-scale gold mining is present in Ghana and may have significant environmental impacts. During mining activities, naturally occurring radionuclides can be released into different parts of the environment, such as soils, surface and groundwater, and agricultural products. This may lead to potential radiological exposure for the local population. Therefore, the investigation of the environmental distribution of radionuclides and their possible transfer through the food chain is highly relevant. The topic is not only scientifically relevant, but also of clear environmental and societal significance.

I had the opportunity to participate in the candidate’s preliminary defence and in the initial review of the dissertation, which allowed me to follow in detail the development and refinement of the work; the candidate has taken into account the earlier comments and suggestions, therefore my evaluation of the final version is summarised below, in accordance with the regulations of the Doctoral School.

The dissertation text is carefully written and generally easy to read. It is evident that the candidate has invested considerable effort in preparing the manuscript. Only minor formatting inconsistencies were observed.

The figures and images are generally clear and of good quality, and they are placed in appropriate locations in the text. The theoretical background has an appropriate length, and its role in supporting the interpretation of environmental processes is clear.

The structure of the dissertation generally follows the format required by the Doctoral School. The overall organisation of the dissertation is logical and coherent.

In the literature review chapter, the author presents the environmental occurrence and behaviour of naturally occurring radionuclides and discusses radiological aspects related to mining activities. The relevant scientific literature has been well collected and used. The reference list contains a large number of publications, and the citations are correctly indicated in the main text. The literature is processed adequately; however, a more explicitly critical evaluation of selected key studies could further strengthen this chapter. The results are appropriately compared with relevant literature data.

The experimental and results chapters constitute the most important part of the dissertation. The author describes the sampling strategy, sample preparation procedures, and the applied analytical methods. Using gamma spectrometry, radionuclide concentrations in soil, water, and rice samples were determined. Based on these results, the radiological characteristics of the investigated areas and the potential radiation exposure of the population are evaluated. The final version of the

dissertation introduces transfer factors (TF) and concentration ratios (CRW) to quantify radionuclide migration between soil, water, and rice. These parameters are subsequently applied in the Results and Discussion (Section 4.6.1) and form the basis for the interpretation of transfer pathways and the corresponding thesis statements. The applied methods are appropriate, reliable, and consistent with current international practices, and the data evaluation is methodologically sound.

The author formulated the results of the dissertation in six thesis points. Based on these thesis statements and the content of the dissertation, the main scientific results can be summarised as follows:

Distribution of Naturally Occurring Radionuclides in Mining-Affected Soils

Mean activity concentrations of ^{238}U (24 ± 3 Bq/kg), ^{232}Th (25 ± 3 Bq/kg), and ^{40}K (328 ± 63 Bq/kg) were determined. Values are generally within international reference ranges, although localised hotspots (e.g., Ayanfuri, Obuasi) exceed global averages.

Radiological Characteristics of Water Resources

Surface waters show elevated radionuclide levels (e.g., ^{226}Ra : 1.15 ± 0.21 Bq/L), resulting in an annual dose of 0.41 ± 0.08 mSv/y (approximately four times higher than the WHO guideline) and an ELCR of 1.59×10^{-3} . Groundwater sources comply with WHO and Ghana Standards Authority limits and are considered safe for consumption.

Radionuclide Uptake in Rice and Associated Risk

Rice activity concentrations (e.g., ^{226}Ra : 5.03 ± 1.75 Bq/kg) result in ingestion doses of 0.016-0.151 mSv/y and an ELCR of 0.291×10^{-3} , both below international thresholds, indicating no significant radiological risk.

Radiation Exposure of the Local Population

The total effective dose remains ≤ 1 mSv/y, in accordance with ICRP recommendations; however, ingestion of contaminated surface water represents a potentially significant long-term exposure pathway.

Quantification of Radionuclide Transfer Pathways

Transfer analysis (TF, CRW) reveals distinct pathways:

- ^{226}Ra : water-dominated uptake (CRW ≈ 4.37),
- ^{40}K : soil-dominated uptake (TF ≈ 0.12),
- ^{232}Th : limited transfer (TF ≈ 0.07 ; CRW ≈ 1.10).

These results represent new scientific contributions, particularly in the quantitative characterisation of radionuclide transfer pathways and the identification of rice as a partial bioindicator of environmental radioactivity.

According to the regulations of the Doctoral School, obtaining the PhD degree requires the presentation of independent scientific work through written publications. The candidate fulfils these requirements and has an adequate number of scientific publications related to the topic of the dissertation.

Overall, the author has completed the objectives defined in the dissertation. The work demonstrates that the candidate has achieved research results that meet the formal and scientific requirements of the doctoral degree. The dissertation follows the principles of scientific ethics, and the results are properly supported by the presented data. The conclusions are well supported by the results, although a more integrated discussion across environmental media could further strengthen the interpretation.

Based on the above, the PhD dissertation is a valuable work and fully meets the scientific and formal requirements for a PhD degree. The candidate has demonstrated a high level of competence in research methodology, data analysis, and scientific communication.

Based on the work carried out by the candidate, as well as their scientific activity and results, I recommend the acceptance of the dissertation and - upon a successful defence - the awarding of the PhD degree to the candidate.

Szekszárd, May 05, 2026



Dr. Radó Krisztián

Questions:

What is the difference between the estimation of outdoor and indoor gamma dose exposure, and how is this reflected in the calculation and interpretation of radium equivalent activity (Raeq)?

How does the radiological impact of artisanal and illegal mining compare to the environmental and health risks posed by heavy metals (e.g., Hg, Cd, As, Cu) and organic contaminants (e.g., fuel spills, cyanide) associated with these activities?