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QUANTITATIVE ANALYSIS OF GROUNDWATER QUALITY IN WESTERN SAUDI ARABIA

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ABSTRACT

An assessment of the groundwater quality confined in the western part of Saudi Arabia has been carried out on the basis of geochemistry, geomorphology and geology variables. Interaction among these variables has been analysed quantitatively by convensional statistical techniques leading to suitable mathematical models. Criteria of classifications of groundwater quality in the study area are presented which prove indispensible for groundwater exploration, development and exploitation for various purposes such as water supply for domestic, industrial, agricultural and recreational usages.

INTRODUCTION

The main purpose of this paper is to present empirical procedures to explore any significant relationships that may exist between groundwater quality, geology and geomorphology in the hope that they will provide an initiative basis for further studies. Furthermore, this study is expected to give a practical guidance about spatial groundwater quality leading to classification of different quality regions on the basis of which then it will be possible to decide what sort of usage can yield the optimum benefit to agricultural, industrial, domestic supply and recreational usage or not at all!

The study area covers eight wadis in the western part of Saudi Arabia, (see Figure 1). The water samples for chemical analysis were collected from 130 hand-dug wells by the authors as well as others, (refs. 1, 2, 3).

QUANTITATIVE ANALYSIS AND RESULTS

Geochemical (Electric Conductivity, EC), geologic (percentage areas of rocks) and geomorphologic (drainage area, A_u; drainage density, D_d; total number of stream orders, N_u) variables are processed by regression and correlation analyses. Detailed

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information is given in ref.4.

Chemistry - Geomorphology

Field plots and fitted curves are shown in Fig.2, between EC and A_u. The general trend is expressed as,

$$EC = (62230) \times 10^{-0.004A_u} \quad \ldots\ldots(1)$$

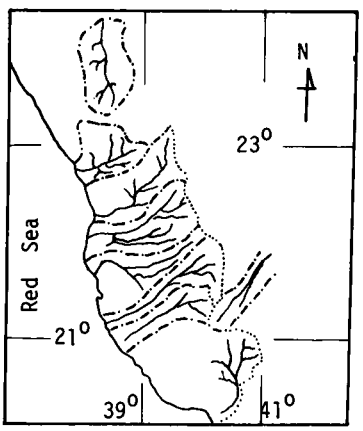

Fig. 1. Study Area

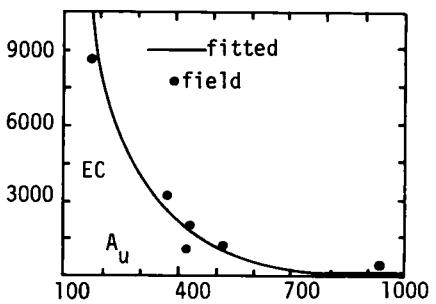

Fig.2. Electric Conductivity Versus Drainage Area.

Obviously increase in wadi area causes decrease in EC hence groundwater quality improves and becomes potable. However, such a decrease is very sensitive for areas less than 400 km^2 otherwise the change is not very appreciable. Since potable subsurface water has EC ranging from 30 to 2000 micromhos, (ref. 5).An instructive water quality criteria on the basis of wadi areas can be developed from Eq. (1) as,

$$A_u \begin{cases} > 900\ km^2 \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{rather pure} \\ = 900\ km^2 - 400\ km^2 \ldots\ldots\ldots\ldots\ldots \text{potable} \\ < 400\ km^2 \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{non-potable} \end{cases}$$

In a single wadi the above criteria means to say that the water quality, in general, deteriorates from the upstream towards downstream, since the area is maximum at upstream and decreases as advanced towards downstream where the salt water intrusion is most probable. Another relationship of EC to geomorphology is given in Figure 3 which reflects a linear trend in double-logarithmic paper.

$$\log_{10} EC = 3.1 + 1.6 \log_{10} D_d \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(2)$$

In general, contrary to drainage area, EC increases with increasing D_d. Regional

water quality criteria based on D_d are

$$D_d \begin{cases} < 0.08\ km^{-1} & \text{.....rather pure} \\ = 0.08\ km^{-1} - 1.3\ km^{-1} & \text{.....potable} \\ > 1.3\ km^{-1} & \text{.....non-potable} \end{cases}$$

Increase in D_d gives rise to more infiltration and subsequently more solution of minerals in various rock types and hence the water quality deteriorates.

Chemistry - Geology

Numerous chemical as well as physiochemical reactions take place between water and rock in the groundwater environment. Although general relations exist between the mineral composition of groundwater and the mineral assemblage with which the water has been in contact, quantitative expressions are rather missing in the literature. However, within the study area a general trend between EC and percentage area of igneous rocks (Ig) has been obtained as the left-hand limb of a parabola, (see Figure 4)

$$EC = 11070 - 22070.Ig + 11556.(Ig)^2 \qquad (0 < \%Ig < 1).....(3)$$

from which the quality criteria based on the percentage igneous rock in the western part of the Kingdom can be obtained as,

$$EC \begin{cases} > 0.55\ \%\ Ig & \text{.....potable} \\ \text{otherwise} & \text{.....non-potable} \end{cases}$$

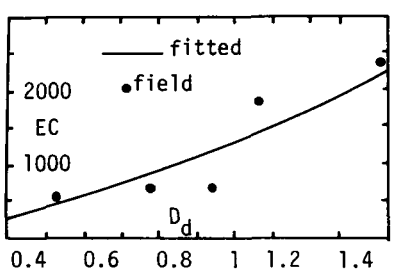

Fig. 3. Electric Conductivity versus Drainage Density.

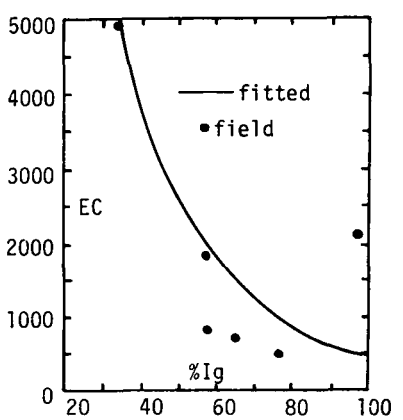

Fig.4. Electric Conductivity Versus % Igneous Rocks.

CONCLUSIONS

A quantitative analysis has been undertaken in this paper to develop groundwater quality criteria on the basis of some external effects such as geology, geomorphology and chemistry. The results are valid only for the western Saudi Arabia, however, their extensions for the rest of the Kingdom is a potential research topic which may lead to a general groundwater quality classifications for the arid regions in other parts of the world at large. The important points that can be drawn out of this paper are, mainly:

(i) there is a reverse relationship between the drainage area and the electric conductivity, provided that the area is measured from downstream.

(ii) a proportional type of relationship exists between the drainage density and electric conductivity.

(iii) increase of percentage area of igneous rocks within the study area yields reduction in the electric conductivity hence improving groundwater quality.

It will be very interesting to extent the content of this study so as to cover the mineralogy and hydrology. However, these points are being currently studied by first author.

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