QUALITY OF LAKE WATERS FOR IRRIGATION IN NORTH DAKOTA

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The extension of irrigated acreage in North Dakota raises the problem of obtaining new sources of water. The main source used today is underground water, and in the future an increasing acreage will be irrigated with river water. With the exception of the Missouri River, the majority of the rivers and aquifers in North Dakota have somewhat saline water. An alternative local source of irrigation water is lake water. There are more than 100 lakes in North Dakota with water available during the growing season that could be used for irrigation, at least in small, local irrigation systems.

Published data on 78 lakes have been used for evaluating the lakes of North Dakota as sources of water for irrigation. They have been collected and analyzed by the United States Geological Survey and cooperating state and federal agencies in North Dakota between 1948 and 1982 (2). Data are from 288 gaging stations during the interval of June-September, when irrigation is generally needed.

The quality of irrigation water is determined by the following indices: (1) salinity hazard or total salt concentration, expressed as electrical conductivity ($EC \times 10^6$ or µmhos/cm at 25°C); (2) alkalinity hazard, expressed by pH values; (3) sodicity hazard or concentration of sodium relative to other cations and/or anions, expressed as sodium adsorbtion ratio (SAR), adjusted sodium adsorbtion ratio (SAR_{adj}), and residual sodium carbonate (RSC); and (4) concentration of boron, fluorine, lithium and other trace elements that may be toxic to plant growth in very low concentration, expressed in mg/l.

Table 1 presents the variation of data on total salinity for 1579 samples, pH for 1547 samples, SAR for 252 samples, SAR_{adj} for 236 samples, RSC for 239 samples, and between 6 and 253 samples for 18 trace elements. The most commonly used trace elements to characterize the quality of water for irrigation are boron, fluorine, lithium, and selenium; copper, nickel, aluminum, and arsenic are considered if industrial pollution of natural water with toxic heavy metals occurs.

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The lakes in North Dakota have a variable total salt concentration. The electrical conductivity ranges from 51 to 130,000 µmhos/cm. In spite of such large extremes, the majority of the samples are in the class of medium salinity hazard (51 percent), but only 1 percent are in the class of low salinity hazard. The remaining samples are in the classes of high (38 percent), very high (3 percent), and excessively high (7 percent) salinity hazard. The majority of the samples are excessively alkaline (71 percent). The high alkalinity is not always dangerous to crops because water pH tends to be buffered by the soil and most crops tolerate a wide pH range.

With regard to sodicity, the majority of the samples have low values of SAR (61 percent) and RSC (83 percent), which means a low sodicity hazard. Unfortunately, in the waters with high RSC there is the tendency for calcium, and to a lesser degree magnesium, to precipitate in the form of carbonate; this leads to an increase in the SAR of the soil solution and consequently to a higher exchangeable sodium percentage (ESP) of the irrigated soil. This tendency is much better expressed by adjusted SAR values. Indeed, the data from Table 1 show that SAR_{adj} has higher values than the regular SAR.

In regard to trace elements, lake water quality for irrigation is generally favorable. Only four of the 18 trace elements present intolerable concentrations: lithium in 12 percent of the water samples, boron in 5 percent, selenium in 3 percent and fluorine in 1 percent. Concerning the concentrations which are restrictive for long term irrigation (max. 20 years), seven other trace elements raise problems. These are: boron in 35 percent of the water samples, manganese in 20 percent, molybdenum in 12 percent, arsenic in 9 percent, vanadium in 4 percent, chromium in 2 percent, and fluorine in 2 percent. The other trace elements (Al, Be, Cb, Cu, Fe, Pb, Ni, and Zn are present in all water samples in concentrations which are considered tolerable for a continuous irrigation on all soils and crops of North Dakota.

However, the occurrence of toxic levels of the trace elements mentioned in North Dakota lake waters does not necessarily render the water unusable for irrigation. As the water penetrates the soil, some trace elements

Table 1. Minimum, maximum and mean values of salinity indices; their class limits and frequency.

Salinity indices	No. of lakes	No. of samples	Min.	Max.	Mean	Std. error of mean	Classes/Frequency (%) Low	Freq.	Medium	Freq.	High	Freq.	V. High	Freq.	Excessive	Freq.
EC-µmhos/cm	78	1579	51	130000	2464	230	<250	1	250-750	51	750-2250	38	2250-5000	3	>5000	6.9
pH	72	1547	5.1	9.8	8.5	.01	< 6	.1	6.8-7.2	2	7.1-7.5	2	7.5-8.3	26	>8.3	71
SAR	49	252	.2	383	18.6	2.2	< 10	61	10-18	12	18-26	9	>26	18	----	----
SAR adj.	42	236	.43	1320	64.8	8.3	< 10	52	10-18	2	18-26	4	>26	42	—	—
RSC-meq/1	42	239	-1321	350	-53	11.9	< 1.25	83	----	-	1.25-2.50	12	—	..	>2.50	5

Table 2. Concentration and tolerable limits of selected trace elements.

Trace elements	No. of lakes	No. of samples	Minimum	Maximum	Mean	Std. error of mean	Tolerable for continuous irrigation mg/l	Freq.	Tolerable for irrigation of max. 20 yrs. mg/l	Freq.	Non-tolerable for irrigation mg/l	Freq.
			Milligrams per liter									
Aluminum	7	86	0	1.1	.09	.017	<5	100	5-20	0	>20	0
Arsenic	7	86	0	.25	.03	.005	< .1	91	.1-2	9	> 2	0
Beryllium	2	6	.002	.01	.006	.001	< .1	100	.1-.5	0	> .5	0
Boron	26	225	0	30	2.05	.278	< .75	60	.75-10	35	>10	5
Cadmium	7	84	0	.008	.001	.0001	< .01	100	.01-.05	0	> .05	0
Chromium	7	82	0	.21	.012	.003	< .1	98	.1-1	2	> 1	0
Cobalt	7	85	0	.005	.0009	.0001	< .05	100	.05-5	0	> 5	0
Copper	7	86	0	.16	.006	.002	< .2	100	.2-5	0	> 5	0
Fluorine	49	253	0	19	.406	.081	<1	97	1-15	2	>15	1
Iron	23	128	0	.76	.067	.009	<5	100	5-20	0	>20	0
Lead	7	80	0	.02	.004	.0005	<5	100	5-10	0	>10	0
Lithium	7	85	.02	13	1.04	.239	<2.5	88	----	--	> 2.5	12
Manganese	23	118	0	2.3	.19	.034	< .2	80	.2-10	20	>10	0
Molybdenum	7	85	.001	.03	.005	.0005	< .01	88	.01-.05	12	> .05	0
Nickel	7	85	0	.01	.004	.003	< .2	100	.2-2	0	> 2	0
Selenium	7	85	0	.024	.003	.0005	< .02	97	----	--	> .02	3
Vanadium	7	82	0	.14	.013	.003	< .1	96	.1-1	4	> 1	0
Zinc	7	88	0	1.0	.069	.016	<2	100	2-10	0	>10	0

may be precipitated, adsorbed, or fixed on the soil particles and become inactive, but the excessive concentration of boron and lithium in some lake waters may raise a serious problem. This is because even waters with low and medium salinity and/or sodicity hazard may have toxic concentrations of boron and lithium to some plant crops, or at least these trace elements may have the tendency to accumulate in the irrigated soil in excessive quantities.

The information on the influence of trace elements in water on irrigated soils is limited world wide. Only recently, the maximum permissible levels of the main trace elements have been established by a U.S. committee on water quality. The limits presented in Table 2 are from this committee (1). They are based on experiments conducted in southwestern U.S., which has a warm climate and waters mainly dominated with chloride. The cool climate in North Dakota, the high content of calcium carbonate in the soil, and the predominance of sulfates in irrigation water may influence these limits. However, the waters from the Devils Lake Basin should not be recommended for irrigation until boron and lithium contents have been determined. The water from Carmel, Ordway, Matecjekk, Renwick, and Spiritwood lakes and the Jamestown reservoir may raise supplementary problems due to excessive concentration of manganese, molybdenum and fluorine.

Finally, the maximum concentration of cadmium in some lake waters (near 0.008 mg/l) may be restrictive for potatoes.

References

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2. U.S. Geological Survey. 1948-1982. Water Data Reports ND-48 to ND-82.