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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Introduction

- The effects on human health of hydrogen sulphide and trace elements that may be found in geothermal power plant emissions and volcanic activities
- High levels of geothermally emitted elements may also be hazardous to the natural ecosystems, causing toxicological stress on plant and animal life and affecting ecosystem functions
- Research on the impact of geothermal power plant emissions and volcanic activities on non-vascular plants like mosses is limited.

Introduction

- The aim of this study :
  1. Ecosystem accumulation of elements emitted
  2. Relation to patterns of moss growth
  3. Physiological traits of moss
  4. Moss damage
- This study assessed the chemical compositions of the soil and the dominating moss species, *R. lanuginosum*., at different distances along transects in the prevailing wind direction.
- Prediction :

  Element concentration in moss and soil is higher when more close to the power plants than further away, and higher downwind than upwind, and the concentration pattern is reflected in moss health.

Materials and methods

Study area and species

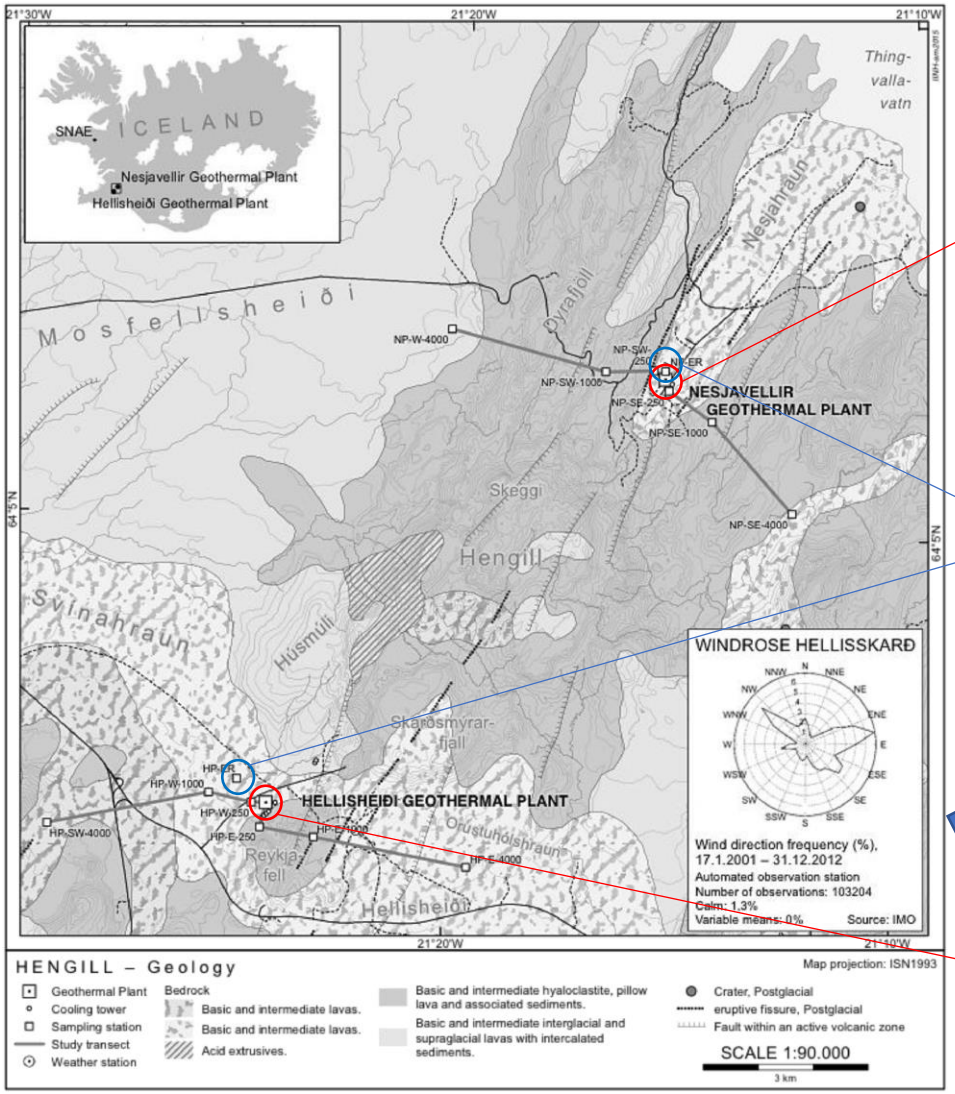

Fig.1.

Nesjavellir power plants
- Installed capacity :120MWe
- H2S : 9816 tonnes/year
- Operated since 1990
- Above sea level:180 m
- to the north in a small valley

Extensively damaged areas

Wind

[illegible]i power plants
- [illegible] capacity :303MWe
- H2S : 10072 tonnes/year
- Operated since 2006
- Above sea level: 260 m

Study design, sampling and field measurements

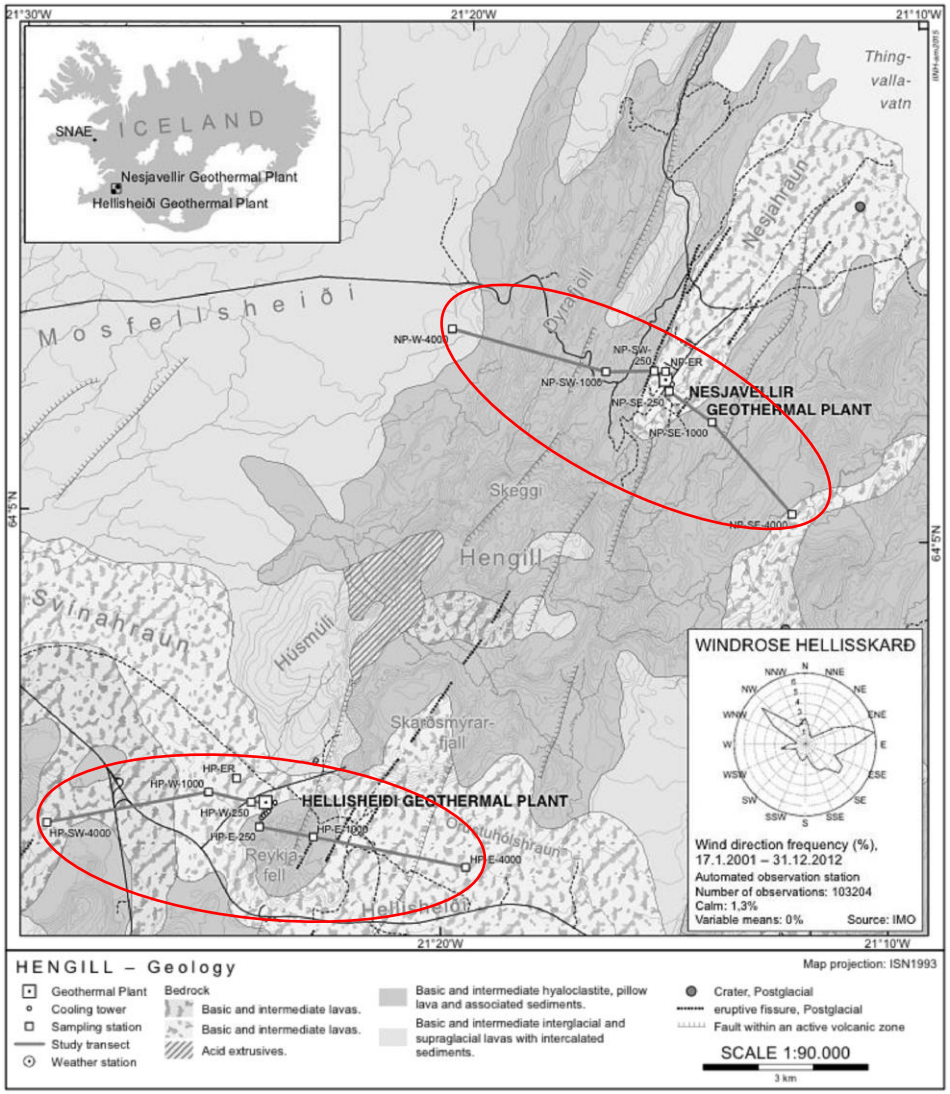

Fig.1.

- Two 4 km transects were selected at each power plant : one upwind (E) and one downwind (W)
- Sampling stations were selected at 250 m, 1000 m, and 4000 m from the power plants along each transect

R. Lanuginosum

- Widespread distribution
- Dominance
- Sensitivity to atmospheric contaminants
- Highly relies on atmospheric sources for nutrients

Study design, sampling and field measurements

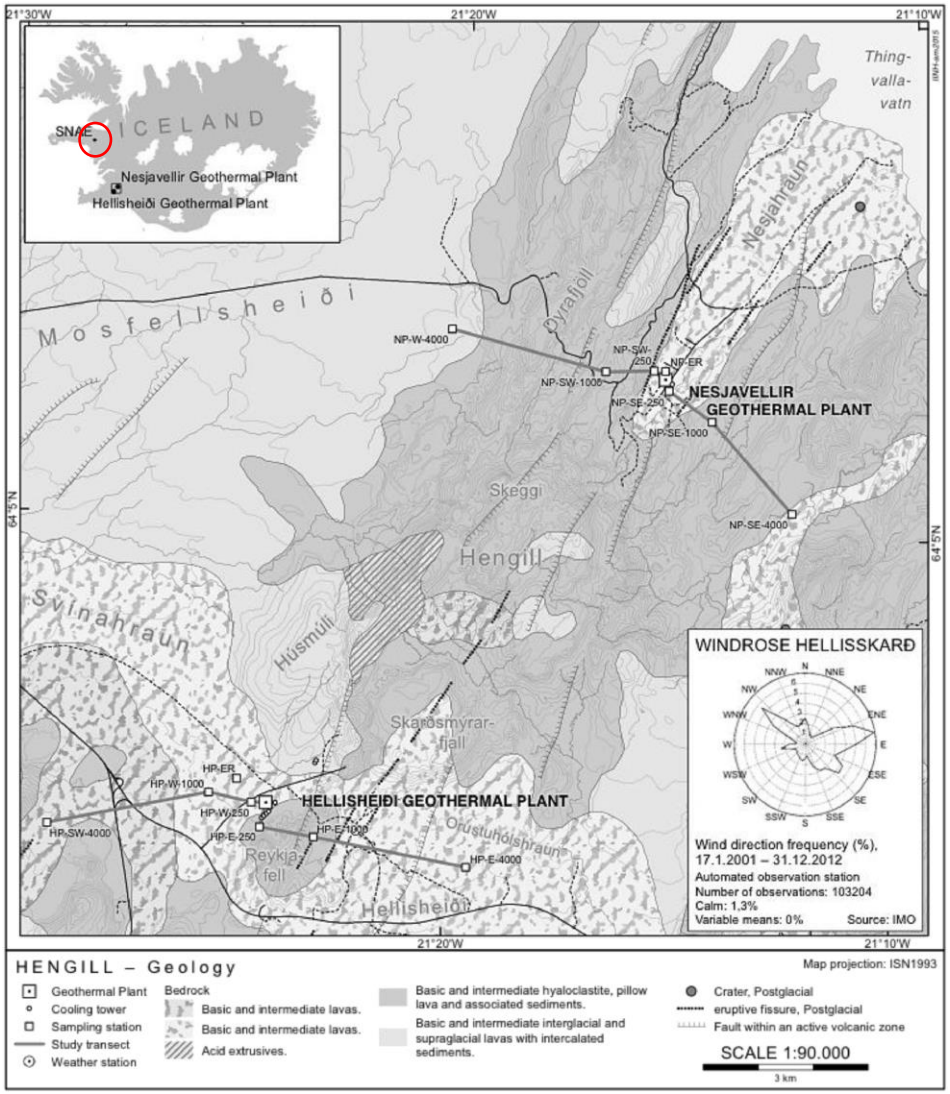

Fig.1.

- The data set was divided into four groups

1. Systematic sampling area
2. Damaged moss patches
3. The presumably geothermally unaffected area with a similar ecosystem, Raudhalsahraun
4. The extensively damaged areas

Results &Discussion

Element concentrations in moss – systematic sampling

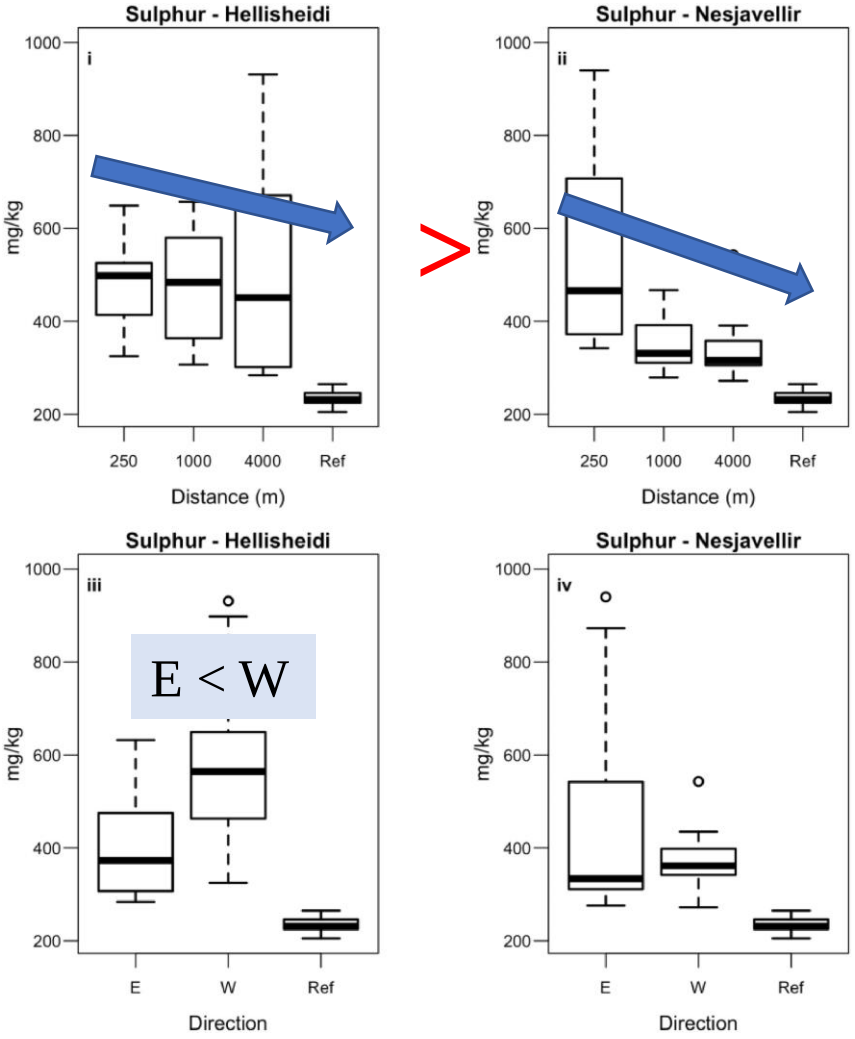

Fig. 2a. Concentrations of sulphur in R. lanuginosum shoots at Hengill

The concentration of elements varies more with distance and direction at Hellisheidi than at Nesjavellir.

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1. The Nesjavellir geothermal power plant is situated in a valley, well sheltered from the easterly wind.
2. The Hellisheidi geothermal power plant lies exposed at a higher elevation.

Element concentrations in moss – systematic sampling

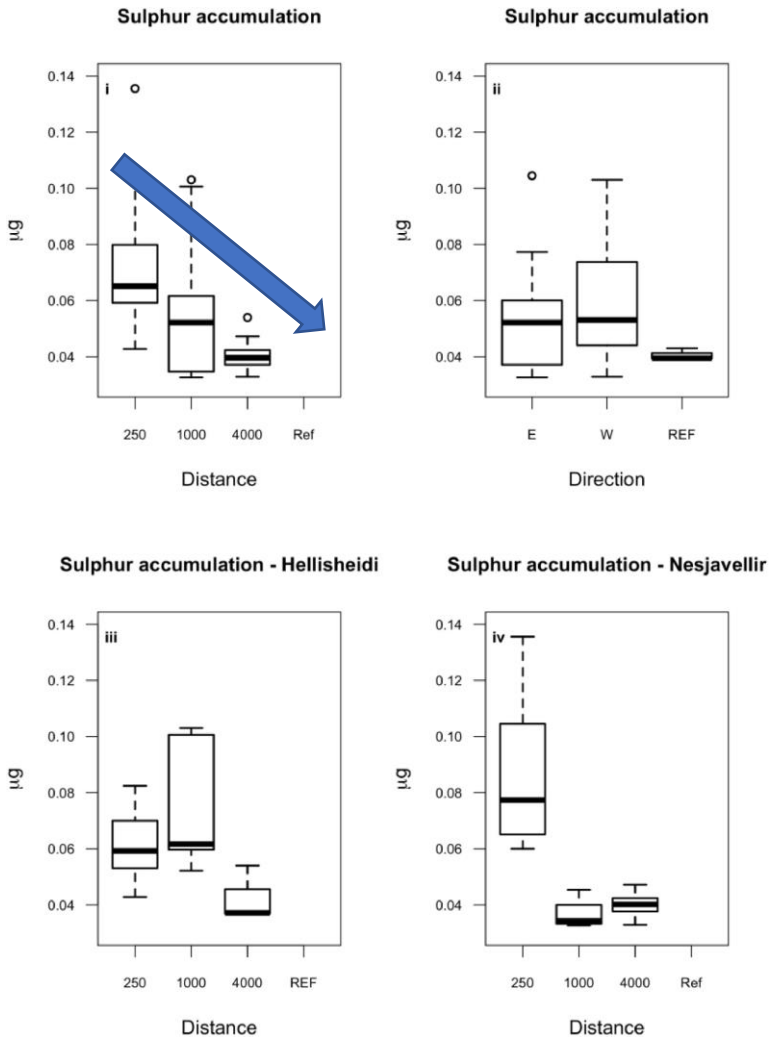

Fig. 2b. Sulphur accumulation in R. lanuginosum shoots in Hengill at the systematically sampled areas

- Sulphur accumulation in moss shoots tended to be higher closer to the power plants than further away
- Direction and location did not affect sulphur accumulation in R. lanuginosum shoots

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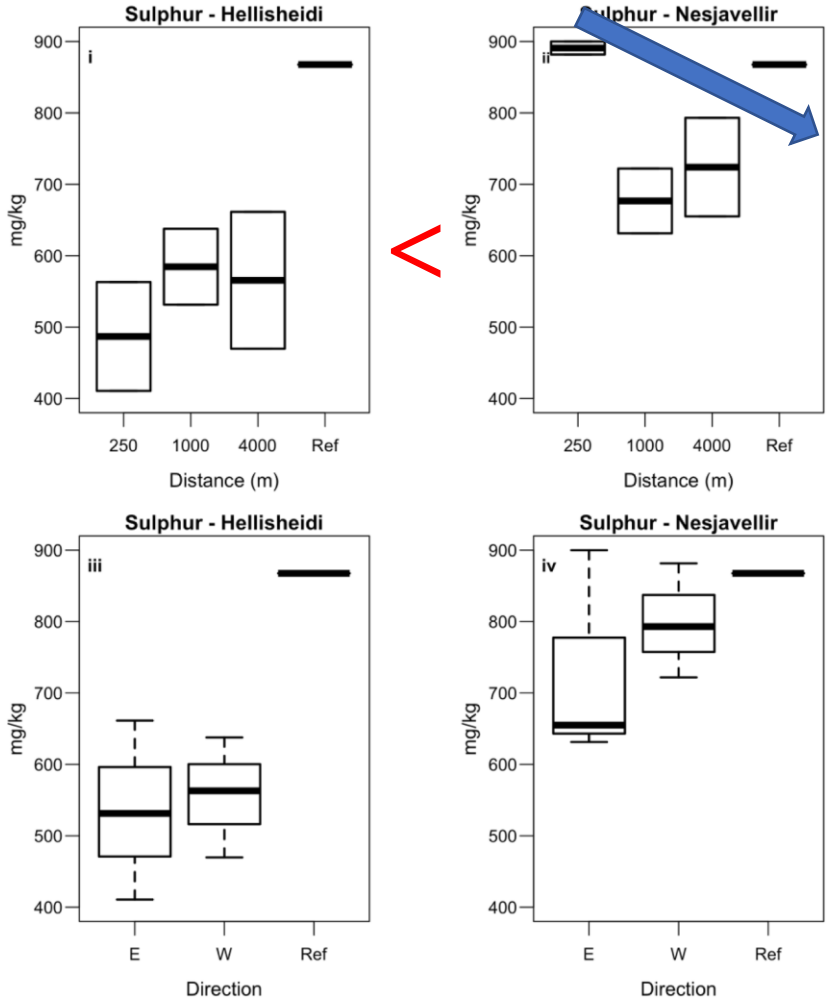
Element concentrations in soil – systematic sampling



The trend of high sulphur concentrations in Nesjavellir soils

- A transfer of sulphur from the decaying moss to soil (bio-accumulation) over a longer period of time at the Nesjavellir power plant (since 1990) compared to Hellisheidi (since 2006).

Fig. 3. Concentrations of sulphur in soil in Hengill

Element concentrations in soil – systematic sampling

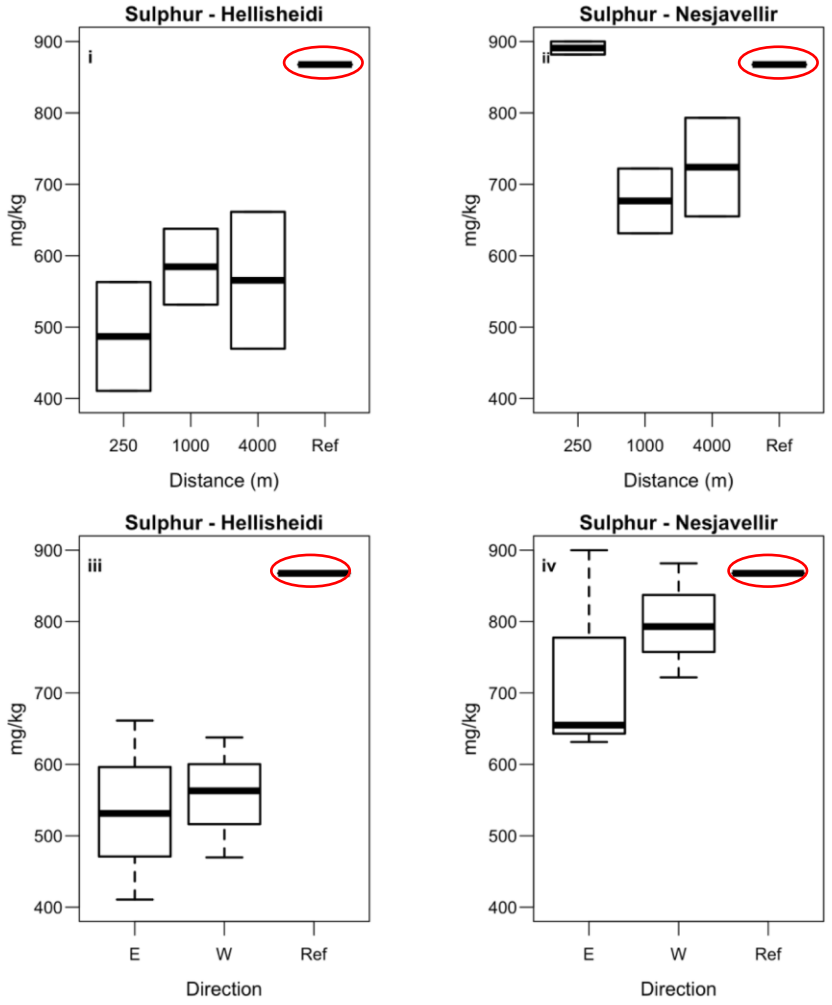


Fig. 3. Concentrations of sulphur in soil in Hengill

Soils in the Raudhalsahraun reference area had the highest sulphur concentrations, 13% more than in the Hengill geothermal area.

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1. This could be due to different concentrations of sulphur in Raudhalsahraun lava and Hengill lava and/or due to differences in the age of the lava.
2. The Raudhalsahraun area is more exposed to ocean spray, with more marine deposited SO4 than at Hellisheidi.

Element concentrations in soil – systematic sampling

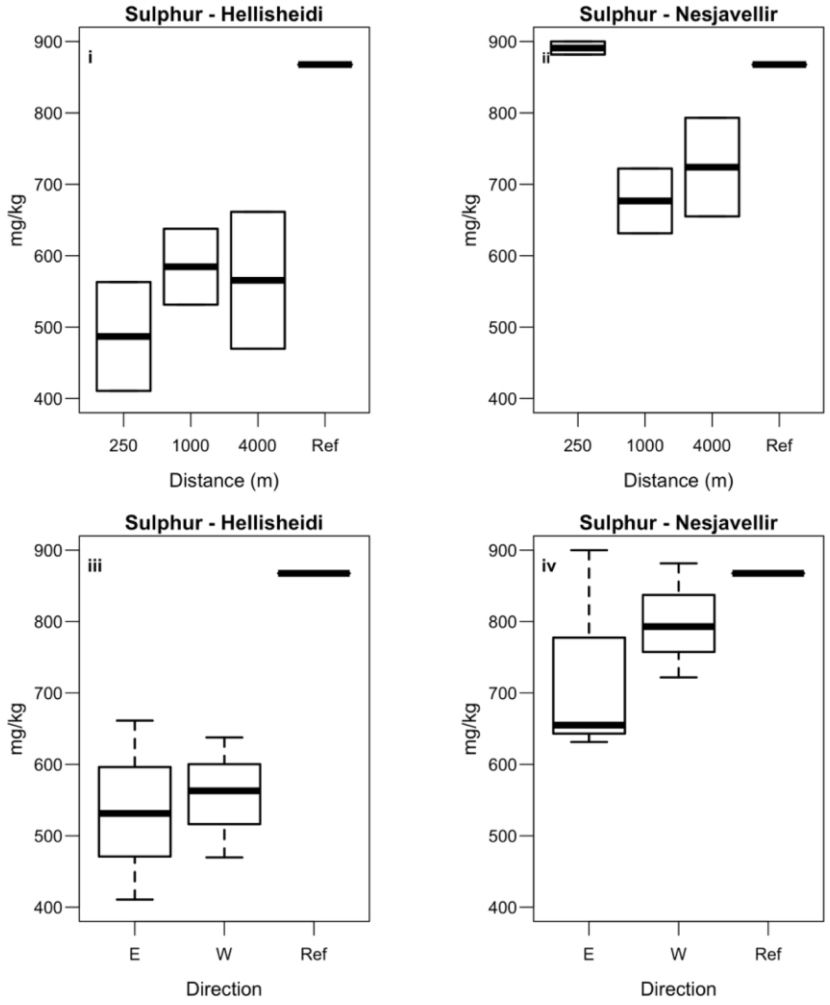

Fig. 3. Concentrations of sulphur in soil in Hengill

Around the power plants, sulphur concentrations were overall higher in soils than in moss tissues.

- This is because of the ectohydric nature of the rootless mosses where nutrient/element uptake is mainly passive, directly from the atmosphere.

Moss traits and moss damage– systematic sampling

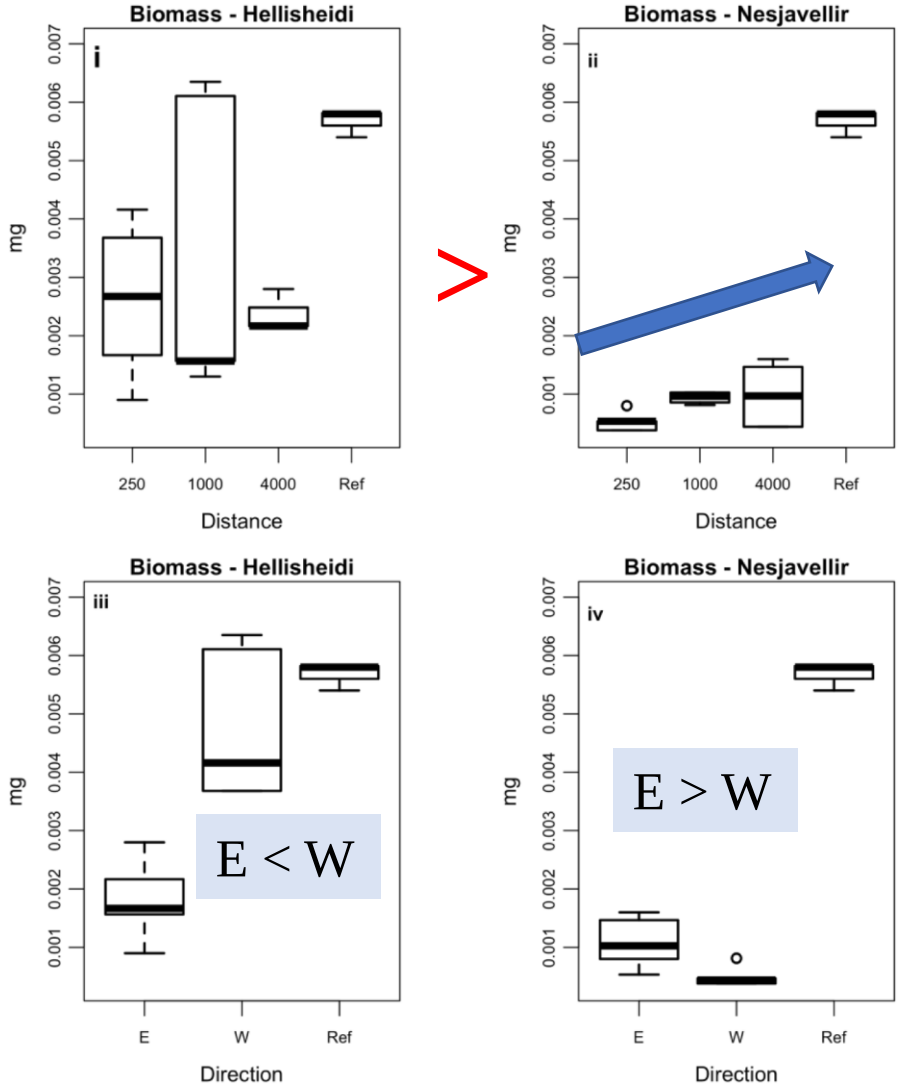

Fig. 4. The biomass increase of Racomitrium lanuginosum shoots (growth) at Hengill

The pattern of increasing moss growth about distance at the Nesjavellir power plant and less growth downwind than upwind.

- As sulphur concentration in moss at Nesjavellir was high when close to the power plants, it could be that the mosses received excessive sulphur enrichment which negatively affected their growth.

The element concentrations in moss in the systematic sampling and damaged moss patches did not reveal any significant correlations with element concentrations in soil .

Conclusion

- Element concentrations in moss and soil differed between the two power plants in southwest Iceland.
- Moss growth was greater at the power plant where moss element concentrations were high.
- There are some trends of high element deposition in moss and soil around the Hengill geothermal power plants.

Thank you for listening

- Why The comparable H2S gas emission levels between the two power plants
- may be due to the geothermal power developer (Reykjavik Energy) that have contributed a 25% decrease in H2S gas emissions from the Hellisheidi power plant. This is being done through gas re-injection (H2S and CO2) and sequestration as minerals in nearby, subsurface basaltic formations.

- They also determine some soil characteristics, including pH, moisture content, total carbon, and total nitrogen.
- These characteristics were considered as other environmental factors that could affect soils and ultimately plant health and were included in our statistical models as co-variables.

Sampled

- The stations were located on convex lava ridges, exposed to wind and dominated by thick (at least 10 cm) and dense moss mats of R. lanuginosum.
- Due to the topography of the area, the sampling stations varied in altitudes, between 138 m and 420 m above sea level. At each sampling station, we systematically sampled along a 20 m sub-transect perpendicular to the main transect. Ten 10 × 10 cm squares were marked at 2 m intervals along these sub-transects.
- At each 10 × 10 cm square, moss damage was scored (brown to indicate deteriorating health or black colour indicating extensive damage) to obtain the frequency of damage for each station

Table 2

Element	Direction	Distance (m)	Nesjavellir		Hellisheidi		Reference area	
			Shoot	Soil	Shoot	Soil	Shoot	Soil
Sulphur	W	250	375.50 ± 9.64	875.00	446.60 ± 34.53	565.5		
		1000	363.30 ± 13.77	778.83	594 ± 12.39	637		
		4000	360.10 ± 23.63	764.17	687.20 ± 56.69	566.67		
							234.40 ± 5.55	**867.67**
	E	250	700.50 ± 49.17	838.83	511.50 ± 17.41	370.5		
		1000	331.60 ± 16.39	704.5	357.10 ± 11.04	575		
		4000	312.50 ± 6.60	543.17	323.20 ± 15.19	620		
Arsenic	W	250	<0.1	2.46	1.44 ± 0.11	1.45		
		1000	<0.1	1.35	2.12 ± 0.20	2.84		
		4000	0.20 ± 0.02	1.09	2.34 ± 0.41	2.14		
							<0.1	**0.23**
	E	250	0.30 ± 0.02	1.14	<0.1	1.40		
		1000	0.40 ± 0.02	1.12	<0.1	1.83		
		4000	0.50 ± 0.02	1.12	0.30 ± 0.03	2.43		
Boron	W	250	<1	2.2	3.44 ± 0.62	3.81		
		1000	<1	<1	4.76 ± 1.48	2.34		
		4000	<1	<1	<1	<1		
							<1	**3.05**
	E	250	<1	<1	<1	2.98		
		1000	<1	3.62	<1	3.08		
		4000	<1	2.47	<1	3.87		
Antimony	W	250	0.02 ± 0.00	0.24	0.17 ± 0.01	0.15		
		1000	0.02 ± 0.00	0.17	0.22 ± 0.02	0.31		
		4000	0.03 ± 0.00	0.16	0.25 ± 0.03	0.26		
							0.04 ± 0.00	**0.11**
	E	250	0.03 ± 0.00	0.14	0.03 ± 0.00	0.17		
		1000	0.02 ± 0.00	0.12	0.03 ± 0.00	0.19		
		4000	0.02 ± 0.00	0.09	0.04 ± 0.01	0.25		
Mercury	W	250	0.04 ± 0.00	0.08	0.06 ± 0.01	0.06		
		1000	0.03 ± 0.00	0.08	0.09 ± 0.01	0.15		
		4000	0.02 ± 0.00	0.06	0.13 ± 0.02	0.09		
							0.01 ± 0.00	**0.18**
	E	250	0.04 ± 0.00	0.06	0.06 ± 0.00	0.05		
		1000	0.02 ± 0.00	0.04	0.03 ± 0.01	0.07		
		4000	0.02 ± 0.00	0.04	0.06 ± 0.02	0.13		

Moss characteristics	Direction	Distance (m)	Nesjavellir	Hellisheidi
Moss mat depth (cm)	W	250	19.27 ± 2.47	28.17 ± 2.05
		1000	22.96 ± 1.87	17.50 ± 1.37
		4000	25.59 ± 1.87	28.63 ± 2.56
	E	250	20.03 ± 1.72	30.23 ± 0.76
		1000	27.56 ± 2.36	27.52 ± 0.93
		4000	33.20 ± 2.36	26.90 ± 2.53
Shoot length increase (cm)	W	250	0.46 ± 0.25	0.63 ± 0.09
		1000	0.50 ± 0.06	0.60 ± 0.06
		4000	0.37 ± 0.03	0.10 ± 0.00
	E	250	0.43 ± 0.03	0.50 ± 0.06
		1000	0.40 ± 0.06	0.53 ± 0.03
		4000	0.04 ± 0.06	0.53 ± 0.03
Shoot turnover (%)	W	250	3.00 ± 1.71	2.41 ± 0.29
		1000	2.39 ± 0.61	3.56 ± 0.63
		4000	1.64 ± 0.19	0.52 ± 0.16
	E	250	2.08 ± 0.22	1.70 ± 0.31
		1000	1.63 ± 0.35	1.82 ± 0.16
		4000	1.13 ± 0.20	2.14 ± 0.42
Chlorophyll concentration mg/g	W	250	0.04 ± 0.01	0.06 ± 0.01
		1000	0.05 ± 0.02	0.67 ± 0.12
		4000	0.02 ± 0.01	0.06 ± 0.01
	E	250	0.18 ± 0.03	0.04 ± 0.05
		1000	0.11 ± 0.02	0.04 ± 0.00
		4000	0.04 ± 0.01	0.04 ± 0.01

Moss Characteristics	Nesjavellir	Hellisheidi	Reference area
Moss mat depth (cm)	11.39 ± 1.22	23.18 ± 3.36	21.76 ± 1.45
Chlorophyll concentration (mg/g)	0.011 ± 0.00	003 ± 0.08	0.01 ± 0.02
Shoot length increase (cm)	NA	NA	0.57 ± 0.03
Shoot turnover (%)	NA	NA	2.94 ± 0.18