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Review Report on the thesis in fulfilment of the requirements for the degree of Doctor of Philosophy, University of Adam Mickiewicz Poznan, Poland

Author: Dr Juliana Souza-Kasprzyk

Title: " Biogeochemistry of chemical elements in Arctic soils: multi-factor effects on element concentrations from different locations in Billefjord, Svalbard"

Scientific Supervisor: prof. dr. hab. Przemysław Niedzielski

The presented review report is organized in the following sections: reviewer statement, project background, general description of the thesis, specific comments followed by a final evaluation statement.

Reviewer statement

At the beginning of the review of this dissertation, I think it is important to clarify that I assessed this work from the perspective of a geographer and a researcher on the transformation of polar landscapes, rather than that of a chemist. I trust that the intention of the Discipline Council in selecting me as one of the reviewers was to properly assess the environmental elements of the work by a scientist who is well acquainted with the chosen area and has conducted research in selected glacial valleys. My assessment precisely emphasizes these elements.

Project background

Although most Arctic regions are far from large, industrialised zones, the circumpolar environment bears traces of man-made pollution - from soot to plastics, methane to pesticides. It is important to note that some pollution can be created in the Arctic, for example by burning wood, coal and other fossil fuels. However, many pollutants are transported long distances, reaching Arctic through rivers, oceans and air - where they can have far-reaching negative effects on the environment and human health. To some extent Arctic region acts like a reservoir or 'sink' for industrial and agricultural chemicals from Europe, Asia and even further afield

which are transported there in the air and ocean currents. The cold temperatures, permafrost and glacial environments trap the toxics in the ground, air, water and ice where they degrade very slowly. In the summer when the ice melts, the toxins get washed into the valleys or directly to the seas. Reports published by AMAP (Arctic Monitoring & Assessment Programme) show that major contaminants in the Arctic region are heavy metals, such as mercury and lead, and persistent organic pollutants, which evaporate into the air but are slow to degrade. These toxic materials bioaccumulate in the food chain, passing from planktonic organisms through fish, and then on to larger wildlife.

Despite this tremendous research effort there are areas that still require deepened study. Candidate in her doctoral research decided to challenge one of the underexplored problems in the discipline the contamination of Arctic soils.

Geographical focus of the thesis was one of the best studied areas of Svalbard Archipelago (High Arctic) – northern part of Billefjorden in Central Spitsbergen. Quite unique setting offering sites with different levels of human impact such as abandoned, Soviet mining town Pyramiden and pristine valleys with rapidly retreating glaciers. The overarching aim of PhD thesis was to investigate the multiple factors that can affect the accumulation of chemical elements including Essential Elements (EEs), Potentially Toxic Elements (PTEs), Rare Earth Elements (REEs) and Other Elements (OTs).

Thus, this thesis addresses the highly relevant and vital areas of current Arctic environmental contamination research.

General description of the thesis

The submitted thesis presents investigations on biogeochemistry of chemical elements in Arctic soils.

The dissertation comprises 175 pages (plus 5 pages of Appendix with the scientific achievements of the Author – the Candidate has already achieved a PhD in Biology) and does follow the classic structure of a PhD thesis in natural and physical sciences (traditional monograph).

Thesis begins with abstract and a general introduction to Arctic region, which directly leads to a characteristics of chemical elements and Arctic contamination. This part is providing a background for understanding the rest of the thesis.

Surprisingly, the main goals of the thesis are presented in Chapter 2. *I'd expect to have the major aim of the thesis presented in the opening chapter.*

Second chapter should consist of a literature review and includes the fundamentals of the biogeochemistry of chemical elements in soils with emphasis on cold region soils and explanation what are a key differences in soil contamination processes between polar and lower latitude environments. *I expect the Candidate to provide such an explanation during the defence.*

It is understandable that, with a scientific field as developed as environmental chemistry, it is difficult to cite all the key papers, but I am nevertheless surprised

by the lack of reference to a few papers from the Arctic and sub-Arctic regions, which would have been excellent papers to compare and expand the discussion. *I recommend checking the following works from various parts of Arctic region and confront their findings with results obtained in this study:*

Perryman, C.R.; Wirsing, J.; Bennett, K.A.; Brennick, O.; Perry, A.L.; Williamson, N.; Ernakovich, J.G. Heavy metals in the Arctic: Distribution and enrichment of five metals in Alaskan soils. *PLoS ONE* **2020**, *15*, e0233297.

Kowalska, J.B.; Nicia, P.; Gašiorek, M.; Zadrożny, P.; Węgrzyn, M.H.; Waroszewski, J. Are Natural or Anthropogenic Factors Influencing Potentially Toxic Elements' Enrichment in Soils in Proglacial Zones? An Example from Kaffiøyra (Oscar II Land, Spitsbergen). *Int. J. Environ. Res. Public Health* **2022**, *19*, 13703. <https://doi.org/10.3390/ijerph192013703>

Antcibor, I.; Eschenbach, A.; Zubrzycki, S.; Kutzbach, L.; Bolshiyarov, D.; Pfeiffer, E.M. Trace metal distribution in pristine permafrost-affected soils of the Lena River delta and its hinterland, northern Siberia, Russia. *Biogeosciences* **2014**, *11*, 1–15.

Or

Lund K.E.; Young K.L. Contaminant Transport in High Arctic Soils: A Tracer Experiment. *Permafrost and Periglacial Processes* **2005**; *16*, 195-207.

The main part of the thesis consists of two chapters (Chapters 3-4). Chapter 3 explains the methodology and experimental design. Chapter 4 presents results of laboratory analyses and discusses the main findings. Linking results with discussion is not a standard approach. *I think that presenting the discussion in a separate chapter would improve the structure of the work.*

The final section (Chapter 5) is the weakest part of the thesis and only vaguely meets the criteria of a dissertation summary chapter. In general thesis conclusions should: a) clearly state the answer to your main research question; (b) summarize and reflect on your research process; (c) acknowledge the limitations of your research; (d) show what new knowledge you have contributed to your field; (e) make recommendations for future work on your thesis topic.

I expect that during the defence this is how the key achievements and conclusions of the dissertation will be presented.

The thesis figures are prepared in good editing standard. The language is comprehensive and coherent at least for readers for whom English is not their mother tongue. Errors and inaccuracies are relatively rare (however, please check the translation of Norwegian names used in the text – for instance one of the glaciers in Adolfbukta catchment is called Pollockbreen NOT Pollackbreen),

Specific comments

The subject that could have been treated in more depth are processes responsible for soil formation in polar climates and clear definition of soil used in the thesis. *I expect the Candidate to explain what she considered to be soil and how she distinguished soils from deposits.* In general, soils are vertically weathering profiles that develop in place. Soils require time and a stable ground surface to develop. On the contrary, sediments, are particles transported by water, mass movement or wind or by people. We call these transported sediments deposits. So deposits of sediment are the result of movement, while soil profiles develop in the absence of movement.

Third chapter starts with a description of a study area, part which I would expect in the introduction, where selection of site is explained in detail and key environmental characteristics are described.

From the perspective of geographer this part requires an essential correction during the defence and has to be addressed by the Candidate with great commitment. The key missing information in the study area description are climatic and geological conditions. Those two factors – climate and geology decide on the formation process and type of soil evolving in given place.

The selected study area is characterized not only by specific climatic conditions, when comparing to western coast of Spitsbergen, where most of research stations are located, but its' geological structure is also unique. Surrounding of the northern Billefjorden offers a spectacular insight into geological history of the Archipelago and modern geological processes. The area is cut by one of the most important fault zones in the region – N-S trending Billefjorden Fault Zone what exposes a complex set of rocks to the earth surface. From old crystalline rocks, through clastic sandstones and coal to sequences of carbonates such as anhydrites and gypsum. It is known that *soil consists of rock that has been modified by physical and chemical interaction with organic material, rainwater, and organisms.* Therefore, soil chemistry developing in Billefjorden had to some extent reflect that unique diversity of geological units. *I would to ask the Candidate to check whether it is by chance the geology of the local glacial valleys that determines the differences in concentrations of specific elements. Please note that the east and west coasts of Petuniabkuta - are geologically different worlds. During the defence, I expect the candidate to answer the question of whether the chemical components present in a particular type of rock were not the main determinant of the concentration of elements and contaminants in a particular soil type.*

With reference to soil types, the dissertation lacks information on which soils the samples came from. *Does the Candidate see any chance of reconstructing from field notes, photographs and archival material what types of soils were tested?* I am aware that the dissertation is not in soil science but the lack of basic recognition of the soil

types is puzzling. In this setting I would expect to find initial loose soils and poorly developed soils, which are typical for rare vegetation and dry tundra ecosystems. During the defence *I expect the Candidate to present field sketches or photographs of sites from where the samples were collected and a short characterization of soil type.* If there are not available a short commentary and explanation is needed.

It would also be a great improvement in the quality of the results presented if reference were made to local climatic conditions including the presence of permafrost in the ground - *whether its presence has an impact on the concentration of contaminants in soils - I would like to know the Candidate's opinion on this.*

Finally, I am also curious to know whether differences in the concentration of contaminants in soils depend on the degree of glaciation of the valley in question. The study area has one of the best-recognised glacial recession rates on the whole island, so it seems reasonable to compare how the concentration of specific pollutants changes in areas with different glacial ice cover. For instance, the case of Ferdinand valley, almost completely left by glacier may suggest that decay of ice mass very quickly results in lowering of elements concentration.

Final evaluation statement

I appreciate the candidate expertise in the field of environmental chemistry applied to polar environment, which added new information about the soil contamination in one of the key sites for environmental change monitoring in Svalbard. I am aware that the Candidate previously received a PhD in biological sciences from Federal University of Rio de Janeiro. During her first doctoral thesis she researched contaminants in Antarctic penguins. Therefore, I regard the Candidate as a specialist in polar biology who wished to expand her knowledge of contaminants in this unique environment. The information received about the candidate suggests that her research interests include anthropogenic impacts on the polar environment, ecotoxicology, marine pollution, environmental health, and scientific communication. The Candidate therefore represents the type of scientist who cares about broad research horizons and is not afraid of new challenges. This is an important quality that should be appreciated. I would like the Candidate to take my review as an indication of what elements in a research work prepared by an adept chemist are expected by environmental change researchers (geologists, geographers), and to use this in the future. It is important to note that her work was conducted and prepared for publication during the outbreak of COVID-19 pandemic, what had blocked fieldwork organization in 2020 and 2021 and limited the more extended sampling strategies.

I trust that the candidate will clarify most of my concerns about environmental conditions during the defence. I hope that the shortcomings shown by the geographer, which relate primarily to soil science and climatic and geological

controls, will be erased by the demonstration of high chemical skills to be assessed by other experts.

In conclusion, the dissertation submitted to me for evaluation by Dr Souza-Kasprzyk constitutes an original solution to the problem posed and meets the requirements for dissertations PhD thesis by the Act of 20 July 2018 "Law on Higher Education and Science" (Journal of Laws 2018, item 1668). In my opinion, this thesis is ready to be defended orally.

In view of this, I submit to the Scientific Council of the Discipline of Chemical Sciences of the University of Adam Mickiewicz University in Poznań to admit Dr Souza-Kasprzyk to the further stages of the proceedings for the awarding of the degree of doctor in the field of sciences and natural sciences in the discipline of chemistry.



Mateusz C. Strzelecki
Alfred Jahn Cold Regions Research Centre
Institute of Geography and Regional Development
University of Wrocław