AVAILABILITY AND QUALITY OF IRRIGATION WATERS IN ARID "LAGUNAS" OF NORTHERN MEXICO

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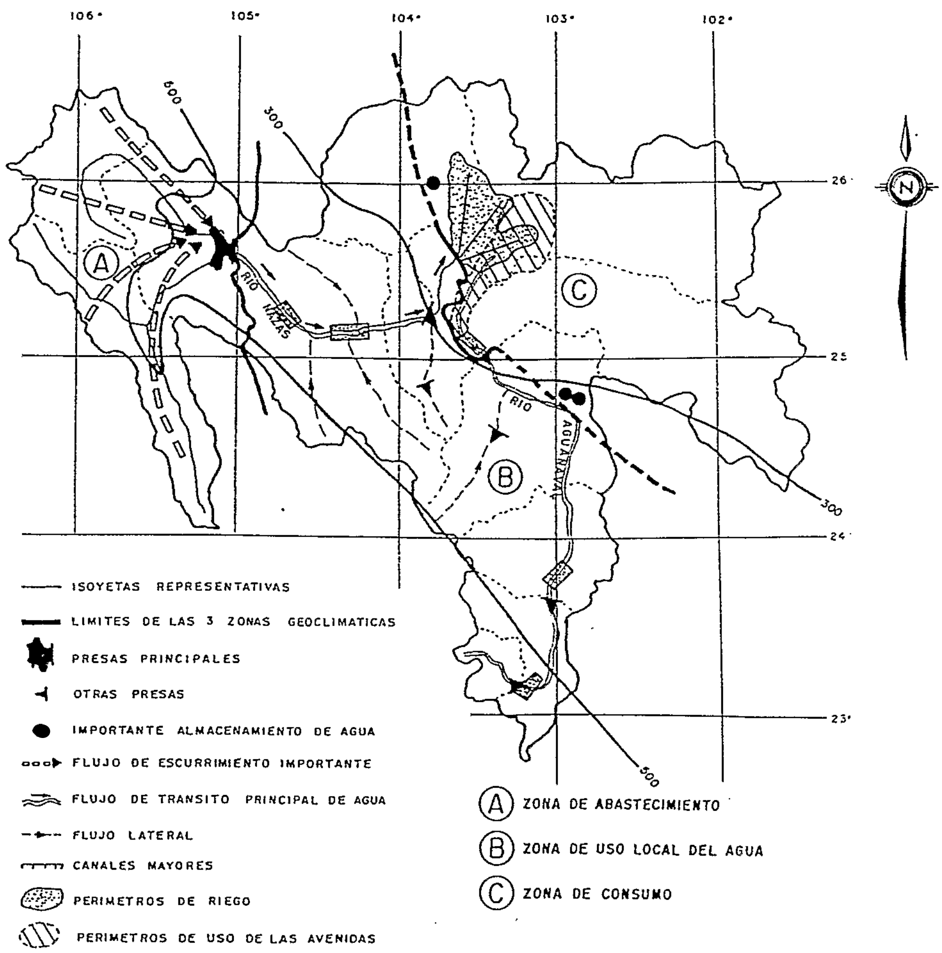
INTRODUCTION

In Northern Mexico, between the Western and Eastern mountain chains of the Sierra Madre, a large region is extended (from 1000 to 1200 m. and slope < 0.5 degrees), with a great number of endoreic "lagunas" in the lowest parts.
Among the 37 Hydrologic Region of Mexico, the three with an endoreic system (Map 1), are located in this arid region, (precipitation 200 to 300 mm/year).

A little part of these very large plains is irrigated in vast areas (Comarca Lagunera in Torreón, Las Delicias in Chihuahua...), with surface waters coming from Occidental Sierra Madre mountains (3000 m.). The main problem in this desert system is to get enough water for irrigated lands, so subsurface waters must also be exploited and are actually overexploited because the used volumes for crops production, exceed largely the water requirements of cultived plants (alfalfa and ray grass). In return the very important soil leaching fraction is restricting the soil salinization process.

Today, a more rational quantitative water use foresee the reduction of irrigation water volumes by adaptation to the strict plant necessities, and by increasing efficiency in irrigation techniques. What are the potential evolution of water quality with this new orientation and under strong evaporative conditions ?

Map 1 - General map of location



Map 2 - Endoreic system of Hydrological Region 36

MATERIAL AND METHODS

Hydrological prospects (1, 4) in one of the three endoreic Hydrologic Regions of Mexico (Hydrologic Region 36, 92000 km^2, Nazas and Aguanaval rivers, Map 2), have permitted to identify three main sources of irrigation waters used for the regional agriculture in the Comarca Lagunera plain:

- Runoff waters
- Underground waters
- Urban residual waters.

The chemical analysis of these waters and their potential evolution under evaporative conditions, by simulation with a thermodynamic model "Soprex", (5), are presented and interpreted in order to suggest hydrochemical basis for an agricultural water management.

RESULTS and DISCUSSION

- Runoff waters coming from the Nazas and Aguanaval watershed (60 000 km^2), catch the rainfall waters from the highest part of the Hydrological Region (altitude, 2000 to 3000 m.), The stream flow of the main river (Nazas river, 1350 million of cubic meters/year), support almost 59 % of irrigation water supply in the Laguna plain (200 000 ha. of irrigated lands), (Map 2).

These runoff waters are low mineralized, with a calcium-magnesium bicarbonate kind of chemical feature (Fig.1, Tab.1).

- Underground waters are coming from 3500 pumping wells. The aquifer is ranging from 50 to 200 m. depth, in the plain. These waters support almost 39 % of the irrigation supply in Laguna region (900 Mm^3/ year), but the aquifer is subject to a dangerous drawdown (1.50 m. by year for 30 years).

Waters are generally mineralized with a calcium or sodium sulphated chemical feature (Fig.1, Tab.1).

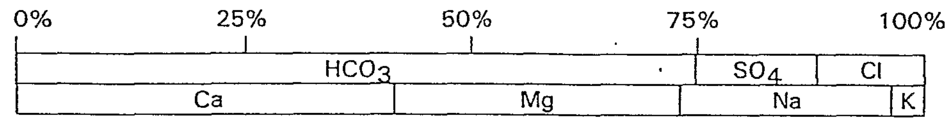
- Urban residual waters are coming from domestic drainage (waste waters), of the three main regional cities established in the plain (Ciudad Lerdo, Gómez Palacio, Torreón, 1 million inh.). These waters support up to 2 %, (50 Mm^3), of the water supply in regional agriculture.

They are more or less mineralized, with a mixed bicarbonated kind of chemical feature, calcic and sodic, (Fig.1, Tab.1).

AGUAS DE ESCURRIMIENTO SUPERFICIAL

aguas del río Nazas a nivel de la presa L. Cardenas

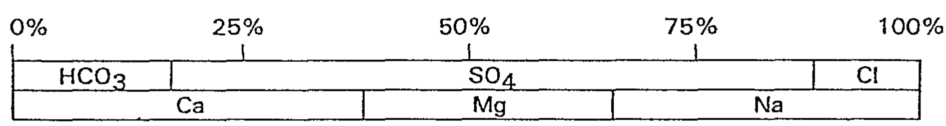
CE	RAS	CTD	pH	Ca	Mg	Na	K	CO_3	HCO_3	Cl	SO_4
dS m^{-1}		g L^{-1}				meq	L^{-1}				
0.5	0.9	0.32	7.85	2.1	1.67	1.30	0.33	0	3.64	0.75	0.78



AGUAS DE ORIGEN SUBTERRANEO

aguas de pozos de bombeo (promedio de 4400 análisis)

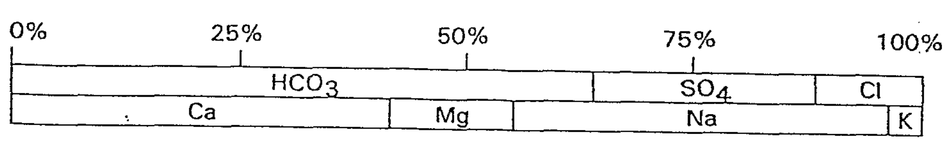
CE	RAS	CTD	pH	Ca	Mg	Na	K	CO_3	HCO_3	Cl	SO_4
dS m^{-1}		g L^{-1}				meq	L^{-1}				
1.63	4.1	1.38	7.66	7.52	4.42	8.38	0.02	0.05	3.24	3.02	14.1



AGUAS RESIDUALES URBANAS

promedio de las tres ciudades más grandes
(Torreón, Gómez Palacio y Lerdo)

CE	RAS	CTD	pH	Ca	Mg	Na	K	CO_3	HCO_3	Cl	SO_4
dS m^{-1}		g L^{-1}				meq	L^{-1}				
1.14	3.4	7.3	7.2	4.2	1.3	4.0	0.3	0	6.7	1.3	1.9



Tab.1 - Chemical characteristics of the three sources of water irrigation in the HR 36

Concerning mineralization, it is possible to estimate the potentiality of salt accumulation in soil:

- Underground waters: 1.0 to 1.5 kg $m3^{-1}$, (900 to 1350 103 T/year).
- Residual waters : 0.7 to 0.8 " , (35 to 45 10^3 T/year).
- Runoff waters : 0.3 to 0.6 " , (480 to 810 10^3 T/year).

Alternate use or mixing of these irrigation waters can be often observed.

After irrigation, used waters drain naturally to the lowest parts of the endoreic plain called lagunas of Mayran and Viesca, where they contamine a part of the aquifer which reach a very high salt concentration. This brine is exploited for salts extraction, (NaCl, Na2SO4), by wells from 10 to 500 meters.

Besides the mineralization criterion, a geochemical consideration must be also applied on the ionic proportion of each kind of water (1, 6), in order to foresee the chemical evolution of these irrigation waters under strong evaporative conditions, and determine their implications on soils. Simulation of water evaporation was possible using the thermodynamic model "Soprex" (5). The hydrochemical behavior of each irrigation water is presented in Fig. 2 that shows:

- In one hand, runoff and urban residual waters with an increasing alkalinity and sodium values following the concentration factor after calcite and gypsum precipitation; that means an hydrochemical evolution into the alkaline way with formation of sodium bicarbonated and carbonated salts at final state of water evaporation (thermonatrite (Na2CO3,H2O) trona (NaHCO3 Na2CO3, 2H2O), gaylussite (CaCO3 Na2CO3, 5H2O) have been identified in eruptive plains with poor drainage (2)).

- In other hand, underground irrigation waters show a stabilized alkalinity value even if sodium, sulfate and cloride values are increasing with concentration; that means a hydrochemical evolution into the neutral way, with formation of sodium sulfate and sodium chloride salts (thenardite (Na2SO4), mirabilite (Na2SO4, 10H2O), bloedite (Na2Mg(SO4)2) and halite (NaCl), have been identified in the lowest zones of sedimentary plain.

Potential implications on irrigated soils can be foreseen for each kind of water. Thus, even if runoff and waste waters have a low concentration permitting the leaching of excessive soil salinity, their alkaline way could lead to problems of soil salinization in situations of poor drainage, internal (clay soils), or external (topographic), with ionic toxicity and pH increase (strongly alkaline carbonated Solonchaks, (3)).

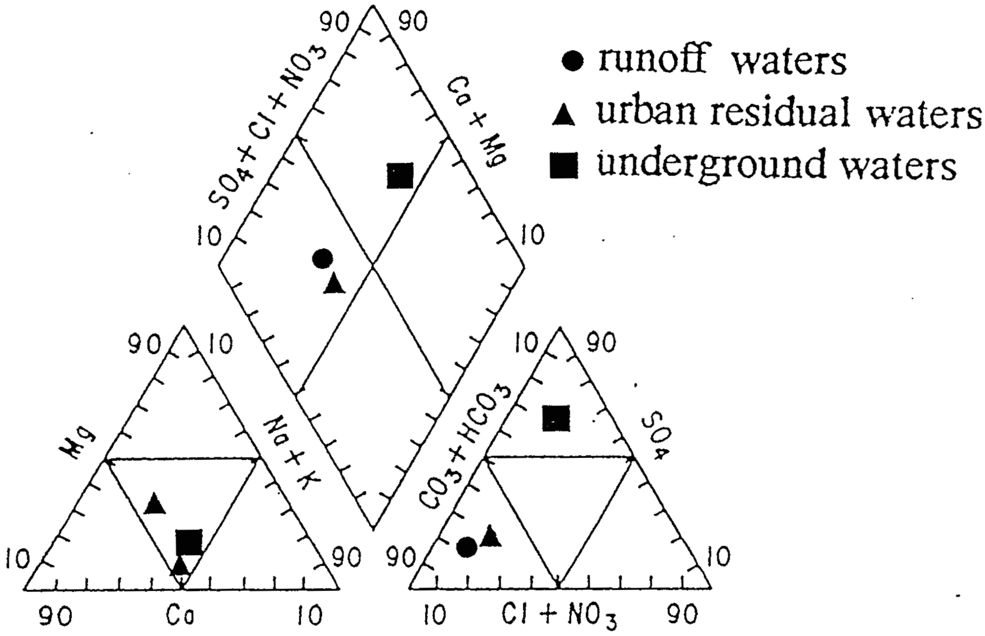


Fig. 1 Chemical features of irrigation waters

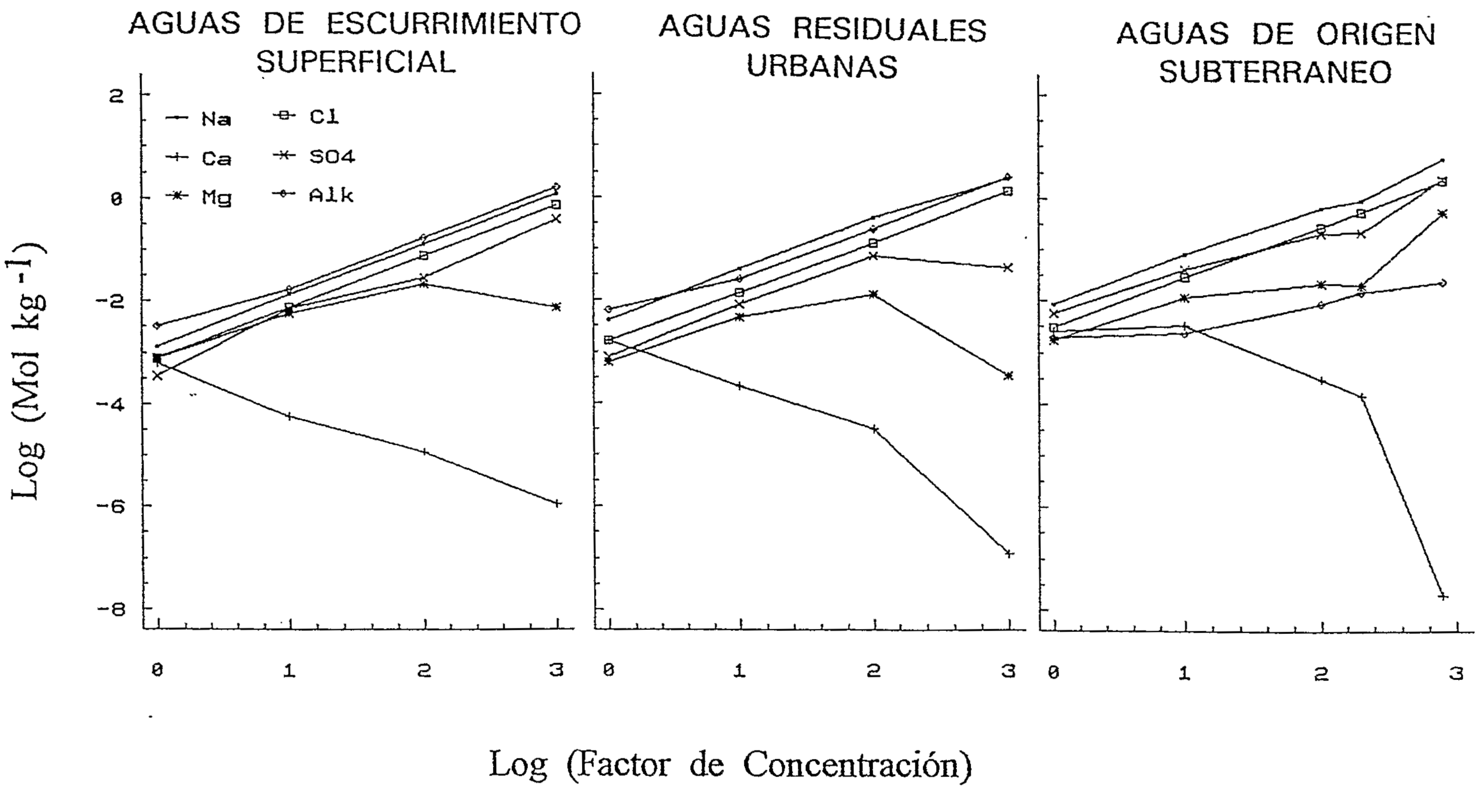


Fig.2 Potential evolution of irrigation waters

On the contrary, the use of underground waters presents a higher salinization risk for soils, but they follow a neutral hydrochemical evolution, (neutral chloride or sulfated Solonchaks, (3)), that will be less dangerous than alkaline way. Nevertheless it is necessary to consider also the soil characteristics in order to determine precisely the exchanges in irrigated water-soil system.

In this endoreic plain - "laguna", another problem is generated by the overexploitation of grounwaters: its drawdown is causing a lateral migration of salts and toxic elements such as arsenic from the lagunas brine to the aquifer in the plain that is from downstream to upstream. Arsenic concentration for example, can reach 2 mg L-1 in some irrigation waters, (1).

Finally, management works to preserve waters of this desert region and prevent soil degradation must be carried out by application of an efficient leaching fraction, keeping the salts out of roots range and in the same time provide for crops needs, but without the actual excess.

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International Symposium on Salt-Affected Lagoon Ecosystems

ISSALE-95

Valencia (Spain) 18-25 September 1995

Organized by

Universitat de València, Estudi General

International Soil Science Society