

Dissolved Salts in Root Zones Containing Inorganic Amendments

Inorganic amendments are generally sand-sized, mineral particles that are employed to increase water and nutrient retention in sand-based root zones. There are three major classes of inorganic amendments including calcined clay products such as Profile (Profile Products); clinoptilolite zeolite products such as Ecolite (Western Organics); and diatomaceous earth products such as Axis (Eagle-Picher Minerals).

A distinguishing feature of inorganic amendments is their internal porosity, composed of small diameter pores internal to the amendment particles themselves. Thus, 20 percent of an inorganic amendment by volume in mixes with USGA-guideline sand contained 8 to 12 percent of the total volume of pores with diameters < 0.08 mm, considered to be internal pores (Bigelow et al., 2004). These internal pores, due to their small size and because they are not connected to one another, contribute to water retention of the root zone. Inorganic amendments can also contribute to CEC of a root zone with the greatest contribution from clinoptilolite zeolite and the least from diatomaceous earth. Further, as shown by McCoy and Stehouwer (1998) the exchange sites of these inorganic amendments prefer monovalent versus divalent cations.

There is, however, a concern that root zones containing inorganic amendments at rates approaching 20 percent by volume, in conjunction with the use of saline irrigation waters, may lead to incomplete leaching and salt retention within the root zone. Consequently, we conducted a column leaching experiment to test this concern where the columns were built to represent a USGA-style putting green profile and the root zones contained 20 percent by volume amendment with Axis, Ecolite, Profile or sphagnum peat.

The column leaching experiment

Unamended sand and 8:2 sand:amendment volume ratio mixes using Axis, Ecolite, Pro-

file or sphagnum peat were each packed into 2-inch diameter by 18-inch-long PVC columns that contained 3 inches of gravel in the bottom. The test columns were prepared to allow removal of the top 3 inches by cutting off a 3-inch section and reattaching with duct tape. After assembling the columns, the root zones were extensively washed with a dilute, 0.01 M CaSO_4 background solution to remove resident ions.

After allowing the columns to drain overnight, a 3 dS m^{-1} saline solution (a very high salinity content for water to irrigate turf) that contained 225 mg L^{-1} NaCl, 1070 mg L^{-1} Na_2SO_4 , 248 mg L^{-1} MgSO_4 and 380 mg L^{-1} CaCl_2 was applied to the columns at a sufficient quantity to replace all of the background solution with the saline solution. The columns were then allowed to drain overnight.

Prior to the leaching phase of the study, the upper 3-inch segment was removed and weighed to determine the water content. Its root zone contents were emptied onto aluminum foil to air-dry for an hour. Based on preliminary work, this was the drying time required for mixes amended with inorganic amendments to reach a water content of about 14 percent volume, ensuring that most of the salts in the surface layer of the column were contained within the internal porosity. The soil sample was subsequently weighed, repacked into the 3-inch sub-column and replaced.

The background solution of CaSO_4 was then applied to the column at the rate of 0.75 in h^{-1} and a fraction collector set to collect approximately 15 ml of solution leaching from the bottom of the column was turned on. The fraction collector sampling interval was 22.6 min per sample for all experimental runs. This was the salt leaching phase of the experiment, and delivery of saline solution to the column continued for approximately 32 hours (Photo 1). Subsequently, the syringe pump was turned off and the surface of the column

By Ed McCoy, Ph.D., and Keith Diedrick, Ph.D.

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The experimental set-up of the column leaching experiment showing the 2-inch diameter columns, the syringe pump (center top) and fraction collector (center bottom).

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was covered to prevent drying. Collection of leachate samples continued until the column had finished draining, typically overnight.

The solution samples leached from the bottom of the columns were analyzed for Ca, Mg, K and Na using ICP and for Cl and SO₄ by ion chromatography. The EC_w (electrical conductivity) values were also determined. These results were plotted as a function of cumulative leachate volume to form breakthrough curves for both the saline solution loading and leaching phases. In this way, we could graphically compare the leaching behavior of the various root zones to determine if inorganic amendments retained the saline solution to a greater degree than either the unamended sand or the 20 percent by volume peat amended root zone. Finally, the entire experiment was repeated with similar results and interpretations.

Column leaching results

Electrical conductivity breakthrough curves —

The electrical conductivity (EC_w) break-

through curves during saline solution leaching are shown in Fig. 1. The general behavior of the leaching phase is the mixing with and displacement of the saline solution by the more dilute background solution. Thus the early volumes of leachate displaced from the columns had EC_w values of approximately 3.0 dS m⁻¹ (3000 μS cm⁻¹) equal to that of the saline solution. Subsequently, the leachate solution EC_w values declined to the smaller values of the background solution. Comparison of the breakthrough curves showed rather small differences between the amendment treatments for leaching of the saline solution. The unamended sand exhibited saline solution displacement with the smallest cumulative leaching, followed by similar rates of displacement between Ecolite and Profile. Axis and the peat amendment required the greatest cumulative leaching. This ordering is similar to the measured water contents of the root zones prior to the solution leaching phase where the peat amended root zone was the wettest and the unamended sand was the driest. Thus, it appears that the leaching dif-

ferences are explained by the larger volume of resident saline solution in the root zone requiring greater cumulative leaching by the background solution.

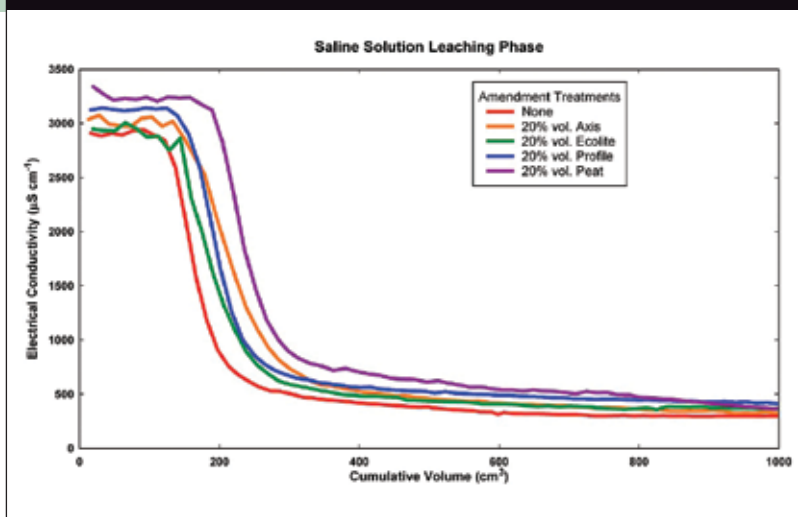
Chloride breakthrough curves — Cl breakthrough curves from the saline solution leaching phase are shown in Fig. 2. The fate of chlorine ions during leaching is important because being an anion, Cl does not interact with the cation exchange sites within the root zones yet can interact with the internal porosity of the inorganic amendments. Thus, any substantial delay, in terms of cumulative volume, of Cl leaching within the inorganic amendment columns would be an indication of such an interaction.

As with leaching of total EC_w , the earliest leaching of Cl occurred for the unamended sand and the latest leaching occurred for the peat with the inorganic amendment treatments intermediate. Thus, the results of Cl leaching show treatment differences that can principally be explained by differences in initial water contents within the experimental columns. Those columns that retained a greater solution volume after draining showed the greatest delay in leaching of Cl. No effects on Cl fate were apparent from the internal porosity of 20 percent by vol. amendment of Axis, Ecolite or Profile.

Sodium breakthrough curves — Na breakthrough curves from the saline solution leaching phase are shown in Fig. 3. Na, being a cation is expected to interact with the cation exchange complex within the root zones. Because the initial column washing solution was dilute $CaSO_4$, it is expected that the columns entering the saline solution loading phase contained very few Na ions on the exchange complex or in solution. Further, because the saline solution contained large quantities of Na ions, one would expect a Na for Ca exchange to occur as the saline solution was progressively introduced into the columns.

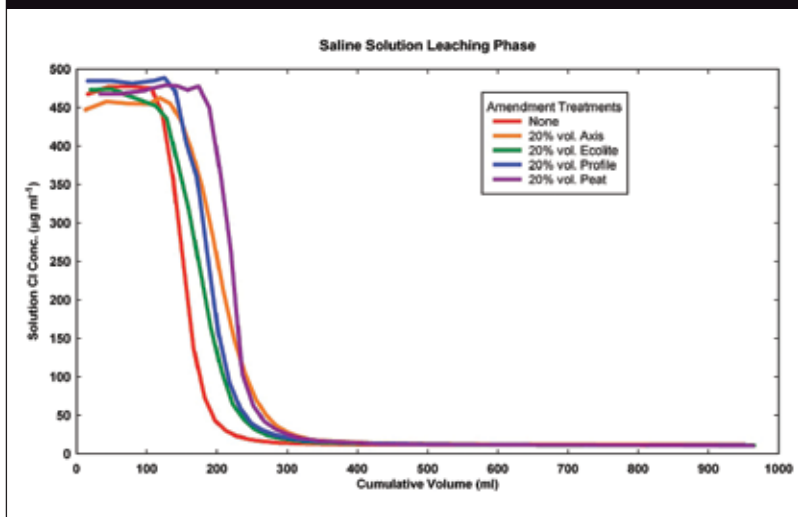
The saline solution leaching phase results of Fig. 3 show initial Na concentrations roughly equal to those at the end of the loading phase. The lower values for Ecolite were due to incomplete saturation of cation

FIGURE 1



Column leachate EC_w values as a function of cumulative leachate volume from the saline solution leaching phase of the column leaching experiment.

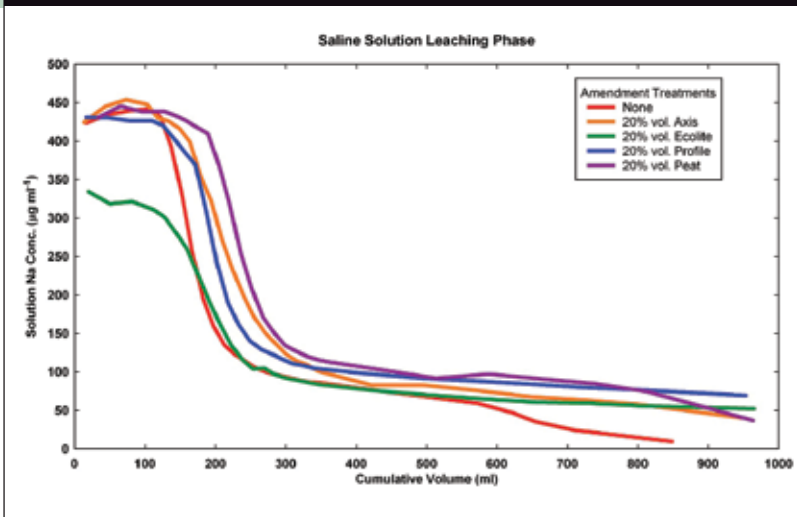
FIGURE 2



Column leachate Cl concentrations as a function of cumulative leachate volume from the saline solution leaching phase.

exchange sites of this column during the loading phase. This corresponds to the large CEC value of the Ecolite amendment. Regardless of the initial concentration differences, however, the earliest leaching occurred for the unamended sand and the latest leaching occurred for the peat with the inorganic amendment treatments intermediate. These results were similar to those of total EC_w and Cl suggesting that treatment differences

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FIGURE 3

Column leachate Na concentrations as a function of cumulative leachate volume from the saline solution leaching phase.

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in Na leaching were principally due to differences in initial water contents within the experimental columns. Yet following this initial Na leaching, ending at between 200 and 300 ml, there was a slower, linear decline in Na concentration that appeared quite similar for all amendment treatments. Likely this was due to cation exchange.

Thus, Na release from the root zones appeared to occur at two different rates, an early rapid rate and a later slower rate. But this too can be explained by a rule of cation exchange whereby a given cation is more easily displaced when at a high degree of saturation on the exchange complex than when at a lower degree of saturation. During the early phases of Na leaching it was likely that a high degree of Na saturation occurred on the exchange sites, resulting in easier Na displacement by the incoming solution. As Na was leached, however, the degree of Na saturation declined, making the remaining Na ions harder to displace.

Overall summary

A column leaching experiment was conducted to determine if the presence of inorganic amendments within the root zone had an influence on leaching of salts from a putting green soil profile. Comparisons were made between an unamended sand root zone and root zones containing 20 percent by volume of Axis, Ecolite, Profile, or sphagnum peat.

The columns were first washed with a dilute solution and then infiltrated with a saline solution having EC_w value of 3 dS m^{-1} . Following an overnight period to drain and a drying step to concentrate the salts within the internal porosity, the columns were infiltrated with dilute $CaSO_4$. The final step was the saline solution leaching phase during which samples were collected from the outflow at the bottom of the soil profiles. These leachate solution samples were analyzed for Ca, Mg, K, Na, Cl, SO_4 and total EC_w . The resultant breakthrough curves for EC_w , Cl and Na were all similar with the earliest salt leaching occurring for the unamended sand, and the most delayed salt leaching for the peat amendment. Salt leaching for the inorganic amendments was intermediate. Further, these differences were related to the water contents of the columns prior to leaching. Thus, it appears that leaching differences between root zones are explained by the larger volume of resident, saline solution requiring greater cumulative leaching by the background solution. The Na results also showed an expected cation exchange response between the resident Na ions and the displacing Ca ions.

Consequently, the results of this research failed to find a salinity hazard from the use of high rates of inorganic amendments within turfgrass root zones. Diffusive salt exchange between the leachable, inter-particle porosity and the non-leachable, internal porosity was sufficiently rapid, such that a typical irrigation cycle should displace accumulated salts. Responses due to cation exchange, a perceived benefit of both organic and inorganic amendments, were, however, also apparent.

Ed McCoy and Keith Diedrick are in the School of Natural Resources at The Ohio State University. Inquiries can be directed to mccoy.13@osu.edu.

FUNDING SOURCES

This research was funded by Profile Products, LLC, Buffalo Grove, Ill.

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