# Atmospheric deposition of beryllium in Central European mountains

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## INTRODUCTION

Little is known about atmospheric input of beryllium (Be) into ecosystems, despite its highly toxic behavior. Atmospheric deposition of beryllium in the Czech Republic was evaluated using Be concentrations in precipitation at 10 remote mountain-top locations (Fig.1, Table 1). We focused on winter months, and separately evaluated Be concentrations in rime (horizontal deposition) and snow (vertical deposition).

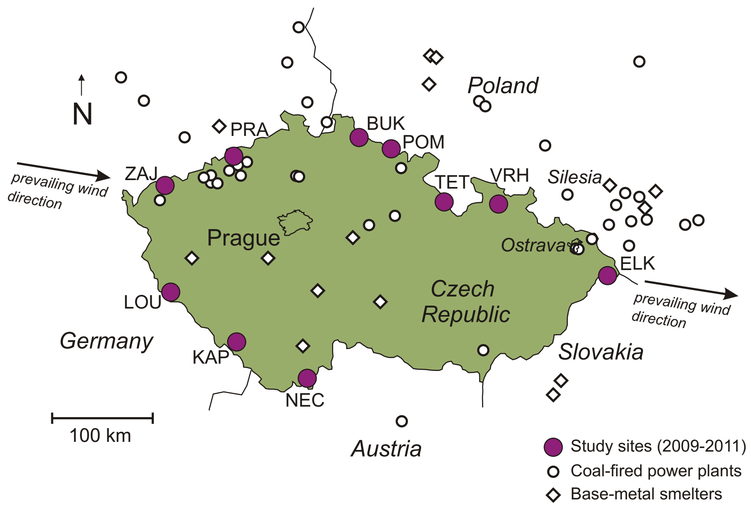



*Figure 1. Map of sites.*

## METHODS

Three identical, specially designed, sampling devices were installed at each site for the sampling of rime (Fig.2). Snow was collected from snowpack surfaces (30 by 10 cm, 3 cm deep) in triplicate. Sector-field ICP MS with an extremely low detection limit of 0.03 ppt was used to measure Be concentration. Beryllium was determined both in filtered waters, and in HF digests of solid particles.

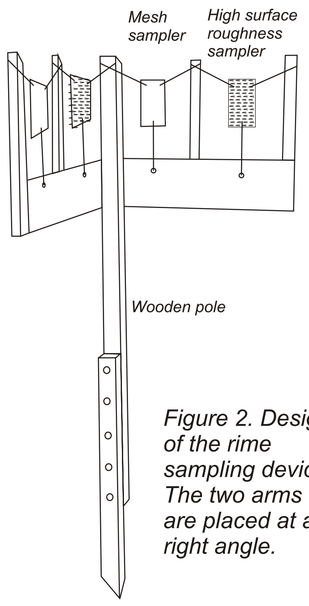



*Figure 2. Design of the rime sampling device. The two arms are placed at a right angle.*

## RESULTS I

Be concentrations in precipitation rarely exceeded the ppb level.
Across the sites, 7 times higher concentrations were found in rime than in snow (6.1 vs. 0.9 ppt; Fig. 5). Rime scavenged the pollution-rich lower segments of clouds.
Comparison of fresh and old snow (Figs. 6b,c) provided an estimate of vertical wet and dry deposition (Fig. 7b).
We found spatial differences in Be inputs within the Czech Republic, the highest total Be input was found in the northeast of the country, close to the Polish border (Fig. 7a).

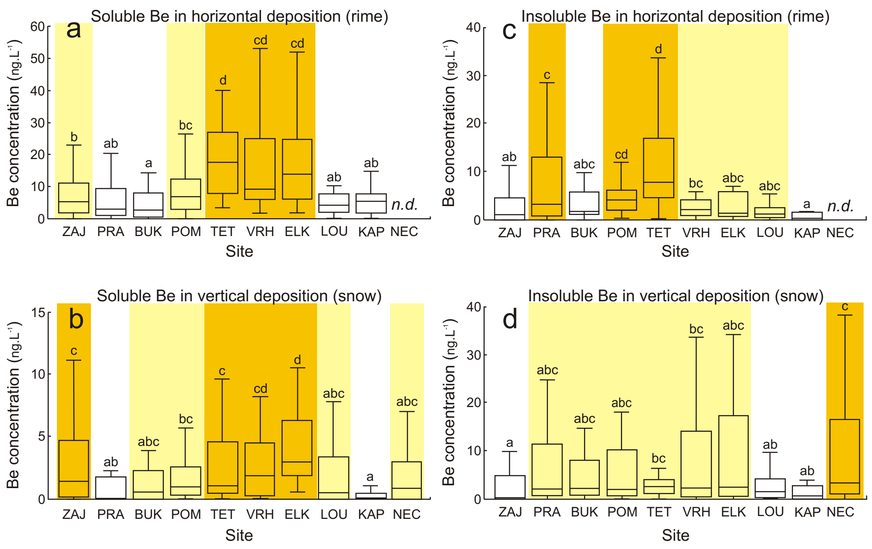
*Figure 3. Kamenna loucka, Bohemian Forest Mts. (LOU).*

*Table 1. Site characteristics.Sites were selected in places remote from local sources of pollution specifically for this study. The distance of each sampling site from the nearest dwelling and/or trail was at least 2 km. As a rule, the nearest village or road was situated at a 5-10 km distance from each study site. The distances between two neighbouring study sites were about 80 km.*

| Site | | Location | Elevation (m a.s.l.) | Mean annual temperature (°C) | Mean annual precipitation (mm) |
|---|---|---|---|---|---|
| ZAJ Zajeci vrch | Ore Mts. (west) | 50°23´ N, 12° 43´E | 1 008 | 4.8 | 982 |
| PRA Pramenac | Ore Mts. (east) | 50°42´ N, 13° 43´E | 935 | 4.3 | 857 |
| BUK Bukovec | Jizerske Mts. | 50°48´ N, 15° 21´E | 1 006 | 2.5 | 1360 |
| POM Pomezni hreben | Giant Mts. | 50°43´ N, 15° 49´E | 1 183 | 1.5 | 1415 |
| TET Tetrevec | Eagle Mts. | 50°16´ N, 16° 26´E | 987 | 4.7 | 1301 |
| VRH Pricny vrch | Jeseniky Mts. | 50°13´ N, 17° 22´E | 954 | 4.9 | 1018 |
| ELK Velky Polom | Beskydy Mts. | 49°30´ N, 18° 40´E | 1006 | 5.1 | 1295 |
| LOU Kamenna loucka | Cesky les Mts. | 49°22´ N, 12° 46´E | 925 | 4.8 | 1016 |
| KAP Kaprad | Bohemian Forest Mts. | 48°51´ N, 13° 46´E | 941 | 4.7 | 953 |
| NEC Kamenec | Novohradske Mts. | 48°34´ N, 14° 39´E | 988 | 4.4 | 827 |

*Figure 4. Rime samples.*

*Figure 5.Box plots of Be concentrations in rime and snow. Outliers are not shown. Darker yellow vertical bands denote higher-pollution area.*




## RESULTS II

In general, 34% of the total beryllium was in soluble (bioavailable) form (Fig. 7a).
Beryllium fluxes decreased in the order: vertical dry deposition insoluble > vertical dry deposition soluble > horizontal deposition soluble > vertical wet deposition insoluble > vertical wet deposition soluble > horizontal deposition insoluble. The average contributions of these Be forms to total deposition were 56, 21, 8, 7, 5 and 3 %, respectively.
Figs. 8a,b show that there was no correlation among Be and sulfate concentrations in rime and snow.
Figs. 9a,b compare sulfate concentrations in rime and snow across the study sites. There was no correlation between mean snow pH and mean Be concentration.

*Figure 6. Relationship between insoluble and soluble Be concentration in vertical deposition (snow; a) at the site ELK. The amount of both soluble (b) and insoluble (c) Be in snow increase with snow age.*

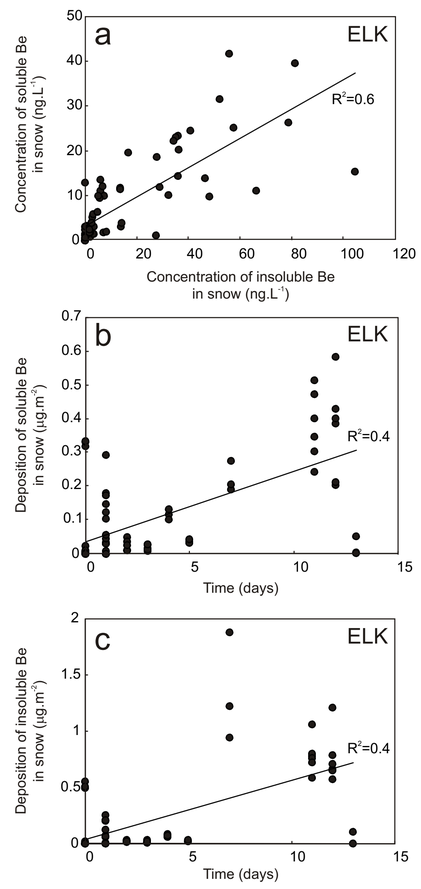



*Figure 7. Winter-time deposition of Be at the study sites; a- total deposition; b- percentages of individual types of Be fluxes.*

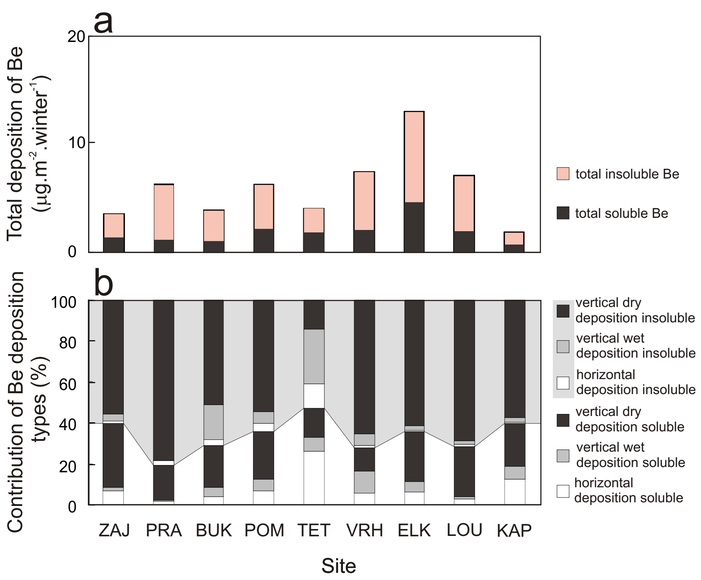



*Figure 8. Lack of correlation between Be and sulfate concentration. a snow, b rime.*

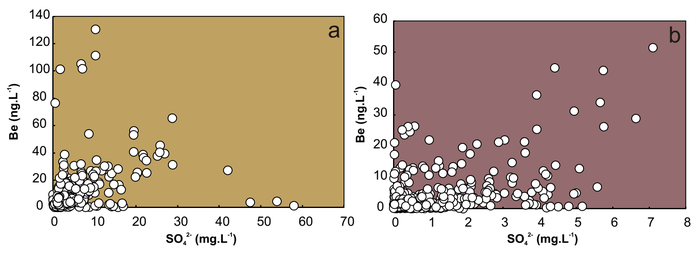



*Figure 9. Systematics of sulfate concentrations in rime (a) and snow (b) at the 10 Czech study sites. Vertical shaded bands in the background of sulfate concentration box plots indicate the level of Be pollution (dark yellow band - the highest Be concentrations, white background - the lowest Be). c pH values in snow at 6 small forested catchments (unpublished monitoring database by Fottova) situated near our study sites. In the inserted map the catchments are marked with grey solid circles.*

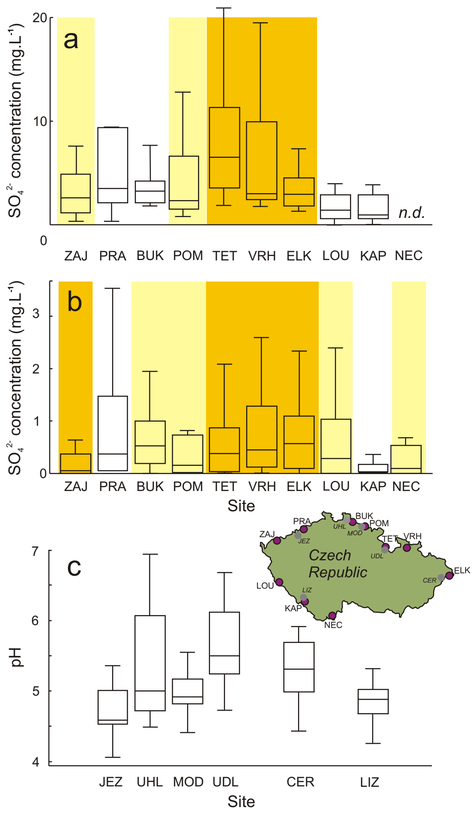
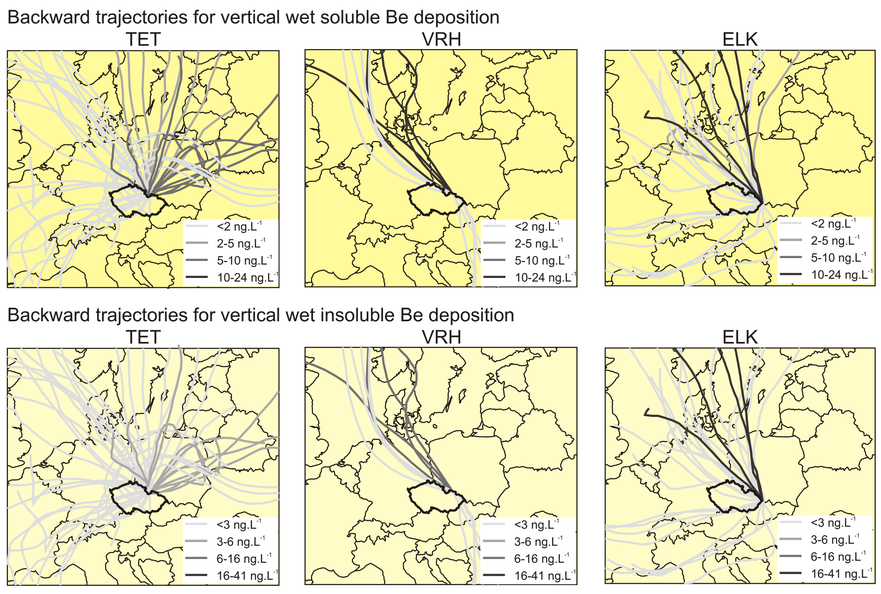



*Figure 10. Collecting rime samples.*

## RESULTS III

We used HYSPLIT model to compute backward trajectories of air masses and to identify possible sources of Be pollution for the most polluted sites in the northeast (Fig. 11). The industrial part of southern Silesia (Poland) was the largest source of Be for the Czech Republic.

*Figure 11. Back trajectories of air masses for fresh snow. The three sites in the northeast were selected for model HYSPLIT application.*

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