

Chemical Composition of Salts Associated With Saline Seeps in Stark and Hettinger Counties, North Dakota

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Salinity associated with saline seeps in western North Dakota can reach levels that restrict or eliminate plant growth. The composition and concentration of salts also can affect soil physical properties. Information is presented that can be of value for management and reclamation decisions.

Introduction

The movement of water associated with saline seeps results in a redistribution of salts in the soil profile. High levels of salinity may result where seepage waters emerge and salt concentrations increase due to evaporation. This leads to a deterioration of physical and chemical properties that restricts or eliminates plant growth. In addition, high levels of salinity or nitrate in seepage water may preclude its use for livestock or irrigation. This report provides information on the composition and distribution of soluble salts found in several saline-seep areas of Stark and Hettinger Counties, North Dakota. This information can be of value for management and reclamation decisions.

Several reports (Bahls and Miller, 1973; Ballantyne, 1963; Doering and Sandoval, 1976; Ferguson, Brown, and Miller, 1972; Greenlee, Pauluk, and Bowser, 1968; Halvorson and Black, 1974) describe the salt content of soils and water in seep areas in Montana, North Dakota, Alberta and Saskatchewan. In most cases sodium and sulfate were the predominant cation and anion with magnesium and calcium commonly present in significant amounts. Nitrate concentration varied considerably but often was found in high amounts, making seep waters unsafe for human or livestock consumption.

The effect of excessive salinity is primarily a reduction in the water availability to plants (Bauer, 1976). The affinity of the dipolar water molecule for the salt ions reduces the soil-water potential and, thus, its availability to plants. Plant species response and composition varies with the degree of salinity in the soil. *Kochia* (*Kochia scoparia*) was predominant at high salt concentrations in seep areas in Divide County, North Dakota (Worcester and Seelig, 1976). Barren soil was observed where the electrical conductivity (EC) of a 1:1 soil: water extract exceeded 20 mmhos/cm. While all soluble salts tend to reduce water availability, excessive amounts of sodium also can result in soil dispersion and undesirable physical properties. (U.S. Soil

Salinity Staff, 1954). These dispersed areas are sometimes called "slick spots" or "scab spots" and have very low water infiltration rates resulting in "droughty" areas in fields. High levels of salinity may also cause germination injury, toxic effects, and nutrient imbalances (U.S. Soil Salinity Staff, 1954).

Data Selection

Soil and water samples from numerous saline-seep areas eight to 16 kilometers northwest of Dickinson, North Dakota, were obtained during the summer of 1975. Based on visual observation these areas were obviously affected by excessive wetness and salinity. Discussions with area farmers indicated the study areas were new saline seeps or areas where the seeps had been increasing in size in recent years. Approximate site locations are shown by Figure 1.

Details on sampling procedures and methods of analyses can be found elsewhere (Deutsch, 1977).

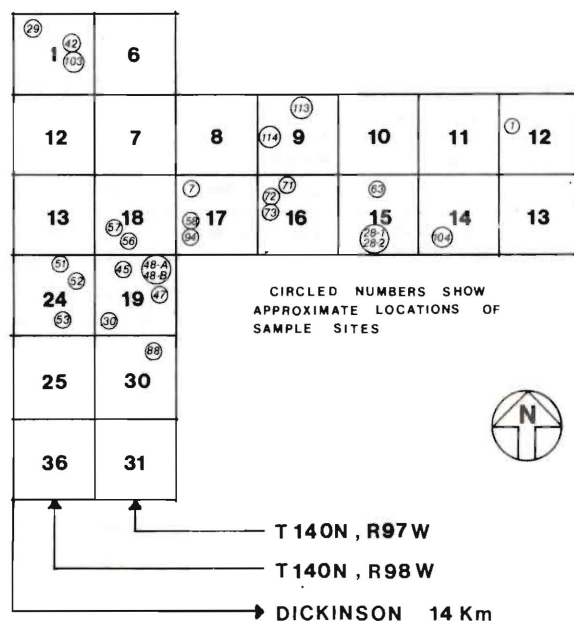


Figure 1. Approximate locations of sample sites in Stark County. Sections 31 and 36 are bounded by I-94 on the south.

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Soluble Salt Analysis of Soil Supernatant

A large number of soil samples and cores were obtained from numerous saline seeps. Five hundred forty-one samples from 29 cores were saved for determination of EC, nitrate, chloride, bicarbonate, carbonate, sodium, potassium, magnesium, calcium, and hydrogen ion activity (pH) from a 1:5 soil: water supernatant. In most of these seeps lignite veins act as water bearing layers, although, in some cases, the lateral movement of water is caused by textural discontinuities or by combinations of lignite veins and textural discontinuities. Data for a typical site are shown in Table 1 and illustrated in Figures 2 and 3. Location 1 is in the seep while location 3 is on the upper part of the backslope.

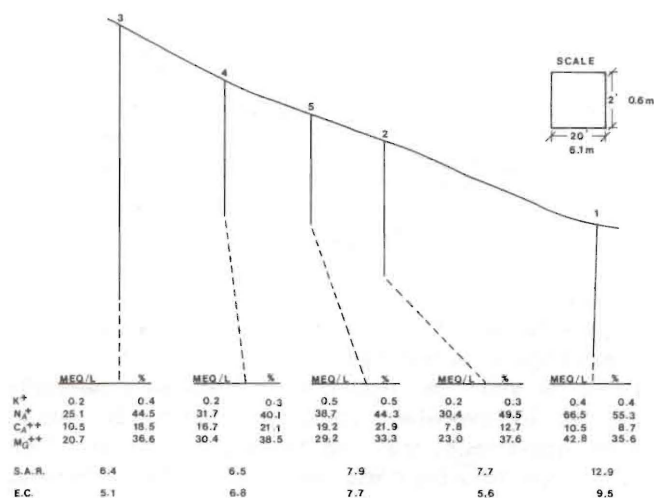


Figure 2. Chemical composition of ground water in various landscape positions at Seep 1. EC is expressed as mmhos/cm at 25°C.



Figure 3. Aerial view of Seep 1. Numbers indicate location of sample sites. Arrows show direction seep has been expanding.

Sodium, calcium and magnesium were the principle cations found in the soil: water supernatant with the sodium being the predominant cation in most cases. Despite the relative abundance of sodium, only 5.5% of the samples (30/541) had sodium adsorption ratios (SAR) of 15 or more. These high SAR's were confined to seven core samples and usually found below 91 cm. The concentration of potassium was always rather low compared to other cations and little variations was noted among samples.

Sulfate can be estimated from the sum of cations (meq/l) minus the sum of the anions (NO₃⁻, Cl⁻, HCO₃⁻, and CO₃²⁻) analyzed. This shows that sulfates must be the principle anion in most of the samples because of the low amounts of nitrates, carbonates, bicarbonates, and chloride found. The concentration of nitrate and chloride was low relative to the sum of the cations. Often only traces of these ions were measured.

Table 1. Soluble Salt Analysis of Soil Supernatant at Seep 1.

Location	Depth In/cm	E.C. mmhos/cm at 25°C	NO ₃ ⁻ Meq/1	Cl ⁻ Meq/1	HCO ₃ ⁻ Meq/1	CO ₃ ²⁻ Meq/1	SO ₄ ²⁻ Meq/1	Sum of Cations Meq/1	Na ⁺ Meq/1	K ⁺ Meq/1	Mg ⁺⁺ Meq/1	Ca ⁺⁺ Meq/1	pH	SAR
1	0- 6/ 0- 15	1.6	0.1	T	1.9	-----	13.1	15.1	10.4	0.3	3.2	1.2	8.3	7.0
	6-12/ 15- 30	1.2	0.2	T	2.0	0.1	9.4	11.7	8.8	0.2	1.9	0.8	8.4	7.6
	12-18/ 30- 46	1.1	0.2	T	1.8	0.1	8.8	10.9	8.8	0.2	1.3	0.6	8.6	0.9
	18-24/ 46- 61	1.0	0.3	T	1.4	1.1	8.0	10.8	10.1	0.1	0.4	0.2	9.3	18.4
	24-30/ 61- 76	1.5	0.4	T	1.6	1.6	9.4	13.0	12.5	0.1	0.2	0.2	9.6	28.0
	30-36/ 76- 91	1.1	0.6	T	1.4	2.3	5.9	10.2	9.9	0.1	0.2	T	9.8	31.3
	36-42/ 91-107	0.6	0.6	0.1	1.8	2.3	4.4	9.1	8.3	0.2	0.5	0.1	9.6	15.2
	42-48/107-122	0.7	0.5	T	1.7	2.5	5.8	10.5	7.3	0.3	2.6	0.3	9.5	6.1
	48-54/122-137	0.6	0.4	T	1.7	1.9	5.4	9.4	6.4	0.3	2.4	0.3	9.4	5.5
	54-60/137-152	0.7	0.4	T	0.9	1.8	3.7	6.8	6.4	0.1	0.3	T	9.4	16.5
3	0- 6/ 0- 15	0.1	T	T	0.5	-----	0.3	0.8	0.1	0.2	0.2	0.3	7.4	0.20
	6-12/ 15- 30	0.1	T	T	0.5	-----	0.2	0.7	0.1	0.1	0.2	0.3	7.2	0.20
	12-18/ 30- 46	0.2	T	T	1.6	-----	0.2	1.8	0.2	0.2	0.7	0.7	8.0	0.24
	18-24/ 46- 61	0.1	T	T	1.2	-----	0.3	1.5	0.3	0.1	0.6	0.5	8.2	0.41
	24-30/ 61- 76	0.7	T	T	1.0	0.3	0.4	1.7	0.7	0.2	0.5	0.3	8.5	1.1
	30-36/ 76- 91	0.2	0.1	T	1.4	0.4	0.4	2.2	1.4	0.2	0.4	0.2	8.7	2.6
	36-42/ 91-107	0.3	0.2	T	1.3	0.7	0.6	2.6	2.0	0.1	0.4	0.1	9.0	4.0
	42-48/107-122	0.4	0.2	T	1.0	0.8	1.6	3.4	2.8	0.1	0.4	0.1	9.1	5.6
	48-54/122-137	0.6	0.2	T	1.0	0.5	4.0	5.5	4.2	0.2	0.8	0.3	8.9	5.7

T indicates less than 0.1 Meq/1.

SO₄²⁻ = sum of cations - (NO₃⁻ + Cl⁻ + HCO₃⁻ + CO₃²⁻)

Ground Water Analysis

Where possible, ground water samples were obtained from core holes at the time of drilling. Thirty-one samples from 12 saline seeps were analyzed for pH, EC, calcium, magnesium, sodium, and potassium. Figure 2 illustrates a commonly observed deterioration in water quality as we go from the upslope positions to the area where the seep waters emerge. The following general observations were made going downslope.

1. The electrical conductivity (EC) of the water increased.
2. The sodium adsorption ratio (SAR) of the water increased.
3. The total concentration and relative proportion of sodium tended to increase.
4. The total concentration and relative proportion of calcium tended to decrease. (In some cases the total concentration of calcium increased but at a much slower rate than sodium.)
5. The concentration of magnesium sometimes in-

creased but at a much slower rate than sodium.

In cases where the water bearing layer is relatively shallow at lower landscape positions, evapotranspiration may result in increased concentrations of salts in the ground water. The higher sodium levels usually found in the soil profile at lower landscape positions can also contribute to higher sodium levels in the ground water. In addition, there must be considerable precipitation of calcium and, in some cases, precipitation of magnesium to result in lower concentrations of these ions.

Salt Crust Analysis

Salt crust samples were obtained from 20 saline seeps in the study area northwest of Dickinson, North Dakota, and from two saline seeps in Hettinger County. These samples were analyzed for sodium, potassium, calcium, magnesium, carbonate, bicarbonate, and chloride with the results expressed as percentage of total concentration (Table 2). These data further illustrate the shift in ionic composition from upslope positions to the emergent salt crust on the seep. The crusts were almost entirely composed of sodium and magnesium sulfates with very little calcium present.

Surface Water Analysis

Surface seepage water was collected for analysis from six seeps in the study area northwest of Dickinson (Table 3). The data were normalized by dividing meq/l of sodium and meq/l of magnesium by meq/l of calcium (Table 4). These ratios were then compared to the electrical conductivity (mmhos/cm) of the corresponding water sample giving the following results:

$$\begin{aligned} \text{Na/Ca} &= 1.05 \text{ E.C.} & -2.08 \\ r &= 0.99 \end{aligned}$$

$$\begin{aligned} \text{Mg/Ca} &= 0.55 \text{ E.C.} & -0.09 \\ r &= 0.99 \end{aligned}$$

where r is the correlation coefficient.

The results relate very well to the observations made from ground water analysis. As the electrical conductivity increased the contributions of sodium and magnesium, as

Table 2 - Chemical Analysis of Selected Salt Crusts from Saline Seeps Expressed as Percentage of Total Concentration. H25 and H27 were from Hettinger County approximately 13 km west of Mott.

Site	% Na ⁺	% K ⁺	% Mg ⁺⁺	% Ca ⁺⁺	% CO ₃ ⁻	% HCO ₃ ⁻	% Cl ⁻
7	66.0	0.7	30.9	2.4	----	2.0	0.0
30	44.0	0.5	52.1	3.4	0.5	0.8	0.7
45	54.4	0.5	43.8	1.3	----	1.0	0.0
47	57.7	0.7	38.4	3.2	----	0.8	0.1
48a	44.0	0.2	54.9	0.8	----	1.0	0.0
48b	51.8	1.0	45.7	1.5	----	1.7	0.8
51	28.6	0.8	69.0	1.5	----	1.2	0.0
52	81.1	0.9	15.5	2.5	----	2.1	0.0
53	33.2	0.3	65.6	0.9	----	0.7	0.0
56	43.7	0.3	55.9	1.7	----	0.8	0.2
57	57.0	0.3	41.3	1.4	----	0.5	0.0
58	96.7	0.4	2.6	0.4	7.0	1.7	0.0
63	48.4	0.3	31.2	4.5	----	1.7	0.0
71	40.4	0.3	58.7	0.7	----	0.7	0.0
72	5.2	0.3	93.6	0.8	----	0.7	0.0
73	43.8	0.3	55.3	0.6	----	0.7	0.0
88	39.3	0.6	56.0	4.0	----	1.2	0.6
94	98.4	0.3	0.7	0.7	8.5	3.8	0.0
104	39.1	0.3	57.8	2.8	----	0.8	0.6
113	49.5	0.1	48.9	1.4	----	0.8	0.0
H25	61.2	0.5	34.9	3.4	----	1.2	0.0
H27	47.3	0.3	48.8	3.6	0.7	1.1	0.0

Table 3 - Chemical Composition of Surface Water from Selected Sites

Site	K ⁺		Na ⁺		Ca ⁺⁺		Mg ⁺⁺		Sum of Cations Meq/1	pH	E.C. mmhos/cm at 25°C	SAR
	Meq/1	%	Meq/1	%	Meq/1	%	Meq/1	%				
28-1	0.2	0.3	32.4	31.1	17.7	17.0	53.8	41.7	104.1	7.0	5.5	5.42
28-2	0.3	0.5	12.4	17.3	21.5	30.0	37.5	52.3	71.8	7.3	7.3	2.28
29	0.3	1.6	9.1	47.5	3.9	20.5	5.8	30.4	19.1	8.3	1.7	4.12
42	1.1	0.1	1653.1	64.3	22.2	0.9	893.1	34.8	2569.7	8.6	75.0	77.27
51	0.7	0.5	49.1	34.5	23.6	16.5	69.6	48.5	143.6	7.1	7.9	7.25
103	0.6	0.1	310.1	62.3	9.5	1.9	172.6	35.0	493.0	8.3	26.0	32.50
114	0.5	0.2	179.1	65.7	9.3	3.4	83.5	30.7	272.6	8.3	20.0	26.25

Table 4. Normalized values and E.C. from Table 3 data.

Na/Ca	Mg/Ca	Ca/Ca	E.C. mmhos/cm at 25°C
1.8	3.0	1	5.5
0.6	1.7	1	4.9
2.3	1.5	1	1.7
74.5	40.2	1	75.0
2.1	2.9	1	7.9
32.6	18.2	1	26.0
19.3	9.0	1	20.0

components of the total salinity, increased in a linear fashion. The contribution of sodium to the total salinity was approximately twice that of magnesium. This may be related to the differences in solubility of sodium, magnesium and calcium salts; however, no attempt was made to analyze the results using chemical equilibria.

Summary and Conclusions

The composition of salts associated with numerous saline seeps in Stark County was determined. In all cases the salinity in the seeps themselves had reached a level such that growth of valuable crops was greatly restricted or eliminated.

Soil and water quality deteriorate as one goes from upper landscape positions to the seep area. Sodium and magnesium sulfate were dominant in the area where seep waters emerge. In the areas studied the SAR had not, in most cases, reached levels that would be associated with soil dispersion. The high levels of salinity also tended to suppress soil dispersion.

Information on seep reclamation is quite limited with casual observation predominant over scientific measurement. The authors and their colleagues have observed reclamation success (or at least improvement) when the source of seepage water has been reduced or stopped by

changed management practices without concurrent use of chemical amendments. These data seem to support the contention that most seeps, at least those of recent origin (formed within the last 10 to 15 years), are not so sodic that dispersion is a major problem in reclamation.

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