Factors Regulating the Air-borne Spreading of Pollutants from Roads


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Abstract

Pollutants from roads are spread by mechanisms such as splash, spray and ploughing. In this study the spreading was studied at two locations where information of the local weather was available and the amount of salt applied on the road could be obtained. When comparing the deposition of Na, Ca, K and Mg, the road-related gradient is obvious; the increase of sodium in the containers closest to the road is sometimes more than 1000-fold, and the increase of the other cations 10–100-fold. Also during a period of no de-icing the deposition of cations is higher towards the road. The deposition of Na is related to amount of road salt applied, and also to wind and type and amount of precipitation. The increase of other cations could be an effect of weathering and/or ion-exchange on the fresh surfaces of the road wear.
Introduction

The deposition of pollutants in roadside environments have been studied in several ways. For instance the deposition of de-icing salt next to roads has been assessed by e.g. collecting the deposition in containers of different kinds (Karlqvist 1974, Kelsey & Hootman 1992, Pedersen & Fostad 1996), measuring the accumulation in the snow-layer by snow sampling (Simini & Leone 1986, McBean & Al-Nassri 1987, Hautala et al. 1995, Eliasson 1996), measuring the accumulation in the soil by soil sampling at different depth (e.g. Hofstra et al. 1979, Dragsted 1980, Persson & Røyseland 1981, Jones et al. 1986, Bäckman & Folkeson 1995, Pedersen & Fostad 1996, Bäckman 1997), and analysing salt concentration in vegetation (e.g. Hofstra & Hall 1971, Bäckman & Folkeson 1995, Pedersen & Fostad 1996).

Most of the investigations show that the deposition is largest within some ten metres (approximately) of the road edge (Persson & Røyseland 1981, Hedalen et al. 1995, Eliasson 1996), while some particles have been traced several hundred metres from the road (Kelsey & Hootman 1992, Hedalen et al. 1995).

There are several mechanisms which govern the air-borne spreading of non-gaseous pollutants from the road.

Splash is usually defined as the water thrown away in the forward and side directions from the tire-road interface. It consists of relatively large droplets that are not caught by the air streams around the vehicle to any larger extent (Sandberg 1980). Also the sheets of slush thrown aside by traffic should be regarded as belonging to the splash mechanism. Such mechanical transport in the region close to the road can result in an uneven distribution of salt in the roadside environment (McBean & Al-Nassri 1987).

Spray, however, is thrown out by centrifugal action tangentially from the tire tread and a great portion will break down into small droplets with low sinking speed when hitting other parts of the vehicle. The spray is easily caught by the air streams and may be persistent in the air wake behind the vehicle for a long time. (Sandberg 1980).

Dry residues of salt might be caught by heavy wind and forced off the road as dry salt crystals.

Ploughing as a de-icing action might also play a role as a transport mechanism transferring pollutants from the road to the surroundings.

The importance of each mechanism is then depending on a set of factors such as:
- Road surface characteristics (Ericsson 1995),
- Maintenance and operation (Ericsson 1995),
- Meteorological factors (Lumis et al. 1973, Hofstra et al. 1979, Eliasson 1996),
- Topography (Evers 1981; Persson & Røyseland 1981),
- Vegetation (Hautala et al. 1995),
In this study we have chosen to study the importance of some meteorological factors as wind speed, wind direction and type of precipitation on the deposition pattern of pollution. The deposition is measured as concentration of sodium, calcium, potassium and magnesium. Also the influence on pH is discussed.

Methods and Materials

In Sweden the Swedish National Road Administration has developed a system for supervision of the local weather at some of the more important roads. The system is called VViS (Väg Väder InformationsSystem = Road Weather Information System) and measures e.g. temperature in air and at road surface, wind velocity and direction and, at some location, precipitation type and amount. To be able to investigate the chosen meteorological factors (i.e. wind speed, wind direction and type of precipitation) and how they affect the spreading of the pollutants it was decided to locate the two field investigations close to road weather information system stations that record these features.

One of the localities chosen for field studies was Ålgviken, some kilometres north of Nynäshamn at National Road 73, which has an average daily traffic of ca 8 000 vehicles. At the locality the road runs in a north-south orientation with a ploughed field west of the road and a meadow east of the road. On the west side the road is excavated with a ditch at about four metres from the edge marking. On the east side the road is built on a filling with a ditch at a distance of about six metres from the road. The distance to sea is about two kilometres.

The other locality was Bankekind, 10 km SE of Linköping. The National Road 35 with an average daily traffic of 5 500 vehicles runs in a NW-SE orientation. West of the road there is a meadow and east of the road there is a harvested but not ploughed farmland. There are a ditch on both sides of the road at 4 m from the edge marking.

Road salt is spread in different amounts and with different methods according to the weather conditions in order to decrease the slipperiness of the road surface. Statistics about applied amount of salt is available at the local road maintenance stations responsible for the de-icing of roads. In this case the applied amount of salt was given in g-m² of applicant road surface or in tonnes per km road length. Both amounts were recalculated to kg Na per metre road length in order to compare the amounts applied on the road to the amounts deposited at different distances.

The containers used to collect pollutants from the roads had a size of 2.7 litres and a radius of 8.75 cm at the top. The containers were placed on the ground and fixed by 150 mm nails and rubber bands. Two containers were placed about two metres apart at the distances of 2, 4, 6, 10, 20, and 40 metres from the edge marks of the road perpendicular to both sides of the road. At Bankekind a longer profile also with double containers were placed on the east side of the road at the distances of 2, 4, 6, 10, 20, 40, 60, 100, 200 and 400 metres of the road in order to find how far from the road a gradient was detectable. At Ålgviken the containers were collected and
replaced once a week (i.e. 07.02–15.02, 15.02–22.02 and 22.02–01.03). At Bankekind the containers were collected every two weeks (i.e. 06.02–19.02 and 19.02–03.03). The 400 m profile in Bankekind was left for four weeks (06.02–03.03). For each period the amount of de-icing salt applied was registered together with the amount of precipitation, estimated from the content of the containers at the furthest distances from the road (Fig 1–2).

The samples were stored for one to three weeks and then transported to laboratory for analyses. At the lab the conductivity in all samples was measured and pH for some samples. The water was filtered and samples of 100 ml were stored cool for further analyses. Subsequently, the concentration of Na, Ca, Mg and K were measured with an ICP (Induced Coupled Plasma Emission) of the brand Jobin-Yvon.

Results

At Älgviken (Fig 1), the first two periods showed quite similar results, with a slightly higher deposition closer to the road during the second week. However, the applied amount of salt was approximately the same during these two weeks. In the third week, on the other hand, there was no de-icing action taking place at all. Still there is a deposition of sodium in the containers with an obvious gradient towards the road.

**Figure 1.** Deposition of sodium at location Älgviken.

The amount of sodium spread at each period were:
- Week 1: 160 g·m⁻¹
- Week 2: 145 g·m⁻¹
- Week 3: No de-icing action took place.

The estimated amount of precipitation at each period were:
- Week 1: 15–20 mm,
- Week 2: 15–20 mm,
- Week 3: 6–8 mm.
At Bankekind, approximately the double amount of salt was used during the first investigation period compared to the second period. There is a difference in the symmetry of the deposition patterns during the two periods (figure 2). During weeks 3–4 there was a considerably lower amount sodium deposited on the western side of the road as compared to the deposition during the first two weeks.

![Graphs showing deposition of sodium at Bankekind.](image)

**Figure 2.** Deposition of sodium at location Bankekind.

The amount of sodium spread at each period were:
- week 1-2: 505 g·m⁻¹
- week 3-4: 270 g·m⁻¹
- week 1-4: 775 g·m⁻¹

The estimated amount of precipitation at each period were:
- week 1-2: 25–30 mm,
- week 3-4: 7–10 mm,
- week 1-4: 33–37 mm.

In order to study other deposition than salt the container contents were also analysed for the cations; calcium, potassium and magnesium. In all profiles there were seen an obvious road-related gradient, even in week 3 at Älgviken, when no deicing took place. Below (figure 3) are presented the results from the 400 m profile in Bankekind.

When comparing the deposition of calcium, magnesium and potassium to sodium it can be observed that even if the road-related gradient is obvious, the increase of these ions close to the road is more or less 10–100-fold, while the increase of sodium in the containers closest to the road sometime are more than 1000-fold.
The pH of the water in the containers showed an increase from approximately pH 4.5 – as expected in the precipitation of these regions – to pH 7 closer to the road (figure 4).
Discussion

At Älgviken, the deposition pattern showed a slight difference between the first and second week, even though the amount of de-icing salt applied on the road were quite similar. The higher Na-levels within the first 4–6 m in the second period might be explained by the fact that there were more snowfall during that period, which led to a higher amount of water deposited in these containers. Similarly, Dragsted (1980) found great differences in lateral salt distribution patterns between wetter periods – when spray generation lead to longer transport, and periods with more snow – when deposition take place closer to the road due to ploughing and splash. The wind directions during the first week were varied with both easterly and westerly winds, while, during the second week, there occurred no easterly winds. This might also be an explanation of the non-symmetrical deposition pattern on the two sides of the road.

The difference in the East-West deposition pattern between period 1 and 2 at Bankekind might be explained by the difference in the weather conditions during these two periods. During week 1–2, both westerly and easterly winds were occurring, while there during week 3–4, almost exclusively occurred westerly winds. The wind seem in this investigation to play an important role in ruling to what extent the pollution will be transported on each side.

The increase of pH towards the road should be seen in the context of increased amounts of cations in the deposition. This might be an effect of weathering and/or ion-exchange on the fresh surfaces of the road wear.

The amount of sodium where the gradient seem to be levelling is in the same order of magnitude as expected from background content of precipitation.

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Statens väg- och transportforskningsinstitut (VTI) har kompetens och laboratorier för kvalificerade forskningsuppdrag inom transport och samhällsekonomi, trafiksäkerhet, fordon, miljö samt för byggnad, drift och underhåll av vägar och järnvägar.

The Swedish National Road and Transport Research Institute (VTI) has laboratories and know-how for advanced research commissions in transport and welfare economics, road safety, vehicles and the environment. It also has research capabilities for the construction, operation and maintenance of roads and railways.

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