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POLLUTION OF GROUNDWATERS BY INFLOW OF NATURAL Ca-CHLORIDE BRINES IN ISRAEL

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ABSTRACT

The Bet Shean Valley (Northern Israel) is the recipient and mixing zone for groundwaters originating from three different regional aquifers. In some of the springs outflowing in the valley, changes in the chemical composition of the water indicate the progressive inflow of Ca-chloride brines. These chemical changes and similar phenomena in adjacent areas are caused by a highly concentrated Ca-chloride brine flowing under high pressure in deep-seated strata. The intensive exploitation of fresh groundwaters reduced the hydrostatic counterpressure which precluded initially the outflow of the brines and facilitated the progressive pollution of the groundwaters in the area.

HYDROGEOLOGICAL BACKGROUND

The Bet Shean and Harod valleys branch out from the Jordan Rift Valley and separate the calcareous mountains of Judea and Samaria to the south from the basaltic plateau in eastern Lower Galilee (Fig. 1). These valleys are hydrogeologically connected and form a regional recipient and mixing zone for groundwater draining to them from adjacent provinces (ref. 1).

Groundwater flow north- and northeastwards from recharge areas in Judea and Samaria Mts. through a system of two superimposed calcareous aquifers: The Cenomanian-Turonian Judea Group composed of highly karstic limestones and dolomites and the Eocene Avedat Group which is built of limestones and chalk, is richer in argillaceous components and has significantly lower transmissivities. These two regional aquifers are separated by the Senonian Mt. Scopus aquiclude.

The eastern Lower Galilee is a flat basalt plateau sloping gently towards the valley. It is built by a sequence of Neogene and Quaternary basalts irregularly separated by lacustrine and marine sediments, all included in the Tiberias Group in which the groundwater flow (under phreatic conditions) south and southeastwards.

A dense network of faults related to the formation of the Jordan Rift, dissects the mountains surrounding the investigated valleys producing a complex

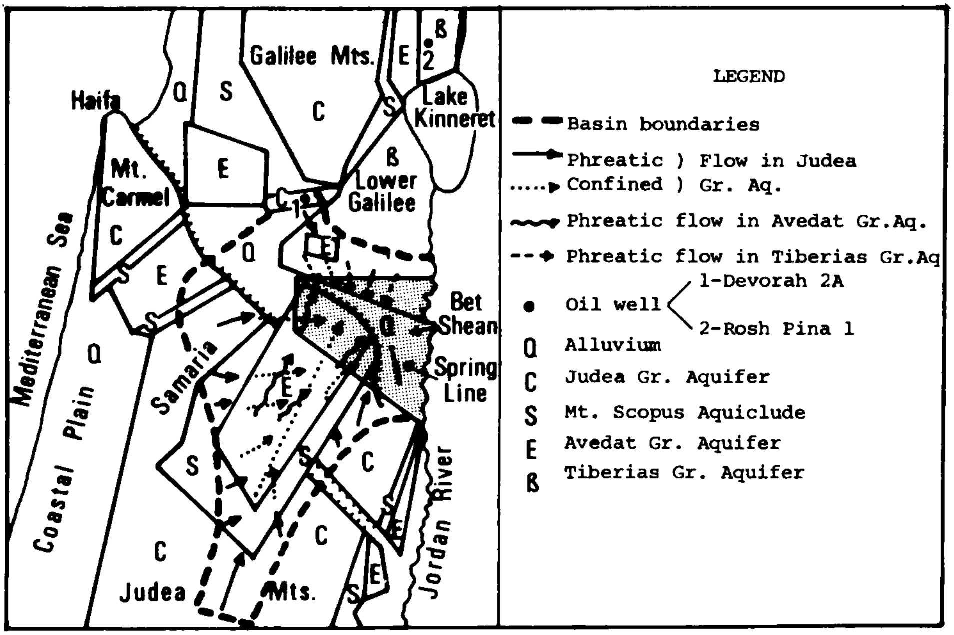

Fig. 1. Schematized hydrogeological location map

system of down-faulted blocks which act as connecting media between the three regional aquifers draining to the valleys.

Two groups of springs flow out in the Bet Shean Valley: one is located close to the mountain-border outlining the valleys and flows out around the absolute elevation of -100 m (below MSL). The other group flows out in the middle of the valley along a N-S striking morphological line, a possible trace of a burried fault. The outflow of these springs is at approx. -200 m (below MSL). All springs in the valley are recharged by the previously mentioned aquifers. In the mid-fifties the annual outflow of the springs was 93.10^6 m^3. Nowadays it decreased to $67.10^6 m^3$ (ref. 4).

SALINITY CHANGES AND STATEMENT OF PROBLEM

In the springs outflowing along the mountain border, the annual yield of chlorides decreased (since 1960) at a rate similar to that of the annual volume of flow (-30%). In the mid-valley springs a clear increase in salinity was recorded and the annual yield of chlorides decreased by only 5%- as against a 20% decrease in the volume of the total outflow (ref. 2). These changes suggest that- in addition to the annual input of chlorides to the springs which are fed by waters from the three regional aquifers- there should be an additional source of salinity manifesting itself in the mid-valley springs.

CHANGES IN THE CHEMICAL COMPOSITION OF GROUNDWATERS

Following the above mentioned hydrochemical trends, the changes in the chemical composition of all groundwaters in the area were examined. Special attention was given to ionic ratios which facilitate the elucidation of the hydrochemical origin of these waters. In the springs flowing out along the mountain border, no noteworthy changes in time were detected. The average ionic ratios in the mid-valley group at the extreme dates of the period of observation, are presented in Table No. 1.

TABLE No. 1

Changes in time of average concentrations and ionic ratios in waters outflowing along the mid valley line, Bet Shean, Israel

Years / Item	1965-7	1979	Δ
TDS^{+}	1276.0	1467.0	+191.0
Cl^{+}	466.0	567.0	+101.0
$rHCO_3/Cl^{\bullet}$	0.91	0.66	-0.25
rMg/Ca^{*}	0.98	0.84	-0.14
$rNa/Cl^{\bullet}$	0.73	0.61	-0.12
$r\,\frac{Ca^{\bullet}}{(SO_4+HCO_3)}$	0.74	0.95	+0.21
Cl/Br^{+}	270.0	180.0	-100.0

+ in mg/l ; * in meq/l

In all these springs a distinct correlation could be established between the increase in salinity and the $rCa/(SO_4+HCO_3)$ ratio (ref. 5) and the decrease in the rNa/Cl, rMg/Ca and Cl/Br ratio values (ref. 5; ref. 3) indicating the occurrence of dilution products of an evaporated Ca-chloride brine. Other dilution products (between an evaporated brine and fresh rechargeable waters) were found elsewhere in the Jordan Valley and in Northern Israel, especially in sources located close to major faults and to such branching out from the Rift system (ref. 3).

SOURCES OF SALINITY

The chemical and hydrological features of the evaporated source brine were- until recently- unknown and caused great controversy. Information from two deep and dry oil-wells (Devorah 2A and Rosh Pina 1) promoted the solution of this problem. The relevant data is presented in Table No. 2.

TABLE No. 2
Hydrological and Hydrochemical data from oil wells

Item \ Oil Well	DEVORAH 2A		ROSH PINA 1
Depth range, m	4842-4895	4834-4864	3845-3864
Age of Formation	Upp. Triassic-Low. Jurassic		Lias
$T^{o}C$	138	140	92
Final Shut-in Pressure (PSI)	7044-7057	7056-7082	?
Hydrostatic Head above perforation, in m	4633	4560	2480^{o}
Abs.Calc.Piez. head (relative to sea level)	-40.3	-105.0	-242.0^{o}
TDS^{+}	188397	207141	172235
Cl^{+}	100528	129393	105230
rNa/Cl^{*}	0.47	0.47	0.48
rMg/Ca^{*}	0.11	0.09	0.17
$r\frac{Ca}{(SO_4+HCO_3)}^{*}$	134.9	162.7	77.6
Cl/Br^{+}	56.6		60.4

+ in mg/l ; * in meq/l ; o , uncompleted pressure release test

The absolute elevations of the calculated piezometric heads (-40.3 ; -105.0) are well above the outflow levels or the water-tables of the sources in which pollution by Ca-chloride brines was detected (ref. 3). The very high hydrostatic pressures measured in the deep boreholes have not been as yet explained. However, two features of interest are noteworthy:

1) In the strata in which drill-stem tests were performed and at lower levels, the presence of methane has been recorded.

2) Water derived during these tests had pH-values of 4.1-4.9 and a $rHCO_3$-content of 5.4-7.0 meq/l. This is an unusually high concentration and more so for deep

brines isolated from active atmospheric recharge.

These unusual values could be caused by dissolved CO_2 formed either by thermal decomposition of hydrocarbons (?) or related to deep-seated volcanic activity (?).

HYDROLOGICAL MODEL OF POLLUTION

Considering the regional geological structure and stratigraphy, there is a high degree of certitude that the deep brine reservoirs are sealed-off from ground surface and that the high pressures cannot be caused by the hydrostatic head exerted by the fresh groundwaters flowing in the overlying regional aquifers. It is suggested that the brines are piston-driven against overlying strata by the high pressures generated by CO_2(?) or methane (?). These gases cannot bubble to ground-surface because of the counterpressure of the overlying strata and groundwater column. The only paths of lesser resistance to these high pressures are the regional faults which may facilitate both horizontal and vertical circulation of the brines. The progressive manifestations of salinity and the pollution of the aquifers were related to the sharp increase in pumpage from the overlying aquifers, from $20.10^6 m^3$/yr in 1966/7 to $56.10^6 m^3$/yr in 1978/9 (ref. 3).

CONCLUSION

The investigation and monitoring of changes in ionic ratios in fresh groundwaters is suggested as a useful method for the identification of major changes in the hydrological regime and of natural pollution processes caused by the inflow of saline water bodies.

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