Jakub Buda

Accumulation, mobility and bioavailability of radioisotopes and their impact on selected components of supraglacial ecosystem

Abstract

Anthropogenic impact on the ecosystem components at different levels of organisation has significantly increased since the Second World War, especially in highly industrialised areas. However, even remote polar and mountain regions are not contaminant-free anymore, and the legacy of our actions in the form of pollutants has spread over the globe. One of the high-risk stressors are radioisotopes, which became a particular threat as a result of military actions and nuclear power plant accidents. Radioisotopes formed by humans, called artificial radioisotopes, peaked in deposition in the 1960s. However, due to the long half-life of some of them, they persist in the global ecosystem.

Dark biogenic sediment on the surface of glaciers worldwide effectively accumulates atmospheric-delivered pollutants, including radioisotopes. This sediment, called cryoconite, is important in the functioning of the supraglacial ecosystems and glacier-adjacent ecosystems, as it can provide nutrients for biological succession after glacier retreat. On the other hand, due to its dark colour promotes glaciers melting. The concentration of radioisotopes in cryoconite is higher than in surrounding habitats. Therefore, all actions towards understanding what impact elevated concentrations of radioisotopes may have on glacial ecosystems and what shape radioisotope distribution and concentration are crucial. The primary goal of this thesis is to understand whether elevated concentrations of radioisotopes may threaten organisms inhabiting glaciers and surrounding ecosystems.

The results obtained in this study provide a comprehensive overview of the spatial distribution, bioaccumulation and potential threats of increased levels of ionising radiation on glaciers by analysing 22 glaciers covering the most glaciated areas of the Alps. This research is one of the few that attempts to answer the question of whether anthropogenic radioactivity also affects organisms outside nuclear disaster sites or nuclear weapons testing sites and first investigates radionuclide-organisms relations on glaciers.

The results of the first chapter revealed a positive association between ^{137}Cs and ^{210}Pb activity concentrations and organic matter content. In addition, ^{210}Pb was also positively related to chlorophyll concentration, suggesting an influence of the photoautotrophic communities in the bioaccumulation. The mobility analysis has revealed that ^{137}Cs are firmly bound to minerals in 72%, while ^{210}Pb is more mobile with a high fraction bound to organic-metallic complexes. ^{137}Cs is only partially associated with organic

matter. However, as it is firmly bound to the outer layers of minerals, it can interact with microbial communities that build biofilms on mineral grains, which seems an important fraction in cryoconite. The activity concentrations observed in the top consumers were detected but relatively low for ^{137}Cs, ^{210}Pb and $^{239+240}Pu$, while not detectable for ^{238}Pu being orders of magnitude lower than those found in contaminated areas like the Chernobyl exclusion zone. Overall, the results indicate that both radionuclides show different spatial relations with organisms and likely have a different fate during glacier melting.

Interglacial analysis of ^{137}Cs, ^{210}Pb and ^{241}Am in the second chapter has revealed that glacier features (surface area, altitude and the amount of organic matter in the cryoconite) play a more significant role in the accumulation of radioisotopes than geographic factors. Apart from the organic matter content in cryoconite and elevation (significant for ^{210}Pb), the glacier's surface area emerges as the most critical predictor of radioisotope activity concentrations on Alpine glaciers. The activity concentration of natural and anthropogenic radioisotopes increases as the glacier's surface area decreases. This suggests that a significant proportion of radioactivity is bound to the supraglacial sediment during glaciers melting.

The most important outcome of the third chapter is that microbial communities in cryoconite holes on the surface of glaciers are influenced by environmental radioactivity due to elevated activity concentrations of fallout ^{137}Cs and ^{210}Pb. In the case of bacteria, the effect is similar for both nuclides, while in the case of eukaryotic communities, ^{210}Pb has a stronger effect for decreasing species richness. These results are supported by the risk assessment in the previous chapters, where ^{210}Pb is more strongly associated with organic matter and organisms itself, while ^{137}Cs with mineral fractions.

Overall, the thesis provides the first evidence that elevated concentrations of radioisotopes on glaciers are an effect of bioaccumulation by surface glacier biota and can threaten biodiversity and ecosystem function. This might be important, as the small glaciers in the Alps are predicted to disappear within the next 50 years, releasing stored radioisotopes. If so, we could witness intense abiotic pressure on glacier and glacier-adjacent ecosystems. A systematic, coordinated monitoring of pollutants released by glaciers can be a key to understanding this problem globally.