

EFFECT OF DISSOLVED DEICING SALTS ON THE MOBILITY OF METALS IN CONTAMINATED URBAN SOILS

A.Bommel-Orsini and J.Ternisien
Environment Engineers, Sétra, MEEDDM, France
Amandine.Bommel@developpement-durable.gouv.fr

&

J-S. Dubé
Laboratory of Environmental geotechnics, ETS, Quebec
Jean-sebastien.dube@etsmtl.ca

RÉSUMÉ

The objective of this work was to study the effect of dissolved de-icing salts on the mobility of metals in contaminated urban soils. Soils were obtained from two urban sites known for their contamination with several metals. The samples used for this study showed metal concentration above and below the quality criteria for site usage as a snow dump. The soil samples were then mixed with solutions having increasing concentrations of dissolved salt. An increase in the leaching of metals from the soil could be related to the increase in dissolved salt concentration. Metal concentrations measured in the soil leachates increased with a dissolved NaCl concentrations ranging from 0.01 mol/L to 1 mol/L. Moreover, a lower threshold effect was observed at the salt concentration of 0.01 mol/L for most metals. For lower salt concentrations, metal leaching could not be differentiated from that observed with leaching with water. Metal leaching experiments were also conducted with calcium chloride, which showed this salt produced an increased mobilisation of metals towards the aqueous phase. This could be explained by a larger cationic exchange with Ca^{2+} than with Na^{+} . A salinity shock effect was observed for specific experimental conditions for which a large increase in Cu, Pb and Zn was observed in the soil leachate. This phenomenon could be explained by a colloidal transport mechanism. The results obtained showed that there effectively exists a risk of mobilising metals from the soil to the aqueous phase, particularly in soil with large metal concentrations. Therefore, when a site is assessed for usage as a snow dump, the required hydrogeological study could include the characterisation of a salt effect on pollutant mobility, for the purpose of preventing the release of metals in the environment. This could be especially important when the concentrations of pollutants are close to the soil quality threshold for this usage.

MOTS CLÉS

DISSOLVED DE-ICING SALTS / SNOW DUMP / MOBILITY OF METALS / CONTAMINATED GROUNDS

1. INTRODUCTION

In wintry period, the roads maintenance is assured thanks to the manuring of de-icing salts allowing the de-icing and the antiglazing of roads. The sodium chloride is the most used salt. The calcium chloride is also used when temperatures are very low. These techniques are very effective to insure the wintry viability of the road network. However the use and the draining of big quantities of salts in the natural environment has important direct and indirect effects on the environment.

To limit the environmental impact and improve the measures of management of salts of public road network, a program of cooperation was set up between the French Ministry of Ecology, Energy, of the Sustainable development and the Sea (MEEDDM), and the

Ministry of Transport of Quebec (MTQ). With this cooperation, the French Technical Department for transport, roads and bridges (Sétra) wishes to develop an **indicator of Potential Impact of the Road's De-icing Salts**. This indicator tries to characterize and to organize the vulnerability of the various receiving habitats crossed by the road infrastructures into a hierarchy, and to optimize the practices of management of the de-icing salt according to the level of risk. It would take into account several parameters : the characteristics of subterranean and superficial waters, grounds, fauna and flora, but also the type of road, the importance of the traffic, and the quantities of salts spread during the winter.

This study joins within the framework of the indicator elaboration. The main objective is to estimate the impact of salts of public road network on the mobilization of present metals in the contaminated grounds.

2. STATE OF THE KNOWLEDGE

2.1. De-icing salts

According to a recent estimation, approximately 4,9 million tons of de-icing salts of roads can be rejected in the environment every year in Canada. In France, the quantity of salt spread annually on the roads varies between 600 000 to 1,6 million tons according to the rigour of the winter [8][13]. Salts penetrate into the natural environment when they are stored and used, and also during the elimination of the snow removed by roads. The ion chlorinates (dissolution of de-icing salts) is not absorbed by the ground and not degraded. So the manuring of de-icing salt on public road network increase the concentration in chloride of superficial and subterranean waters.

The presence of chloride in big quantities in waters has a direct impact on the fauna and the flora. The toxic effects on the aquatic bodies appear only for concentrations in chloride relatively important. However a chronic toxicity is observed for concentrations lower than 1 000 mg / L. Numerous damages on the vegetation are noticed in zones of streaming of waters strongly charged in salts. Moreover, changes of behaviour and toxicological effects were noticed on the mammal and avian fauna [8].

The manuring of de-icing salts has also harmful effects on the physical and chemical properties of grounds : impact on the structure, the permeability, the inflation, the osmotic potential and the electric conductivity [8]. Variations of salinity and Ionic strength of run off water during the seasons can have an effect on the stability of the contaminants present in grounds and sediments, and their release in subterranean and superficial waters [1][3][7][11][12].

2.2. Contaminated grounds

Whether it is during the manuring of salts or during the storing of the snow stemming from roads, road salts are often put in touch with : grounds and contaminated sediments (grounds in border of roads, ...).

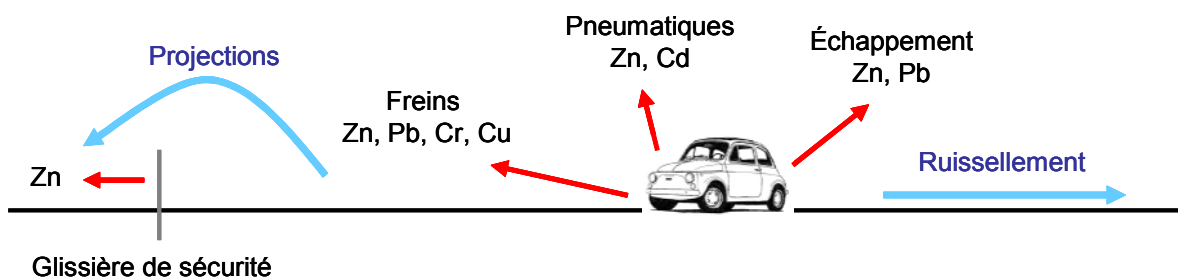


Figure 1 : Main emissions of metals due to the road infrastructures and to the traffic [6]

In urban zones, there are numerous sites formed by heterogeneous excavations because constituted by diverse residual materials mixed with fragments of demolition and reshaped ground. Due to their origin and their constitution, they are often contaminated by any sorts of pollutants, in particular heavy metals and aromatic polycyclic hydrocarbons.

However, in city, these excavations can serve as zones of storage for the stemming snow of the roads and clearing of car parks. When the snow thaws, waters charged in chloride and sodium infiltrate and circulate inside, what can : remobilise some contaminants (in particular metals), transfer metals in the aqueous phase, and contagion of surrounding subterranean or superficial waters.

So, this is important to **estimate the risk of release in environment**. Few studies were made this day on the salt release from the urban contaminated excavations because it is generally considered that the mobile fraction of metals inside is very small regarding to the total concentration.

The risk of remobilisation of the metals in the aqueous phase depends on numerous parameters, in particular on the type of ground, its composition, the nature of the present contaminants but especially the way they are connected to the solid matrix (mechanisms of keeping back of metals in grounds).

2.3. Influence of the variations of salinity on the mobility of metals

Grounds and sediments near roads are subjected to variations of salinity during the seasons. The wintry salting increases strongly the quantities of salts of interstitial waters of the ground, whereas in spring, the streaming of rainwater provokes a sudden fall of salinity (salting shock). These **seasonal swings can modify the physic-chemical conditions of the environment and influence the mechanisms of sorption, complexation and precipitation of metals in grounds**.

Diverse works demonstrated that the lead, the copper and the chromium are more strongly connected to colloids, whereas the cadmium and the zinc are mobile thank to Ionic exchange with the sodium (formation of complexes with the ion chlorinate) [12].The presence of sodium in grounds and of a weak concentration in electrolyte tend to increase the mobility of the organic matter, what can increase the risks of mobilization of complex metals with the organic matter and associated with colloids [1].

On the other hand, the sodium participates widely in the cationic exchange. Metals fixed to the solid matrix can be put back in solution by exchange with the ions Na^+ . The presence of the ion chlorinates in solution can facilitate this Ionic exchange by the formation of complexes chlorinated once metals desorbed by Ionic exchange [3]. The addition of salt can, according to the nature of the ground, modify the pH of the middle, and so have an impact on the mechanisms of precipitation, adsorption and complexation.

Concerning the mechanisms of precipitation/dissolution, the solubility decreases when the pH increases. It can increase again when the element is under anionic shape [5].

All these studies show **that it is not one, but several mechanisms which determine the mobilization of metals**. The main mechanisms are the ionic exchange, the colloidal transport, the formation of complexes with the chloride and the complexation with the organic matter. Their relative importance is function of the type of ground, its composition and the concerned metal.

2.4. Objectives of the study

As a consequence, the works realized until now concern the effect of the increases and the decreases of salinity of waters in touch with the contaminated grounds (only one or two concentrations in NaCl are tested each time).

In order to elaborate the indicator of Potential Impact of the Road de-icing salts, one of the objectives is **to study the relation between the salt concentration applied to a contaminated ground and the contents in mobile metals in the aqueous phase**. This work will allow to establish thresholds values for the salts concentrations below which the effect is similar with water, according to the contagion of the ground on which takes place the manuring of salts or the storing of used snows.

The objectives and the means used are synthesized in the following figure :

Figure 2 : Study Objectives

<i>Objectives</i>	<i>Studied parameters</i>
Study the behaviour of grounds from contaminated urban excavations and from former industrial sites and estimate the impact of the contagion degree	Essays realized with two types of ground : - an urban excavation contaminated with several metals, - a former industrial site strongly contaminated by a metal in particular.
Simply Estimate the behaviour of the ground and the mobility of metals according to time	Variation of the ratio ground / solution
Estimate the contents in metals mobilized in aqueous phase according to the concentration in NaCl	Variation of the NaCl concentrations
Compare effet of NaCl and CaCl ₂	Two tested salts : NaCl et CaCl ₂

3. METHODOLOGY

An approach in static mode was choose. It allows to study the mechanisms of sorption and precipitation of metals (without the hydrodynamics constituent). The conditions are far removed from the reality, but the essays in batch are simple and fast to implement. They allow besides to study the conditions of achievement of the balance for the mechanisms of metals release.

In this case, several ratios of ground/solution are possible. To determine the best to work in the good conditions (correct excitement of tubes, values of big enough concentrations in metals to be exploitable), preliminary essays are realized with a solution of NaCl of 1 mol/L, and ratios ground/solution of 1 :1, 1 :2, 1 :5 and 1 :10. These first essays are used to fix ratios of ground/solution used afterward in 1 :1 and 1 :5.

Present metals in the solutions from essays are analyzed with an ICP - OES method (Varian). Analyzed metals are : Cd, Co, Cr, Cu, Mn, Nor, Pb, Sn and Zn. The results obtained for Sn are too unpredictable, so they will not be presented here. For every metal, the concentration was measured with the first five wavelengths.

Metals concentrations are calculated from an average made on all the wavelengths which intensity allows to observe a clear peak on the graphs of the ICP - OES. The extreme

values were removed. Graphs are always represented with the standard deviation calculated for all the triplicates and the wavelengths.

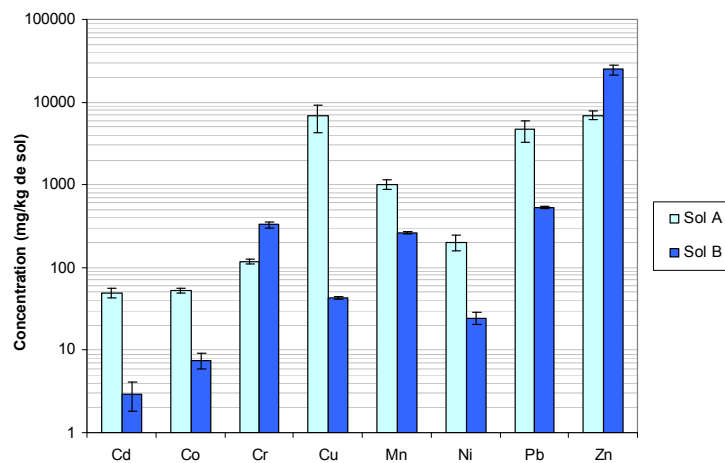
Both types of ground used for the essays were taken from urban excavations in Quebec and in Montreal. The ground A corresponds to the boiler n°3 of samples of Quebec and the ground B of the samples of Montreal. The metals content of the ground was determined from six replica which were analyzed in the ICP-OES after acid digestion in 108°C during 30 minutes and filtration in 45µm according to the method of the CEAEQ (Center of Expertise in Environmental Analysis of Quebec) [4].

4. RESULTS

4.1. Composition of studied grounds

Analyses revealed different compositions for both types of grounds. Globally, contents in metals of the ground A are more high than those of the ground B, excepted for the zinc and the chromium.

Figure 3 : Composition of the two grounds for the principal metals



The analyses of grounds reveal very high concentrations in metals with regard to the regulation, especially for the ground A which respects the authorized value only for the chromium. The ground B is less contaminated, but its zinc content is near five times as high that the authorized limit.

Figure 4 : Contents in metals of grounds tested and values thresholds of the regulations of Quebec [9] (in mg / kg of ground)

	Cd	Co	Cr	Cu	Mn	Ni	Pb	Zn
Ground A	49,8	52,6	117,4	6 720	1 004	202	4 646	6 883
Ground B	3,0	7,6	327,0	43	259	25	530	24 875
Authorised limit	5,0	50,0	250,0	100	1 000	100	500	500

4.2. Influence of variations of the ratio ground/solution

In the batch essays, the ratio of ground/solution conditions the remobilisation of metals in the ground. A first series of tests on the ground A allowed to fix the parameter value for the suite of the experiments. On the other hand, the results obtained for various ratios of ground/solution translate the evolution of mechanisms for various scales of time. The more the volume of water is important with regard to the mass of ground, the more the obtained results can be representative phenomena occurring on a big lapse of time. Principal results are :

- In both essays (distilled water washing and with salt water in 1mol/L), the quantity of metals extracted from the ground A decreases when the ratio ground/solution increases. Extracted quantity is more raised for a ratio ground/solution of 1 :10 than for a ratio of 1 :1. Indeed, the bigger the quantity of NaCl put in touch with the same mass of solid phase is, the more important the extraction of metals is. Furthermore, the quantities extracted with NaCl solution are more raised than with the water, except in the case of the nickel for which no big difference is observed.
- The metals concentrations raised globally more in case of an addition of NaCl solution than of distilled water. The salt increases the mobility of metals contained in the ground towards the liquid phase, what can be a problem if the metals concentrations become too much important in surface waters and groundwater (moreover if the environment water is intended for the population consumption). The metals values, fixed by the government of Quebec, in subterranean waters for the purposes of consumption [10] are synthesized in the following figure, and compared with the concentrations obtained for the washing with some water and NaCl solution in 1mol/L.

Figure 5 : Comparison between control values and the obtained values during the essays (in mg/L) – ground A

	Cd	Cu	Mn	Ni	Pb	Zn
Criteria for the groundwater	0,005	1	0,05	0,02	0,01	5
Water washing	0,01	0,31	2,96	0,10	0,25	0,92
NaCl (1 mol/L) washing	0,26	1,11	6,75	0,16	0,93	3,21

The ground arising from a contaminated excavation, the metals concentrations in solution are often superior to the control values for all the type of washing (water or NaCl). It is the case of Cd, Mn, Ni, and Pb.

In some cases, the distilled water does not involve overtaking of the control values (Quebec regulation), whereas the addition of salt can involve a metals mobilization which exceed these limit values. The Cu concentration remains lower than 1mg/L in the case of the water washing, but can exceed it in the case of NaCl (ratios ground/solution 1 :1 and 1 :2). These values can be even more important in the natural environment because the ratio ground/solution is of the order of 1 :0,15 instead of 1 :1 and 1 :2 in the case of the experiments. Some metals concentrations can really become critical with regard to the regulations.

4.3. Influence of variations of NaCl concentrations

In this essays, the ratio ground/solution is fixed to 1 :1 and 1 :5, and the NaCl concentration varies between 0,001mol/L and 1mol/L. The NaCl concentrations were chosen with regard to the values measured on the ground which can reach respectively 0,5 to 2,3 mol/L in the roads run off water and salt warehouses.

- Case of ratio ground/solution of 1 :1 : the quantity of Mn, Zn and Cu mobilized during the salt solution addition tends to decrease with the concentration in NaCl, and reaches a scale around 0,01 mol/L. Important concentrations in NaCl facilitate the remobilisation of metals present in the ground, whereas for weaker concentrations (< 0,01 mol / L), no difference appears clearly. Only the lead concentrations do not really vary with the increase of salt content. On the other hand, the metals concentrations are appreciably the same after the salting shock, whatever the NaCl concentration is. The effect of the rough change of the Ionic strength (salt shock) is not put in evidence in this essays.

- Case of ratio ground/solution of 1 :5
 - o Ground A : The decrease tendency of the metals concentration with the decrease of the salt content is always observed, and the landing in 0,01 mol/L is confirm for Mn. However, the salt shock effect is much more marked than in the previous essays. Indeed, for NaCl concentrations of 0,1 and 0,01 mol/L, a rough decrease of the Ionic strength involves a net increase of the concentration in Zn, Cu and Pb in the aqueous phase. Below 0,001 mol/L, phenomenon is not visible any more, because salt shock is not enough important.
 - o Ground B : The ground B is much more contaminated in Zn than the ground A, the concentrations obtained after washing are more brought up than previously. The same tendency appears : the metals content is more important for the strong concentrations in NaCl, and stabilizes from 0,01 mol /L. However, the difference observed between the salt and distilled water is not so important that in the case of ground A, and for some metals (Mn, Cu and Pb), the moderate concentrations are sometimes slightly more important with the distilled water than with the NaCl solution. Concerning the effect of the salt shock, the differences are not significant and the results do not allow to conclude.

4.4. Variations of pH

Because the pH of the environment influence the mechanisms of metals retention in grounds, this variable was measured for the NaCl solutions added and for the ground/solution mixes with water and NaCl solution of 1 mol / L.

Figure 6 : pH of NaCl solutions

[NaCl] (mol/L)	0	0,001	0,01	0,1	1
pH	6,26	4,89	4,89	4,84	4,80

The added salt solutions are globally more acid than the distilled water (average pH of 4,8), but the difference between four concentrations of NaCl is rather weak.

Figure 7 : pH of ground/solution mixes at the end of the both washing – ratio ground/solution 1 :5 – Ground A and B

	Ground A		Ground B	
	H ₂ O	NaCl (1 mol/L)	H ₂ O	NaCl (1 mol/L)
First washing	7,85	7,89	8,01	7,98
Second washing	8,76	8,17	8,68	7,95

The addition of a more acid salt solution does not involve important pH decrease in the ground/solution mix, what can be caused by the buffer power of the ground. During the first washing, the obtained values for the water and the salt water are similar. During the second washing with some distilled water (salt shock), a pH increase is observed for both grounds. Globally, the pH is weaker if the ground was beforehand washed with the NaCl than with the water. However, it is surprising to observe an increase of pH between the 1st washing with some water, and the 2nd washing with some water also. Maybe a problem of grading of the device between both measures could explain this.

4.5. Influence of variations of CaCl₂

The obtained results for this essays confirm the fact that the bigger the ratio is, the more important the metals concentrations put back in solution are. The obtained contents for the

ratio 1 :5 are altogether more brought up than those obtained for the ratio 1 :10 (in particular for Zn, Mn and Cu). The Zn concentration after washing by the distilled water couldn't be measured because under detection threshold of the device.

The more the concentration in CaCl₂ is important, the more the release of metals is important. The same tendency is observed with the NaCl. However, the quantity of mobilized Zn is much more important with the CaCl₂. As the difference between these values is of more than a factor of ten, new essays would be interesting to confirm or not these results.

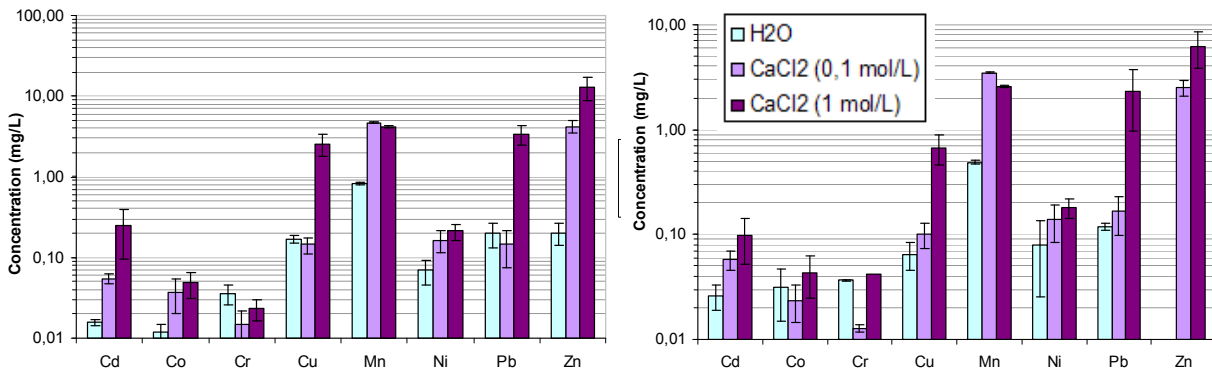


Figure 8 : Metals concentrations after water washing, with two concentrations in CaCl₂ – Ground A – on the left : ratio ground/solution of 1 :5 – on the right : ratio ground/solution of 1 :10

The Cu, Mn and Pb values are similar to those obtained with the NaCl.

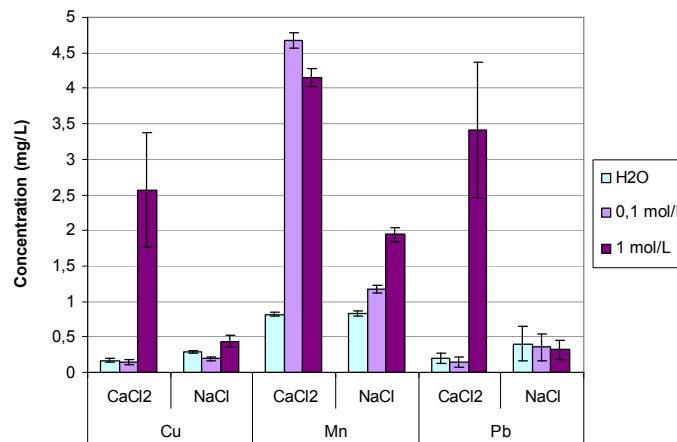


Figure 9 : Metals concentrations after water washing, CaCl₂ and NaCl – Ground A – ratio ground/solution of 1 :5

4.6. Conclusion

The essays led during this study showed that the addition of NaCl or CaCl₂ on both contaminated types of ground provoked a more important transfer of metals of the solid matrix in the aqueous phase than the addition of distilled water.

The concentrations differences measured in solution after washing are less visible from a concentration in NaCl of 0,01 mol/L. On the other hand, the salt shock, which is the washing by distilled water after the washing by salt water, is observed only in certain conditions (ratio ground/solution of 1 :5, concentrations in NaCl of 0,1 and 0,01 mol/L), and only for the ground A.

5. DISCUSSION

This last paragraph tries to explain the results obtained during these essays according to the fixed objectives (See paragraph 2.4.).

5.1. Contagion Degree of grounds of urban excavations

The ground A, stemming from an urban excavation in Quebec, is rather strongly contaminated simultaneously by several metals, whereas the ground B is essentially contaminated by Zn (the content is near five times higher than authorised limit). The state of the knowledge shows that these grounds are much more loaded with metals than grounds used for the previous studies. The difference of contagion between grounds taken in border of roads and those stemming from urban excavations or from former industrial sites is important.

The study results showed that the remobilisation of metals in liquid phase is a phenomenon which also exists in these environment, and metals associated with the residual materials are not so stable as they appear to it. **The use of such sites for the storage of the used snow can present a risk for surrounding superficial waters and groundwater which it is important to estimate.**

5.2. Variation of salinity of the environment

To explain the main mechanisms coming into play in the remobilisation of metals observed during these experiences, two situations will be distinguished : an increase of the concentration in NaCl and a sudden decrease of this concentration, the salt shock.

Among the presented mechanisms, the transport assisted by colloids doesn't explain the remobilisation of metals observed during the addition of NaCl. Indeed, the Ionic strength is one of the most influential parameters on this phenomenon, and it is a decrease, and not an increase, which provokes the mobilization of colloids. The main mechanisms which can intervene are : the precipitation/dissolution, the cationic exchange with the ions Na^+ and Ca^{2+} , and/or the complexation with the chlorinates ion.

The precipitation/dissolution depending strongly on the pH. It does not seem to be the major mechanism of stake of metals in solution because the values of the pH of ground and solution mix are almost the same during the first washing, whatever is the concentration in NaCl. However, the increase of the Na^+ concentration involves cationic exchanges and so releases metals initially fixed to the solid matrix. Presence of Cl^- reinforces this mechanism. It allows the stabilization of metals in solution by complexation. It would seem that is the combination of these two phenomena which explains best the remobilisation of metals. By physical adsorption Mn, Cu, Zn and Pb are partially connected to the ground. The strengths of connections are relatively weak. However, no preferential sequence of release of the metals can be clearly established. Percentages of extraction with regard to the initial content in metals in grounds are relatively close.

Figure 10 : Percentages of extraction of Cu, Pb et Zn from the ground A, with a solution of NaCl of 1 mol / L - Ground A - Ratio ground / solution of 1 : 5

Cu	Pb	Zn
2,34%	2,40%	3,83%

The Zn however seems to be most easily released with regard to two other metals, what corresponds more to the physical adsorption than to the chemical adsorption. These values confirms the hypothesis of the cationic exchange.

The effect of the salting shock appears only for the ground A, with a ratio ground/solution 1 :5, for samples which were beforehand mixed with a solution of NaCl of 0,1 and 0,01 mol /L, and for Zn, Cu and Pb. In all other cases, no difference with the distilled water is observed. These results can be explained by phenomena of the manipulation during the experiences. The column essays would avoid some problems (not sufficient centrifugation) while integrating the hydrodynamics aspect. In this case, results would maybe be more representative. Even if the salting shock is more difficult to simulate, the essays in batch give however a good outline of the effect of the increases of concentrations in NaCl.

In case of salting shock provokes an increase of the metals content, the hypothesis of the remobilisation of the colloids mechanism is the most likely. Indeed, the actual knowledge showed that a sudden decrease of the salinity involves strengths modifications of interaction between the colloidal particles of the porous environment and the solid matrix, involving a destabilization of colloids and metals connected[7]. It would mean that a part of Zn, Cu and Pb is fixed to colloids. A simultaneous study of the effect of the salinity variations, of the colloidal transport and some organic matter would allow to confirm or not this hypothesis.

5.3. Relation between the ground/solution ratio and the time factor

The quantity of metals extracted in mg/kg of ground is more important for a ratio ground/solution of 1 :10 than 1 :1. Now the more the volume of water is important with regard to the mass of ground, the more the surface of exchange is big. Mechanisms of desorption can occur more easily. These results seem to confirm the previous hypothesis according to which one of the major mechanisms of mobilization of metals would be the cationic exchange.

On the other hand, we can suppose that a ratio ground/solution of 1 :10 will be more representative of the long term phenomena. A ratio of 1 :1, closer to the real ratio of the ground in the natural state of 1 :0,16, will correspond more to the short term. Indeed, in the natural environment, in order that a big volume of water circulates in the ground, more time is needed than for a small volume. The results are more coherent with this hypothesis because if metals concentrations in the liquid phase are weaker for a ratio of 1 :10, it is the opposite which is observed for the extracted quantity of metals. More the time passes, more grounds are washed and contaminants taken in the liquid phase.

Finally, the values of the metals concentrations (in mg/L) prove that with a traffic on a big lapse of time of salting water in the ground, it is possible to obtain balanced concentration in solution (which is smaller than the concentration in solution for a time very short). Concretely, at first, there is a washing, then a release. The involved mechanisms can be different according to the scale of time taken into account, but the results obtained here do not allow to identify them.

5.4. Comparison between NaCl and CaCl₂ effects

In strong concentrations (1 mol/ of salt), the calcium chloride provokes a remobilisation of metals in solution much more important than the sodium chloride. However, the essays were made with solutions of 0,1 mol/L and 1 mol/L of salt, but the concentration in chloride of the environment is not the same in both cases : a solution of 1 mol/L of CaCl₂ corresponds to a concentration in chloride of 2 mol/L. In equal concentrations, there are twice more ions chlorinate in solution with the CaCl₂ than with the NaCl. This observations can be explain by a concentration in chloride more important, what could confirm the importance of the ions Cl⁻ during the formation of complexes with metals released in solution by cationic exchange.

6. CONCLUSION

The objective of this work was to estimate the impact of the variations of concentrations in salts of public road network on the mobility of present metals in the contaminated grounds (others than those stemming from edges of roads or from ponds of settling of rainwater). So, two types of grounds (from contaminated urban excavations and from former industrial sites) were used for essays. They were mixed with solutions of different contents in salt. The contagion of these grounds is widely superior to that observed in the studies made until now.

It seemed that the more the volume of water is high with regard to the mass of ground, the more the quantity of metals extracted from the ground is important, and more the concentration in metals in leachates is weak. The values of pH were measured, as well as the results obtained for the various ratio of ground/solution, let suppose that the main mechanisms which involve this mobility of metals are the cationic exchange with the ions Na^+ and the formation of complexes with the chloride.

The salinity shock was also simulated, but the effect was observed only in some very precise cases (for some concentrations in NaCl, a single ratio of ground/solution and a single type of ground). It would seem that the experimental conditions do not allow to reproduce correctly the sudden environment fall of salinity. However, when it was observed, the effect was translated by a strong increase of the content in Zn, Cu and Pb in leachates. This phenomenon is explain essentially by a transport assisted by colloids. Salinity decrease in environment and ionic strength provoke a destabilization of colloids and a training of metals fixed in the aqueous phase.

Essays in column would allow to better simulate the salting shock, to verify the results and to take into account the hydrodynamics aspect. On the other hand, a follow-up of some organic matter and colloids would allow to better understand the mechanisms of keeping back of metals in the ground. In the same way, other types of grounds could be also tested to confirm the stage observed in 0,01 mol/L of sodium chloride. Finally, the same type of cases could be also tested with the calcium chloride (also used for the de-icing of public road networks), and maybe showed in certain cases, a stronger power of release of the metals than for the sodium chloride.

REFERENCES

- [1] Amrhein, C., J.E. Strong et P.A. Mosher (1992). «Effect of Deicing Salts on Metal and Organic Matter Mobilization in Roadside Soils». *Environmental Sciences Technology*, 26(4), 703-709 p.
- [2] Bäckström, M., S. Karlsson et B. Allard (2002). «Metal leachability and anthropogenic signal in roadside soils estimated from sequential extraction and stable lead isotopes». *Environmental Monitoring and Assessment*, 90(1-3), 135-160 p.
- [3] Bäckström, M., S. Karlsson, L. Backman, L. Folkesson et B. Lind (2004). «Mobilisation of heavy metals by deicing salts in a roadside environment». *Water Research*, 38(3), 720-732 p.
- [4] Centre d'Expertise en Analyse Environnementale du Québec (2003). «Détermination des métaux et du phosphore dans les sédiments : méthode par spectrométrie au plasma d'argon après minéralisation acide». MA. 205 – Mét/P 1.0. Ministère de l'Environnement du Québec, 18 p.
- [5] Deschamps, T., M. Benzaazoua, B. Bussièrre, T. Belem et M. Mbonimpa (2006). «Mécanismes de rétention des métaux lourds en phase solide : Cas de la stabilisation des

- sols contaminés et des déchets industriels». VertigO - La revue en Sciences de l'Environnement, 17(2), 11 p.
- [6] Durin, B. (2006). «Transfert et transport colloïdal de polluants métalliques». Thèse de doctorat de l'Université de Nantes, Ecole Doctorale Mécanique, Thermique et Génie civil, Nantes, 394 p.
- [7] Durin, B., B. Béchet, M. Legret et P. Le Cloirec (2005). «Mobilisation par changement de salinité des métaux lourds d'un sédiment de bassin d'infiltration». La Houille Blanche, 5, 19-25 p.
- [8] LCPE (2001). «Liste des substances d'intérêt prioritaire - Rapport d'évaluation : Sels de voirie». Loi canadienne sur la protection de l'environnement (1999) Environnement Canada, 204 p.
- [9] Loi sur la qualité de l'environnement du Québec (2008). Règlement sur la protection et la réhabilitation des terrains.
- [10] MDDEP (1998). Politique de protection des sols et de réhabilitation des terrains contaminés - Annexe 2 : Les critères génériques pour les sols et pour les eaux souterraines. Ministère du Développement durable de l'Environnement et des Parcs
- [11] Norrström, A.-C. et E. Bergstedt (2001). «The impact of road de-icing salts (NaCl) on colloidal dispersion and base cation pools in roadside soils». Water, Air, and Soil Pollution, 127(1-4), 281-299 p.
- [12] Norrström, A.C. (2005). «Metal mobility by de-icing salt from an infiltration trench for highway runoff». Applied Geochemistry, 20(10), 1907-1919 p.
- [13] SETRA (1993). «L'eau et la route. Volume 3 : la gestion de la route». Document technique. 3. 76 p.