Environmental risk assessment of de-icing salts

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The winter road treatment using chemical thawing agents can be responsible for some deleterious effects on the ecosystems around. The environmental risk assessment of de-icing salts shows that these effects are local and transient. Moreover, they can be solved by optimizing various related aspects: spread amounts, analysis of meteorological conditions, choice of adapted plantations, infrastructure of roads...

1. INTRODUCTION

The use of winter treatment agents on our roads guarantees that people and goods can move around freely, whatever the weather conditions. In a society where mobility is one of the essential keys of our economic and social development, the safe, uninterrupted transport throughout the year is self-evident and simply cannot be hindered. Furthermore, the road has become an important link in the industrial production chain (rolling stock, just-in-time deliveries). If the road network were to become unusable it would slowdown or even bring all economic and social life to a standstill.

Environmental awareness is acquiring an increasingly more important profile in the concerns of most of people. The influence of human activity on the ecosystem is receiving more and more attention. The competent authorities, citizens, manufacturers and the scientific world are searching for ways and means to control this influence.

Using a chemical treatment agent implies that this may re-emerge later elsewhere in the environment. This is obvious, but what is important is that this impact should be controlled, i.e. that it does not change the physical, chemical and biological balance of the ecosystem in an undesirable way. [1]

A large number of studies have enabled the impact of thawing salts to be evaluated on various environmental compartments : aquatic flora and fauna, surface waters and groundwaters, soil, terrestrial vegetation,... [2,3]

2. AQUATIC BIOTA

Ecotoxicological studies were conducted on a large number of aquatic species (fish, microcrustaceans and algae). Most experimental work has been concerned with fish ; other research indicates that invertebrates and microorganisms are more sensitive to salts. [4,5]

Nevertheless available data revealed toxicity thresholds far above the observed aquatic salt levels so that de-icing salts do not have a significant deleterious effect on aquatic biota in surface waters where dilution takes place quickly.

Osmotic regulation is the principal response mechanism by which aquatic fauna may adapt to the environmental stress of de-icing salts. The temporary changes in ionic equilibrium are rapidly resolved. Field studies demonstrated that the diversity of species is preserved as is the quality of their development.

The impact is quite different in lakes and ponds receiving salt contaminated runoff. Changes in density gradient are observed : the density of the inflowing water may increase so that the inflow goes directly to the lake bottom. As density increase becomes permanent, the seasonal mixing (spring overturn) of lake waters can not take place preventing oxygen and nutrients distribution . The lake ecosystem is disturbed and only most resistant species are remaining. [6]

3. SURFACE WATERS

The major process impacting surface waters is the saline runoff from roadbeds which is significantly emphasized by precipitation and thaw. [7]

A correlation has been established between road salting and increased chloride concentration in surface waters. This increase is transient and reversible due to the intrinsic river flow rate and dilution effect. A considerable reduction of these concentrations ensues rapidly.

The chemical composition of surface waters is recorded as part of national and international water quality monitoring programmes. Sodium and chloride contents of surface waters are usually reported; these parameters show significant concentration peaks during few-days winter periods where road salting is important but they remain stable over a one-year period. [8]

Numerous studies have shown the value of building retention basins at place where rainwater tends to concentrate. They are used to regulate the rate of discharge in the rivers, and they also help to control the concentration of road de-icers and other pollutants (heavy metals, hydrocarbons,...) encountered on the roads. [9,10]

4. GROUNDWATERS

Unlike surface waters which have almost unlimited power of dilution due to their flow rate and the volumes involved, a water table is characterized by a clearly-defined volume. Saline solutions can percolate through roadside soils from the upper layers into the water table ; ions are retained to a greater or lesser extent, depending on the nature of the soil, its permeability and ion exchange capacity, the existing plant cover, the type of ion, the level of moisture in the soil, the depth of the water table,... [11]

The retention basins built along the roadside reduce the movement of saline solutions in the soil and percolation is therefore brought under control.

Seasonal variations in the ionic composition of the water table are not very pronounced due to the time taken for solutions to percolate from the surface. Accumulation phenomena can be observed at some distance when saline solutions percolate laterally on impermeable layers before flowing through fractures.

The most significant impact of road salting on groundwaters is the contamination of water supplies which results mainly into an alteration of the organoleptic characterisitics (salty taste) of mains water intended for drinking.

Many studies carried out in North America (United States and Canada) have enabled the impact of thawing salts on the groundwater to be evaluated. However, these are not directly transposable to Europe, because the winter conditions and winter road serviceability practices are not the same. Europe has very variable climatic characteristics from North to South or from East to West. The continental or maritime influence plays an important role. [12,13]

5. SOIL

Repeated applications of de-icing salts have a cumulative effect on salt concentrations in soil. These concentrations decrease with distance from the road and from the soil surface. The rate and direction of salt infiltration depend greatly on the moisture content of the soil. In saturated soils (high moisture content), the salt and water will first move downward to groundwater whereas in soil with low moisture content, capillary action will move the salt to the surface. [14]

The sodium and chloride ions move through the soil profile at different rates. Negatively charged chloride ions are highly mobile and quickly transported downward through the soil layers. Indeed, chloride is not involved in oxidoreduction, biochemical or complexation reactions ; it does not significantly adsorb on mineral surfaces. Sodium ions are positively charged and can be removed from solution by adsorption on minerals with high cation-exchange capacity such as clay and organic particles. Soil becomes saturated with sodium and depleted of calcium and magnesium resulting in an alkaline soil pH. A structural deterioration occurs in soil reducing aeration and water availability. [1]

6. VEGETATION

Direct and indirect effects are observed on vegetation. Direct effects result in salt spray on the aerial parts (stem/trunk, leaves and flowers) of the plant causing mainly foliar damage. They are particularly detrimental to young shoots at the end of the winter season, responsible for a retarded growth. Indirect effects allow infiltration of saline solutions in soil and root uptake. [15]

Saline soils induce an osmotic stress situation. De-icing salts increase the concentration of the soil solution and decrease the diffusion pressure gradient between the medium and the plant ; water in the roots is drawn out into the saline soil solution causing deshydration injury to the plant.

The ion-exchange processes in which sodium cation is involved lead to the soil compaction and reduce the availability of the nutritional elements. The fertility of the soil is weakened and the plant respiration is in turn diminished.

The effects on vegetation vary with many factors. There is a great variation in salt tolerance as a function of plant species. Conifers are more vulnerable to salt spray injury than deciduous trees as they remain photosynthetically active throughout the year. Other interactive factors which affect salt injury to vegetation include growth stage of the vegetation, soil type, environmental stresses (wind, precipitation), amount of salt applied,....
Many improvement measures can reduce considerably the impact of road de-icers on vegetation: protection against spray and spume of brine by means of separation spaces, the maintain of a sufficient distance between the trees and the edge of the road, the selection of appropriate species of trees and shrubs, the collection of de-icing waters by means of pipes/drains... [1]

7. CONCLUSIONS

The available studies, qualitative and quantitative, clearly demonstrate a correlation between the use of chemical agents for winter treatment and an impact on salt concentrations in environmental compartments. This relationship is irrefutable but the prediction of salt concentrations and potential deleterious effects is very difficult as site-specific factors are of greatest significance. Nevertheless, in most cases, the environmental risk assessment of de-icing salts leads to the conclusion that their impact is limited to local and transient effects.

Moreover, these studies generally enable measures to be taken in order to control the effects of treatment agents : limitation of quantities spread, changes to road infrastructure (drainage systems, retention basins), selection of resistant vegetable species for planting alongside roads,... The implementation of these recommendations enables winter treatment to be managed optimally, preserving the environment, and maintaining mobility for people and goods.

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