RESEARCH ON ENVIRONMENTAL IMPACT OF SPREAD DE-ICING SALTS

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ABSTRACT

In snowy regions of Japan, road administrators spread de-icing salts on roads to ensure safe driving in winter. The quantity of de-icing salts has increased every year since the use of spiked tires was prohibited, and some people have expressed their fear that scattering de-icing salts that have been spread damages roadside environments. It is necessary to spread de-icing salts in order to ensure safe driving with minimum harm to the natural environment.

This is a report that surveys (1) the relationship of the quantity of de-icing salts spread with the amount of scattering and run off from roads, (2) the salinity of roadside soil, and (3) the growth of and damage to roadside plants, in Japan. These surveys revealed the following:

(1) The relationship of the quantity of de-icing salts with the quantity scattered and run off from roads
  a) The material balance of 94% of the quantity spread de-icing salts was confirmed.
  b) Around 70% of the de-icing salts flowed into drainage ditches and 2% adhered to motor vehicles.
  c) Around 20% of the de-icing salts was scattered outside roads, and 72.5% of the de-icing salts so scattered remained within 3 meters from the road edge.

(2) Salinity of roadside soil
  a) The salinity of soil along roadsides in snowy regions was measured.
  b) The concentration of Cl^- was found to be much lower than the damage threshold of weak salinity vegetation, with some exceptions.

(3) Growth of and damage to roadside plants
  a) We observed whether or not there was defective growth of and/or damage to roadside trees.
  b) There was no clear link found between defective growth and/or damage clearly caused by spread de-icing salts.

In conclusion, we have concluded that spread de-icing salts have no clear influences on roadside environments.

KEY WORDS

DE-ICING SALT / WINTER ROAD MANAGEMENT / SALT DAMAGE / ROADSIDE ENVIRONMENT

1. INTRODUCTION

60% of the area in Japan is in snowy regions (Figure 1). In these areas, as shown by Figure 2, there is a lot of precipitation but the temperature is not very cold. To guarantee road traffic and ensure safety, road administrations must spread de-icing salts on roads when snow has accumulated in snowy regions. The quantity of spread de-icing salts has tended to grow steadily since studded tires became prohibited. However, it is feared that de-icing salts harm the environments surrounding roads. Therefore, the environmental load of spreading must be lowered. This research consisted of a study of (1) the relationship between the quantity of de-icing salts spread and the quantity that is scattered and run off from roads, (2) the salinity of roadside soil, and (3) the growth of and damage to roadside plants. In this study, we focused on NaCl, $CaCl_2$, and $MgCl_2$, which are chloride-based type de-icing salts, the type that is the most common in Japan.

Figure 1 - Snowy and Cold regions in Japan

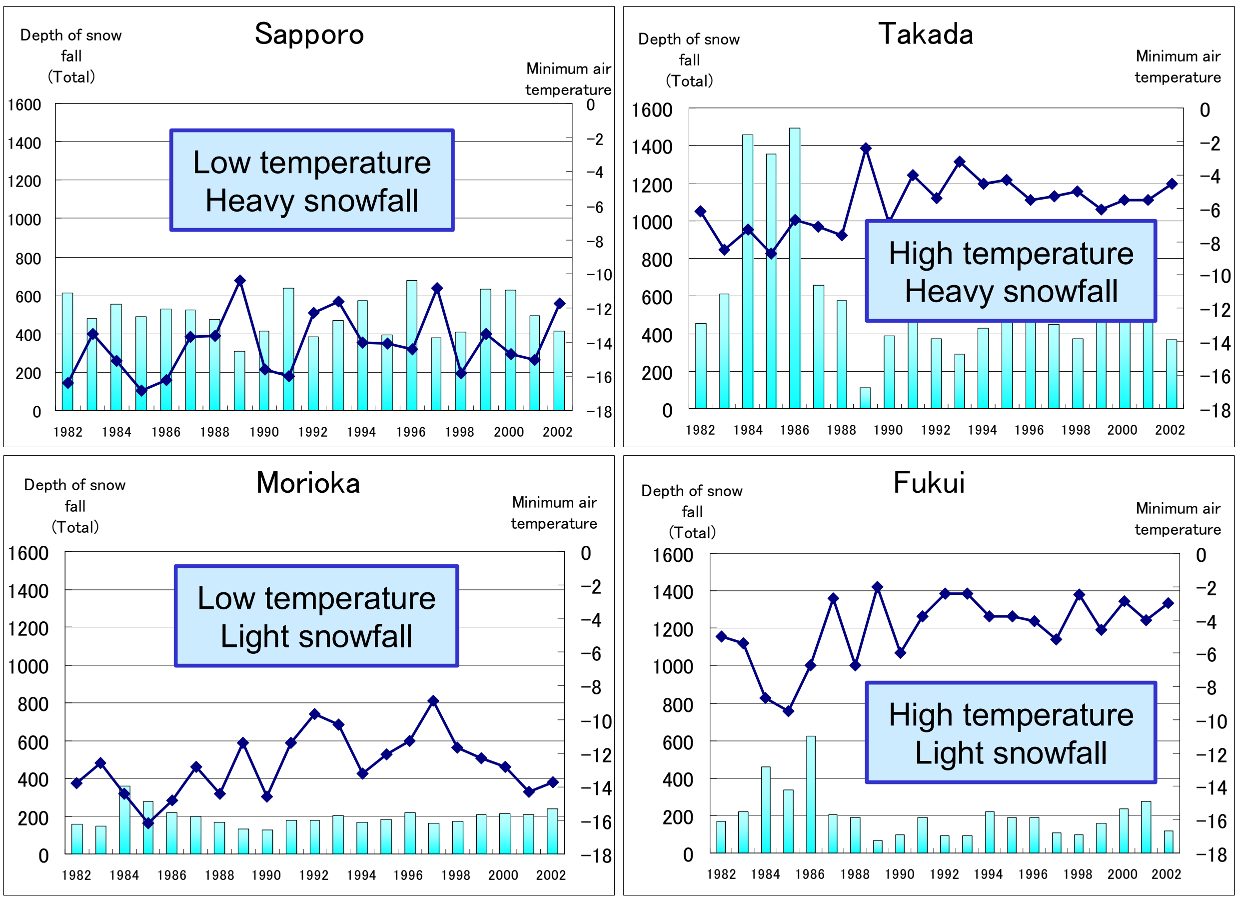

Figure 2 - Temperature and Snowfall by year

2. QUANTITY OF DE-ICING SALTS SPREAD AND THE WAY THEY SCATTERED AND RUN OFF

As shown in Figure 3, there are four main patterns in which spread de-icing salts scatter and run off from roads. This clarifies the status of scattering and run off of de-icing salts that have been spread on road surfaces in winter.

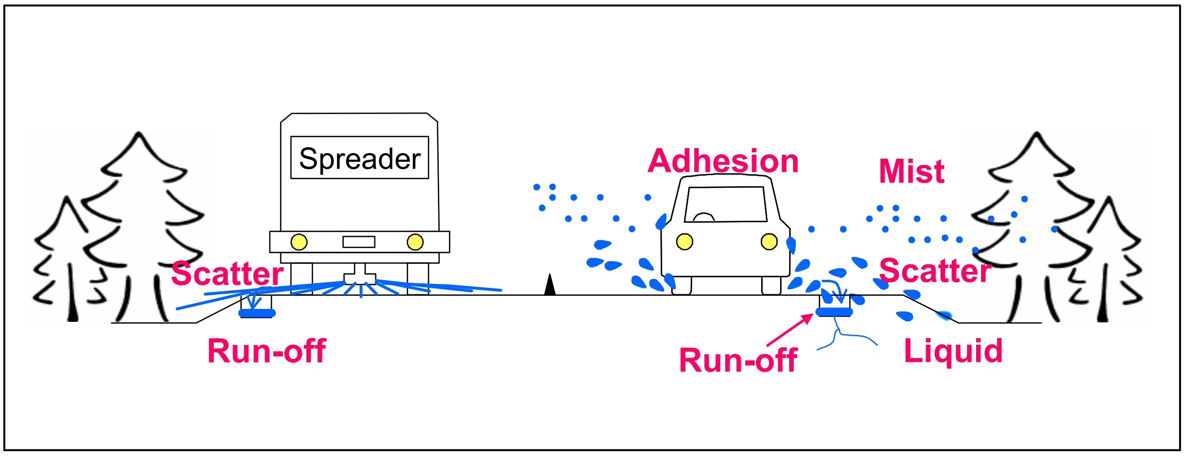

Figure 3 - Patterns of Scattering and Run Off De-icing Salts

2.1. Status of the survey location

Figure 4 shows the survey location (Niigata shown in Figure 1). The de-icing salt was solid NaCl that was spread from a de-icing salt spreading vehicle near the survey location. The de-icing salt spreading vehicle spread 20g/m^2 or 30g/m^2 solid NaCl each time. A total of 2,400g/m^2 of NaCl de-icing salt was spread during the survey period.

The weekly traffic volume ranged from 193,085 to 211,724 vehicles, of which between 12.8% to 13.9% were large trucks, and the traveling speed ranged from 53 to 56km/hour. In terms of inbound and outbound traffic, outbound traffic volume was about 10% higher than inbound traffic, but there were no large differences between shares of large trucks or driving speeds.

1) The Survey Site

2) The survey of the quantity scattered

Figure 4 - Photograph of the Survey (Niigata)

The weather at the location during the survey period was average air temperature of 3.4°C, average wind speed of 3.3m/s, and total precipitation of 188.5mm, while total snow depth during the survey period was 58mm and accumulated snow depth was a maximum of 16mm. During the period, the average fair wind rate was 48.6% and the average wind speed during fair winds was 4.4m/s.

2.2. Quantity spread and quantity scattered outside the roadway

We gathered the scattered de-icing salts by using vessels and gauzes downwind of the road (Figure 4-2)). The background value for comparison was also gathered windward of the road. The quantity scattered outside the roadway tended to decline as distance from the edge of the road shoulder increased from 0m as shown in Figure 5-1). Of the scattered salts, 72.5% were deposited from the area between the road edge to 3 meters away.

The quantity scattered suspended in the air (hereinafter, “Quantity Suspended”) was approximately identical to the background regardless of the distance from the road edge and the height above the ground. This means that fine particles of material produced by de-icing salts either fell without being suspended for very long, as was originally predicted, or they may have been diffused and diluted by the wind, reducing their concentration to extremely low levels.

There are three patterns in which de-icing salts spread: 1) solid, 2) liquid, and 3) mixed solid and liquid. Currently, in Japan, mixed solid and liquid is the major pattern. As this method has excellent adhesiveness, the quantity of salt scattered outside the roadway is less than the above example using the solid method. (Show other sites results in Figure 5-2)&3))

The quantity of outflow was worked out by the amount of flow and the concentration of salts measured in the drainage ditch. The quantity of adhesion on vehicle was estimated by the adhesion test using the pilot car and the volume of traffic at the survey point.

As shown by Figure 6, in terms of material balance, of the total of 656kg of de-icing salt (converted to Cl) spread in the inbound and outbound lanes in the material balance calculation section during the 8 week survey period, 72% was run off, 20% was deposited, 2% adhered to motor vehicles, and the eventual location of the remaining 6% is unclear.

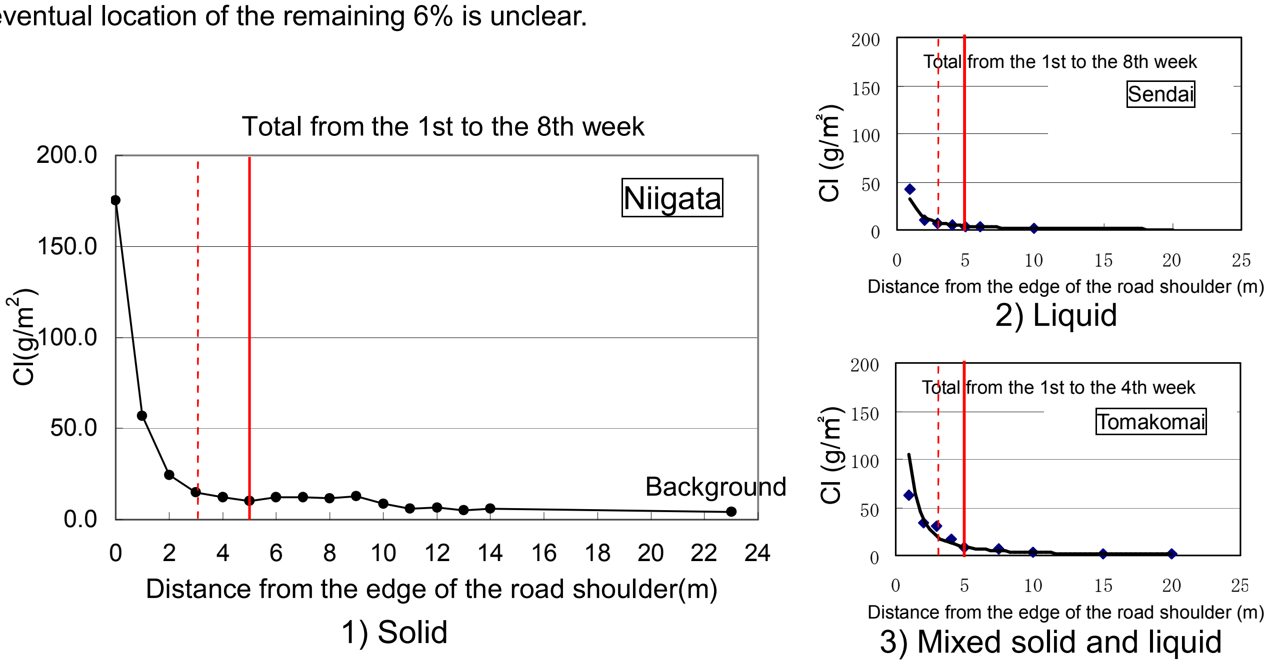

Figure 5 - Quantities of De-icing Salts Scattered Outside the Roadway

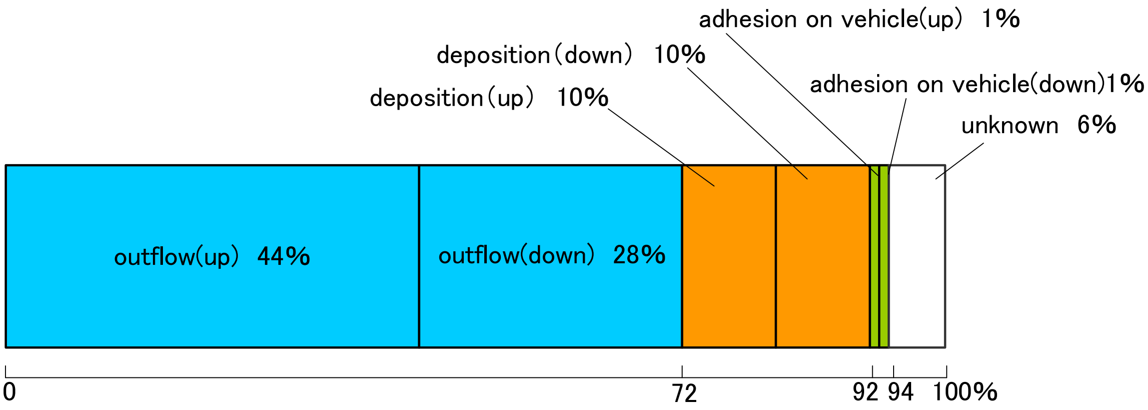

Figure 6 - Material Balance of De-icing Salts

3. SALINITY OF ROADSIDE SOIL

3.1. Content of the survey

As shown in Figure 7, Roadside soils were surveyed at 42 locations along national highways where de-icing salts are spread. These surveys were performed using specimens from locations a few meters from the edge of the roadway. In these surveys, we targeted pH, Na^+, Ca^{2+}, Mg^{2+}, CEC, and Cl^- and then evaluated the influence of these substances on the soil.

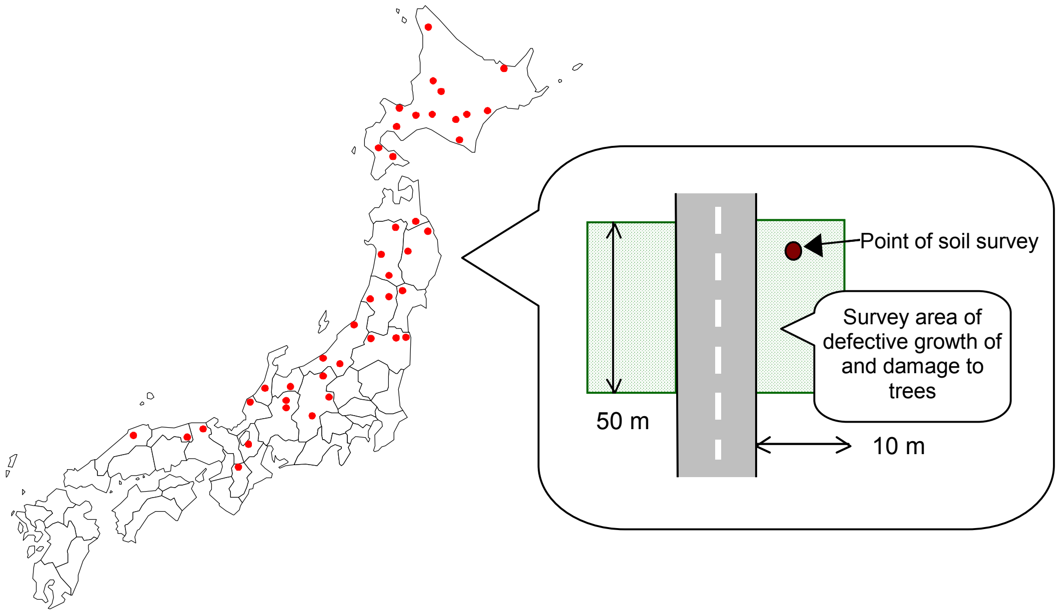

Figure 7 - Survey Locations

3.2. Survey results

Soil hardly adsorbs any Cl^-. According to a reference survey, soil conditions in which the concentration of Cl^- is over 400mg/kg condition have a negative influence on growth of cucumbers, one of the plants with the lowest tolerance for salinity. Figure 8 shows the concentration of Cl^-. Only one point out of the 42 surveyed exceeds Cl^- 400mg/kg.

CEC (cation exchange capacity) is the capability for soil to adsorb and hold Cl^-. CEC is influenced by soil characteristics; If the soil includes much clay and organic materials, CEC is high. When Na^+/CEC exceed 15%, the water permeability of the soil worsens and

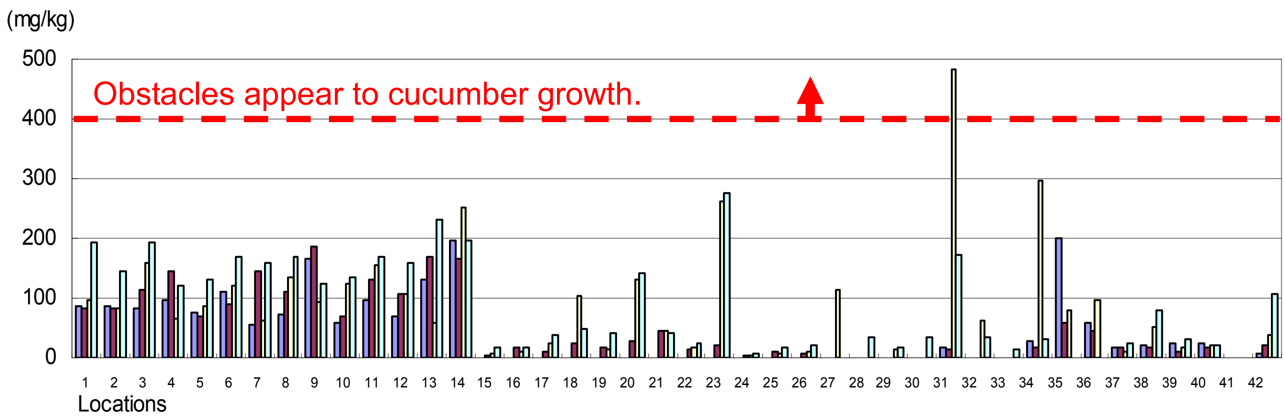

Figure 8 - The concentration of Cl^-

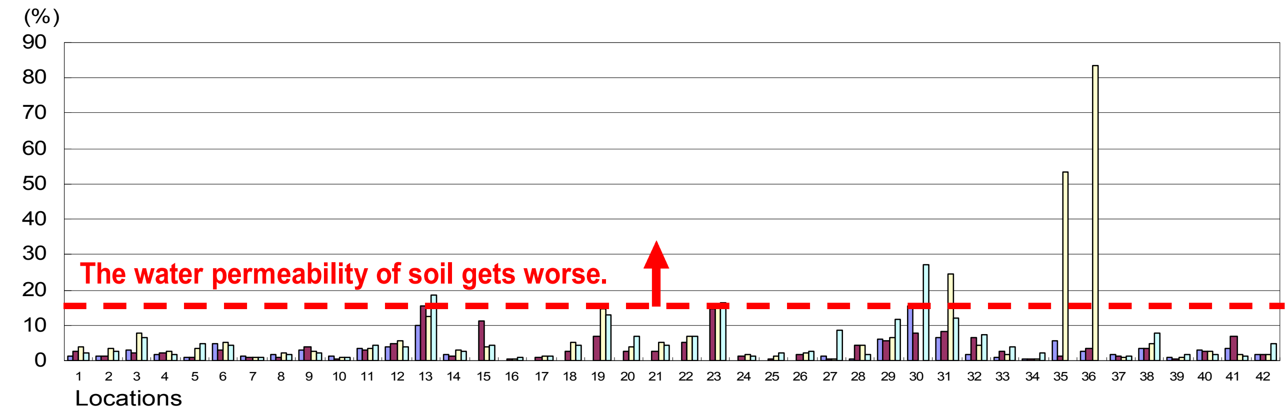

Figure 9 - The ratio of Na^+/CEC

soil hardens during the dry season. Then the soil becomes undesirable for cultivation. Figure 9 shows the ratio of Na^+/CEC. Although Na^+/CEC may exceed 15% temporarily due to the change in Na^+, it was below 15% in general.

There were no points in which pH varied greatly throughout the year. Follow-up surveys are being carried out at locations that exceeded the 400mg/kg and 15% benchmarks.

3.3. Considerations

The point where Cl^- concentration was over 400mg/kg is located where snow removed from the road is deposited and easily accumulates. The points over 400mg/kg and 15% are located inside of drainage ditches. All of points out side of drainage ditches are under 400mg/kg and 15%. As most truck roads in Japan have drainage ditches on both sides, it seems that there is no effect on road side fields.

From the results of the surveys, it is assumed that the spreading of de-icing salt almost never reaches a level that interferes with the growth of farm products. However, the survey also made clear that there are points in which we cannot deny the possibility of localized high values due to roadside topography and snow removal methods. Follow-up surveys must be done and guidelines to appropriate spreading methods and the disposal of snow that has been removed must be studied as necessary going forward.

4. GROWTH OF AND DAMAGE TO ROADSIDE PLANTS

4.1. Vegetation impact process

Vegetation is impacted through two processes. One is the adsorption of de-icing salts deposited on the soil along with the nutrients and water supplied to the vegetation by its roots. The other is the penetration of vegetation by de-icing salts deposited on leaves through the stoma and leaf surfaces.

According to this survey, damage to vegetation caused by saline soil was temporarily high (480mg/kg = 0.048%), but because the high values found by the survey were below 0.1%, which is considered to be the value that causes damage to low salinity tolerance Japanese cedar trees planted on roadsides, it is believed that the increase in the salinity of the soil had only a slight impact on vegetation. Therefore, for this survey, the impact on vegetation was considered to be the impact of the material adhering to and penetrating leaves.

4.2. Vegetation spraying experiment

The elements related to impact on vegetation are the quantity of salt adhering to leaves, the penetration quantity, and the allowed salt penetration of the vegetation; these vary according to the species of tree. The species studied by this survey on the impact on vegetation were selected from evergreen trees, which have leaves during the winter and are planted in large numbers along roadsides due to their high degree of salinity tolerance. These include Japanese spindle bush (also known as “green spire”, Euonymus japonicus), the *ubame* oak (Quercus phillyraeoides), azalea (Rhododendron pulchrum), and the Japanese cedar (Cryptomeria japonica).

The experiments were done by spraying the subjects indoors with a saline solution three times a day (approx. 50ml/projected area (m^2)) for one month or three months to calculate the adhesion and penetration rates. At the same time, component analysis was conducted on the leaves. The results showed that there was a correlation between the quantity of saline spray and the salinity of the bodies of the leaves (Figure 10), and it was confirmed that if the salinity of the leaves exceeded a fixed value, there was a tendency for damage to occur more easily (Table 1).

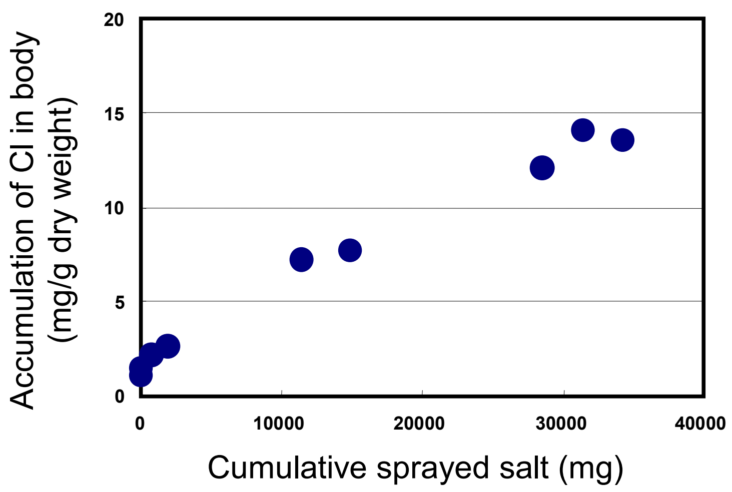

Figure 10 - Example of the Relationship of Quantity of Salt Spread and the Quantity of Salt within the Vegetation

Table 1 - Saline Tolerance, Penetration Rate, and Occurrence Threshold of Trees Tested in the Survey

Species of tree tested	Salinity tolerance characteristics	Salinity tolerance	Penetration rate	Quantity of salt penetrating vegetation (mg/g dry weight)	
				Appearance of discoloration damage	Appearance of 50% or higher discoloration damage
Japanese spindle bush	Salt adheres easily but does not penetrate easily. Salt penetration allowance is high.	Strong	0.039	25	69
Ubame oak	Salt neither adheres nor penetrates easily. Salt penetration allowance is moderate.	Strong	0.043	25	42
Japanese cedar	Salt does not adhere easily but penetrates easily. Salt penetration allowance is moderate.	Medium	0.133	18	-
Lovely azalea	Salt adheres easily but does not penetrate easily. Salt penetration allowance is low.	Weak	0.065	6	31

4.3. Contents of defective growth and damages survey

We observed the growth of the trees and damage caused by de-icing salts of roadside trees in summer. Summer is appropriate for observation because tree cell division is active in summer in areas that have four seasons. Items studied in this survey include kind of trees, location, distance from the road edge, state of defective growth, and damage. Survey locations were the same as in the soil survey. At each location, we surveyed an area within 10meters of road edge (Figure 7).

4.4. Survey results

Table 2 shows the results of observation. Defective growth and/or Damage were observed in 71 of the 819 trees (13 locations of 40). 70% or more of trees which have damage were in the area within 2.5meters of the road edge. The trees which showed defective growth were all observed in the area within 4.5meters of the road edge. Figure 11 shows examples of defective growth and damage that were observed in this survey. We also observed instances where tree trunks bent due to the weight of the snow and where trees were dead only on the side facing the road. There was no large difference of damage according to the kind of tree.

Table 2 - Defective Growth of and Damage to Roadside Trees

<table>
<tr><th>Group</th><th colspan="2">Number of trees</th><th colspan="2">Number of locations</th></tr>
<tr><td>Defective growth</td><td>26</td><td rowspan="3">71</td><td>7</td><td rowspan="3">13</td></tr>
<tr><td>Damage</td><td>5</td><td>2</td></tr>
<tr><td>Both of Defective growth and Damage</td><td>40</td><td>4</td></tr>
<tr><td>Normal (No abnormality)</td><td colspan="2">748</td><td colspan="2">27</td></tr>
<tr><td>Total</td><td colspan="2">819</td><td colspan="2">40</td></tr>
</table>

Figure 11 - Examples of Defective Growth and Damage

4.5. Considerations

Figure 12 shows the number and rate of trees with defective growth and their distance from the road edge. The quantities of salt scattered outside the road (Figure 5) and the rate of trees with defective growth (Figure 12) have the same tendency. Defective growth was not observed in area further than 5meters of road edge because the quantity of salts scattered is low. As such, there is almost no impact on tree growth in areas further than 5 meters away from the road edge.

The area within 5meters of road edge usually accumulates cleared snow. Trees in this area tend to become damaged due to the pressure of cleared snow or collision with a snowplow. These kinds of damage may lead to defective growth because de-icing salts may seep into trees through these wounds. And in this survey, trees that were unstable because the root was shallow, and trees that leaves were discoloured by vehicle exhaust emissions were also observed. Therefore, these kinds of defective growth are caused by a combination of factors such as the method of afforestation, the species of tree, vehicle exhaust emissions, pressure of cleared snow, and collision with a snowplow. Accordingly, the extent of influence on defective growth by de-icing salts is not clear.

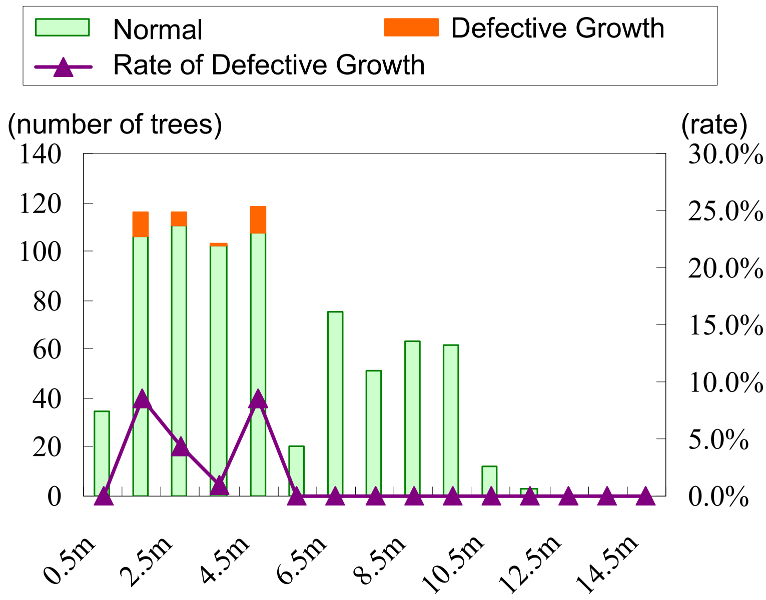

Figure 12 - Number and Rate of Trees with Defective Growth
(including distance from the road edge)

5. CONCLUSION

This survey into the relationship between the quantity of de-icing salt spread and the quantity scattered and run off revealed that of the 20% of the quantity spread that was deposited or scattered outside the roadway, 72.5% reached the ground within 3 meters of the edge of the roadway. Approximately 70% of the quantity of de-icing salt that was spread run off into drainage ditches, while two percent adhered to motor vehicles. The results clarified the material balance of the 94% of the quantity spread. The roadside soil salinity survey observed the soil salinity on roadsides in cold and snowy regions. With some exceptions, the concentration of Cl^- was found to be much lower than damage the threshold of vegetation with weak salinity tolerance. Defective growth of roadside trees was not observed in areas further than 5m from the road edge because the quantity of salt scattered was low.

Through this survey, it became clear that there is no definite impact on the roadside environment caused by de-icing salts, though many points were uncertain at the start of this survey.

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