亞北極土壤和苔蘚中硫和微量元素的濃度與冰島亨吉爾地熱發電廠的關係——生態影響

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摘要

在全球加速增加地熱能利用的計畫中，對發電廠排放物的生態反應確知之甚少。本研究的目的是調查冰島西南部 Hengill 地熱發電廠排放元素在生態系統中的累積情況，與植物生長和健康狀態的關係。苔蘚 *Racomitrium lanuginosum* 被用作生物指示劑，是研究區域的主要植物。本研究測定了土壤和 *R. lanuginosum* 芽中硫的濃度，並評估了 Hellisheidi 和 Nesjavellir 兩個地熱發電廠不同距離和方向上苔蘚的生長情況。Nesjavell 發電廠附近苔蘚中的硫濃度隨著與發電廠距離的增加而降低。土壤中的硫也呈現類似的趨勢。Hellisheidi 發電廠附近苔蘚中的硫濃度隨著與發電廠距離的增加而降低，而土壤中的硫濃度則呈現相反的趨勢。Nesjavellir 周圍土壤含較高濃度的硫，推測是因硫從腐爛的苔蘚中轉移到土壤的時間更長。而發電廠周圍土壤的硫濃度高於苔蘚中的硫濃度，則是因為苔蘚主要從大氣中吸收養分的特性。平均而言，Hellisheidi 的苔蘚生長狀況較 Nesjavellir 佳。結果顯示，地熱發電廠排放的硫沉積在周圍的生態系統中，尚未發現明確的負面影響。

關鍵字：內斯亞維利爾電廠、赫利謝迪電廠、苔蘚生長、地熱發電廠、排放量

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Concentrations of sulphur and trace elements in subarctic soils and mosses in relation to geothermal power plants at Hengill, Iceland – ecological implications

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ABSTRACT

Amidst the globally accelerated plans to increase geothermal energy utilization, knowledge of ecological responses to power plant emissions is limited. The aim of this study is to investigate ecosystem accumulation of elements emitted from power plants in the Hengill geothermal field in Southwest Iceland, in relation to patterns of plant growth and health. The moss *Racomitrium lanuginosum* was used as a bio-indicator, a dominating plant in our study areas. Concentrations of sulphur, arsenic, boron, antimony, and mercury in soil and shoots of *R. lanuginosum*, were determined, and growth and other moss characteristics (moss damage, physiology and mat depth) assessed at different distances and directions from two geothermal power plants, Hellisheidi (303 MWe, operated since 2006) and Nesjavellir (120 MWe, operated since 1990). Higher concentrations of these elements were detected around Hellisheidi than Nesjavellir. Sulphur, antimony, and mercury concentrations in moss decreased with increasing distance from the power plant around Nesjavellir, while arsenic concentrations increased with increasing distance away and boron concentrations were relatively low, below detection. Similar trends for sulphur and antimony followed in soils. Arsenic concentrations in soil on the other hand, increased with increasing distance from the Nesjavellir power plant while boron concentrations were, below detection limit except at 250 m downwind and at 1000 m and 4000 m upwind. At Hellisheidi, sulphur and boron concentrations, in moss decreased with increasing distance away from the power plant and showed an opposite trend in soil. Arsenic, antimony and mercury concentrations in moss showed a general increase in concentrations with increasing distance away from the power plant; while in soil, trace element concentrations did not change significantly with distance, and there were no clear patterns related to the direction of prevailing winds. On average, moss growth and other moss trait values were higher at Hellisheidi than Nesjavellir. At Nesjavellir, moss mat depth and biomass moss response variables increased with increasing distance away and were greater upwind than downwind; while shoot turnover (%) and chlorophyll concentration decreased with increasing distance away from the power plant and did not vary with direction. Moss shoot length did not vary with distance but showed a decrease downwind. At Hellisheidi, trends were non-linear with distance, however biomass increase was the only response variable significantly higher downwind than upwind: other variables did not vary with direction. The frequency of moss damage was quite low around both power plants. We thus conclude that emitted sulphur from the geothermal power plants is deposited in the surrounding ecosystem and has so far no clear indications of harmful effects. In addition, the emerging patterns of arsenic, boron, antimony and mercury concentrations in the ecosystem were not clear to indicate deposition from the geothermal power plants and there were no related harmful effects. Nonetheless, further long-term monitoring of potential environmental impacts is advised. We recommend experimental studies to establish in detail if and how different levels of sulphur deposition may affect ecosystems for appropriate mitigation.