

Snow pollution over three decades in Luleå, Sweden

Pollution de la neige sur trois décennies à Luleå, Suède

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RÉSUMÉ

Le développement rapide de nouveaux matériaux et de nouvelles technologies dans le secteur automobile et la croissance urbaine entraînent des changements dans les émissions de certains polluants dans l'environnement et l'introduction de nouveaux polluants. Cela peut entraîner des changements dans la signature et la teneur en polluants de la neige urbaine. Il est donc important de revoir périodiquement les données rapportées sur la qualité de la neige urbaine afin de s'assurer que la planification de la gestion de la neige est basée sur des informations actualisées. Dans cet article, les concentrations de MES et de métaux urbains omniprésents (Zn, Cu, Cr et Pb) dans la neige urbaine, échantillonnée sur six sites de la ville de Luleå pendant l'hiver 2020-21, ont été comparées aux données précédentes (de 1995 et 2002) pour examiner les changements historiques de la qualité de la neige à Luleå au cours de la période 1995-2021. Les résultats montrent que les concentrations de polluants dans la neige sont influencées par les températures de l'air et les précipitations mesurées, et que ces influences entraînent des incertitudes dans les comparaisons de données.

ABSTRACT

Rapid development of new materials and technologies in the automotive sector and urban growth cause changes in emissions of certain pollutants to the environment and introduction of new ones. This can cause changes in the pollutants signature and content in urban snow. Thus, it is important to revisit the reported data on urban snow quality periodically to ensure that snow management planning is based on up-to-date information. In this paper, the concentrations of TSS and ubiquitous urban metals (Zn, Cu, Cr and Pb) in urban snow, sampled at six sites in the City of Luleå during the winter 2020-21, were compared with previous data (from 1995 and 2002) to examine historical changes in snow quality in Luleå during the period 1995-2021. The results show that the pollutant concentrations in snow are influenced by measured air temperatures and precipitation, and such influences bring uncertainties into data comparisons.

KEYWORDS

urban snow, TSS, metals, pollution

1 INTRODUCTION

Urban snow and snowmelt pollution have been studied for the past 50 years. The focus of these studies were sources of pollution and accumulation of pollutants (Kuoppamäki et al., 2014; Moghadas et al., 2015). Fast material evolution in the vehicular sector, urban growth, and climate change cause changes in emission of some pollutants to the environmental and introduction of new pollutants. For example, banning Pb additives in gasoline reduced Pb emissions from vehicular traffic. Sb concentrations in urban road environment increased rapidly because of replacement of asbestos in brake lining by Sb in the early 1980s (Hjortenkrans et al., 2006). The fine particles derived from wear and tear of metal tire studs made of tungsten carbide are the main source of tungsten. Thus, the assessment of impacts and development of new pollutant control measures requires updating the data on pollutants in snow. This study aims to quantify the occurrence of pollutants in urban roadside snow and examine the historical changes in snow pollution in the City of Luleå over the period 1995-2021.

2 METHODS

Three snow sampling programs were conducted in the Luleå municipality (65°35'N and 22°10'E), northern Sweden, during 1994-95, 2002-03, and 2021-22. The municipality has a population of 78500 and population density of 16 inhabitants/km² (<https://www.lulea.se>, 2021). Temperature in Luleå varies between -30°C to +30°C during a year and winter lasts for around 180 days with snow cover from end of November until April (around 150 days) (<https://www.smhi.se/data/meteorologi/temperatur>). The first study was performed in the winter 1994-95 (Viklander, 1997), the second study during the winter 2002-03 (Reinosdotter, 2007) and the third study during the winter 2020-21. Six sampling sites were selected: three in the central city and three in a residential area, in all three sampling programs. The snow was collected from snowbanks near roads with three different traffic intensity categories: high (>20,000 vehicles/day), intermediate (5000-20,000 vehicles/day) and no traffic (zero vehicles/day). In the residential area, the traffic intensity categories at the sampling points were as follows: intermediate (around 5000 vehicles/day), low (1000 – 4000 vehicles/day) and no traffic intensity (zero vehicles/day). The details of the sampling locations are presented in table 1.

Table 1 Sampling site characteristics

Type of area	Traffic intensity (vehicles/day)	Notation	Comment
Central City	0	C0	Park in downtown
	13000	C1	Connecting road – intermediate traffic
	21000	C2	Swedish highway no 94 – high traffic
Residential area	0	R0	Residential area – away from streets
	1500	R1	Residential street – low traffic
	4500	R2	Connecting road – intermediate traffic

Snow samples were collected using an 1 m long and 12 cm in diameter titanium ice drill. A snow sample was taken at the highest point in snowbank by drilling a hole through the snowbank vertically from top to bottom. After drilling the hole, the snow from the hole was removed and placed in plastic bags. The distance of sampling hole from the edge of snowbank, and the diameter and the depth of the hole, were measured.

The temperature and precipitation data for the sampling sites were abstracted from the Swedish Meteorological and Hydrological Institute (SMHI) website, for a period of about 6 months (November to April for all the three sampling programs) and presented in figure 1.

The collected samples were weighed and melted in separate Teflon bags at the Environmental Laboratory, Luleå University of Technology. The melted samples were shaken well, and subsamples were extracted for TSS and metal analyses. TSS analysis was carried out using the method specified in the Water Investigations Method SS-EN 872:2005 (SS EN 872, 2005). Analysis of total metals was done by ICP-SFMS, as specified in SS EN ISO 17294-2: 2016 and US EPA Method, by an accredited laboratory, ALS Scandinavia AB, in Luleå.

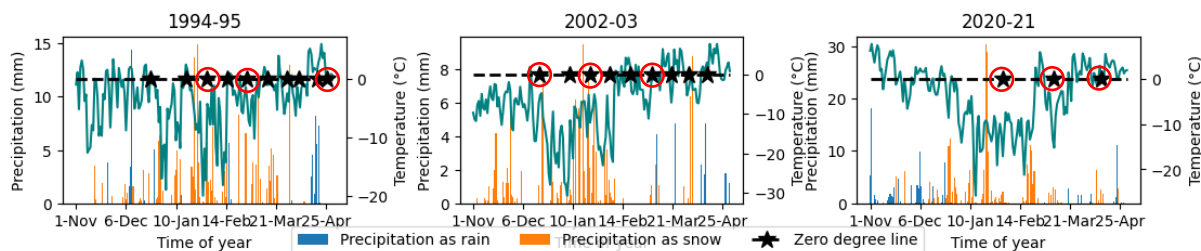


Fig. 1 Temperature and precipitation data for 1994-95, 2002-03 and 2020-21 (selected sampling occasions for this study are marked in red circles)

3 RESULTS AND DISCUSSIONS

The TSS, total Zn and total Pb concentrations measured in snow samples collected during the three sampling programs for three snow ages (around 40 days, 80 days, and 120 days) are presented in fig. 2. As previously reported, the TSS concentrations were generally higher in the central city compared to the residential area and higher at high traffic sites compared to low traffic sites (Kuoppamäki et al., 2014; Müller et al., 2022), indicating that traffic and related activities are the source of suspended solids in urban snow. The highest TSS concentration was at C2 during the third sampling occasion (snow age around 120 days) in 2021. On this occasion, most of the snowbank was melted, thus causing the highest concentration of particles. On all other occasions, the concentrations were highest in the year 2002-03. From fig.1, there was no rain on snow event during the selected sampling occasion in 2002-03. Thus, the rain on snow during 1994-95 and 2020-21 may have carried particles from snowbanks causing lower concentrations of TSS during these years compared to 2002-03.

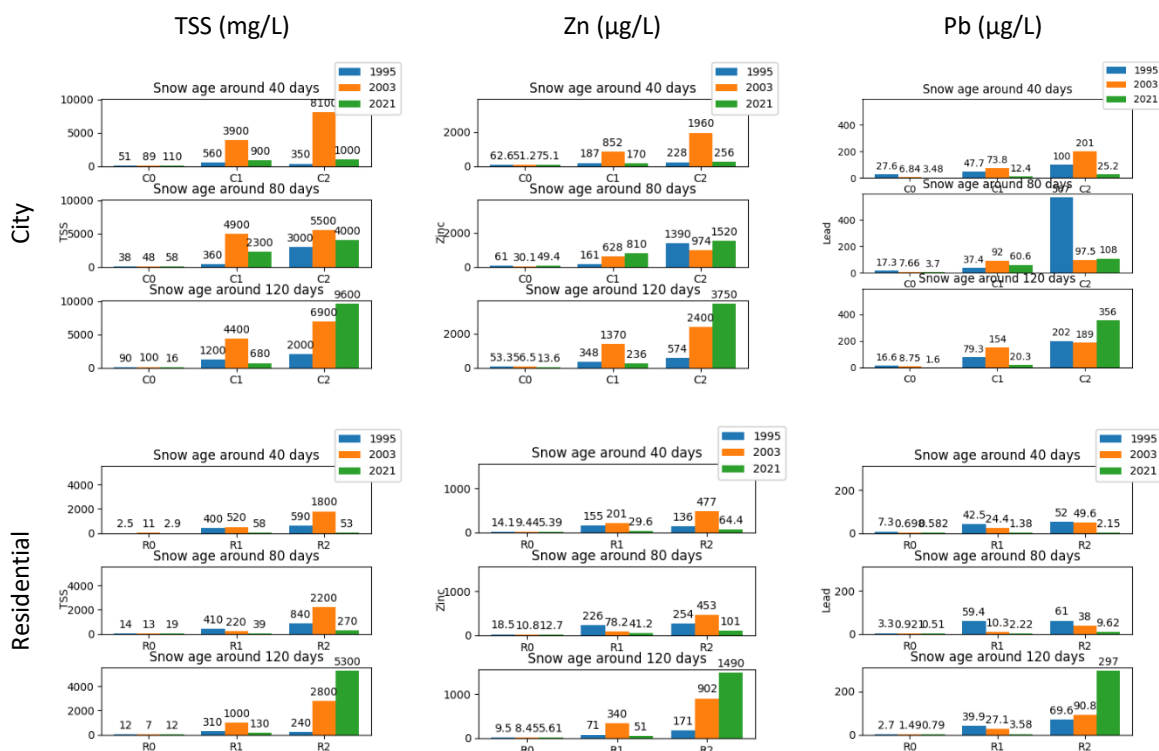


Fig. 2 TSS, total Zn and Pb concentrations measured in snow samples collected from six sampling sites (C0, C1, C2, R0, R1 and R2) during three sampling programs

Among the analysed metals, Zn, Cu and Cr showed similar patterns of concentrations as TSS. However, Pb showed a different pattern than TSS and other analysed metals. Pb concentrations were highest during sampling in 1994-95. The phasing out of leaded gasoline in Sweden was in 1995 (OECD and UNEP, 1999). Other sources of lead from vehicular traffic were brake pads and vehicle body paint, which were substituted by low-

lead, or lead free alternatives contributing to reduction of Pb emissions by vehicular traffic.

4 CONCLUSION

Concentrations of TSS, Zn, Cu and Cr did not show any trends during the period 1994-2022, since these concentrations were influenced by the differences in temperature and precipitation during the three sampling campaigns, and those influences were strong enough to mask any changes in the strength of sources. Even though the metals (Zn, Cu and Cr) did not show detectable trends, but their concentrations were correlated with TSS concentrations. Among the studied metals, only Pb concentrations decreased over the examined period (1994-2022) due to the phasing out of leaded gasoline. Further research will compare the mass pollution loads per m² to get a better indication of changes in pollution loads over the years.

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