JOURNAL OF ENGINEERING RESEARCH

V.4 June 1995

This Journal is Published by the engineering research center - College of engineering - El-fateh University Tripoli -LIBYA

Contents

EVALUATION OF GROUNDWATER AGGRESSIVITY (CORROSIVITY) IN WADI ASHATI AREA.

Authors: - Mr. M.S. Suliman, BSc, Msc, MI Corr ST. - Dr. J.Rouba, Ph.D.

SUMMARY

Internal corrosion within the water distribution systems creates a number of serious economic and technical problems as well as affect water quality. Therefore, internal corrosion control programmes should be undertaken by every water utility. Preliminary survey of water quality in Wadi Ashati area of Libya carried out by the authors (Environmental Research Unit, Higher Institute of Technology, Brack) highlights the seriousness of the internal corrosion problem. The investigations conducted proved that all groundwater coming from Wadi Ashati area is highly or very highly corrosive creating potential danger to water distribution systems as well as humans. Corrosivity was assessed on the basis of physicochemical examination of groundwater and four calculated corrosivity indexes such as Langelier Index, Ryznar Index, Aggressiveness Index and Halogen & Sulfate vs. Alkalinity Ratio. This preliminary study on water quality in Wadi Ashati area proved the need for extensive research on improvement of water quality in this region.

1.INTRODUCTION

Corrosion can be defined as the destruction of a metal by chemical or electrochemical reaction. However, in water environment mainly electrochemical corrosion takes place as a result of electrolyte solutions acting on metals. Corrosion within water distribution systems or in premise plumbing creates a variety of problems. The most significant are economic and technical. For instance, a study conducted in Libya in 1982 showed that the cost of corrosion in industrial and petroleum fields was not less than LD 50 million per year [1]. And the cost of corrosion to the water utility industry in USA was estimated at $ 147 billion in 1982 [2]. Technical problems arising from corrosion are as follows:

- *clogging meters and service lines by corrosion products*
- *losses in carrying capacity of mains due to tuberculation*
- *leaks in mains and service lines*
- *short life of service lines.*

Corrosion can also very seriously affect water quality by creating aesthetic problems such as :

- *staining fixtures and laundry*
- *increasing colour and turbidity*
- *production of bad tastes and odours, and health problems such as*
- *increasing water toxicity associated with the leaching of some metals (lead, zinc, copper, cadium) or fibres (asbestos) into water.*

The importance of these problems was reflected in the amendments proposed as early as 1979 by the Environmental Protection Agency (USA) to the National Interim Primary Drinking Water Regulations which included requirements that community water systems that distribute corrosive water ought to carry out corrosion potential of the system's water (the aggessiveness of different water supplies), the methods for measuring corrosion and the mens for treating corrosion. The monitoring requirements for corrosion control in public drinking water systems were established in the USA in 1980 [3,4].

1.1. GEOGRAPHIC BACKGROUND OF WADI ASHATI AREA.

Wadi Ashati is a longitudinal depression striking east-west in the northern part of the Fezzan. It runs along the southern edge of Al-quarquaf arch which forms the northern boundary of the Murzuq structural basin. To the south of Wadi Ashati extends the Ubari sand sea. [5] Wadi Ashati is about 160-200 km long and 10-20 km wide. In the bottom of the Wadi is a dry stream channel with a width at some poins of about 1 km. The base level of Wadi Ashati does not differ much from place to place, lying between 250-300 m above sea level.

Wadi Ashati has been regarded as probably the most fertile basis in the Fezzan province owing to the relative abundance of groundwater which has come out in numerous artesian springs along the Wadi and to shallow groundwater available by means of dug wells. Sometimes water appears on the surface in the form of small shallow lakes and swamps. The population in Wadi Ashati is settled in a linear pattern of oases groups following the sources of groundwater (natural artesian springs, artificial wells) from Eshkeda to Idri .

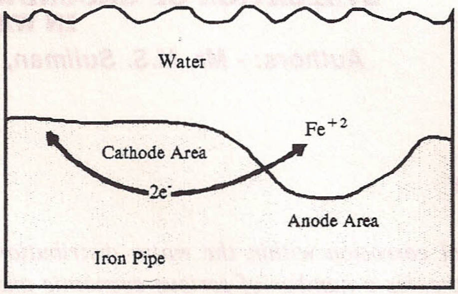
Recently many deep wells were drilled to support the economic development of this region which relies entirely on irrigated farming. Hydrogeological studies on the framework of the agricultural projects for this area showed that the potential sources of groundwater for further agricultural development are the cambro-ordovician and devonian sandstones, several hundred metres thick with favourable hydraulic properties [5]. These two aquifers are regarded as a part of a single hydraulic system in Wadi Ashati. Groundwater quality in these aquifers was found to be uniform in chemical *composition (Table 1). The important feature of this water is the considerable amount of dissolved CO_2. It was suggested that these waters are highly corrosive. That was evident from the frequent replacement of pipelines, plumbing fixtures in water distribution system as well as the quick deterioration of storage tanks in Wadi Ashati area.*

No	Parametrs	Aquifer Devonian	Cambro-Ordovician
1	Temperature	31	34.5
2	PH	6.6	6.6
3	EC	783	799
4	TDS	515	510
5	Ca^{+2}	19.2	18.0
6	Mg^{+2}	10.8	12.9
7	Na^{+}	122.8	155.6
8	K^{+}	22.3	25.8
9	HCO_3^-	176.9	155.6
10	SO_4^{-2}	11.5	20.6
11	$C1^-$	166.3	159.5
12	Fe^{+2}	2.6	2.1
13	Mn^{+2}	0.25	0.5
14	CO_2	72	80

Table 1 : Chemical Composition of two typical Analyses of water form the devonian and Cambro-Ordovi cian Sandstones (5)

1.2. BACKBROUND OF INTERNAL CORROSION.

Corrosion occurring inside water distribution systems, water tanks, reservoirs etc. is also called internal corrosion to differentiate it from external corrosion. Internal corrosion of water distribution systems originates from the chemical composition of water to be transported through this system. Water which causes corrosion of pipe materials is called aggressive or corrosive, both these terms being used more or less interchangeably. Corrosivity of water is usually considered as aggressiveness of water to metals. While aggressivity refers to chemical composition of water that can cause deterioration of nonmetal materials of water distribution systems, like concrete, asbestocement, cement etc. The mechanism of internal corrosion occurring in water distribution systems built from metals can be explained in terms of oxidation-reduction reactions which proceed in every electrochemical cell (Fig.1). Corrosion of metals usually occurs at the anode. [4] Metal ions go into solution at the anode area according to the following reation (oxidation).



(Fig.1) Corrosion cell for iron pipe contacting water[4].

$$Fe \longrightarrow Fe^{+2} + 2e^-$$

$$Fe + 2H2O \longrightarrow Fe(OH)_2 + 2H^+ + 2e^-$$

Electrons are transferred to the cathode area and several reduction reactions may occur as follows:

In deaerated solution the cathodic reaction is

$$2H^+ + 2e^- \longrightarrow H_2 \text{ (reduction)}$$

In aerated solution the cathodic reaction can be accelerated by dissolved oxygen in water solution.

$$2H^+ + 1/2\ O_2 + 2e^- \longrightarrow H_2O$$

Easy access to dissolved oxygen converts ferrous hydroxide to ferric hydroxide accordingly with reaction:

$$2Fe(OH)_2 + 1/2\ O_2 + H_2O \longrightarrow 2Fe(OH)_3$$

Ferric hydroxide is orange to red-brown in colour and comprises most of ordinary rust in water pipes.

The deterioration of non-metal materials of water distribution systems results in the formation of soluble salts according to the following reactions:

$$CaCO_3 + CO_2 + H_2O \rightleftharpoons Ca(HCO_3)_2$$

$$Ca(OH)_2 + 2CO_2 \rightleftharpoons Ca(HCO_3)_2$$

Insoluble salts present in nonmetal material (e.g. concrete) are converted into soluble bicarbonates and deterioration proceeds very quickly. The main constituent responsible for aggressive actin of water and deterioration of water distribution system is aggressive CO_2 - part of free CO_2. Low alkalinity of water, that is carbonate hardness below 100 mg $CaCO_3/1$ speeds up aggressive action of water against concrete significantly. Corrosion as a chemical or electrochemical phenomenon is associated with all natural and treated waters from source through distribution systems upto consumer's houses. Although corrosion cannot be completely eliminated from water systems it whould at least be controlled through corrosion *control programmes.*

In the light of the above statements it is quite obvious that assessing the extent of the corrosivity of water is a very serious and essential part of every corrosion control programme. In other words, monitoring of corrosivity of water should be integrated into water quality practice.

Therefore, the basic aim of this research undertaken by the Environmental Research Unit, Higher Institute of Technology (HIT), Brack was to carry out a survey of the groundwater aggessivity (corrosivity) in Wadi Ashati where this Institute is located and which region is of special scientific interest to it. It is well known that groundwaters in Wadi Ashati are rich in dissolved iron coming from dissolution of iron ore deposits in this area. Since that dissolution takes place only in the presence in water containing large quantities of aggressive CO_2 these waters are expected to be corrosive. But this problem is not reflected in existing studies therefore this study is aimed to assess the extent of aggressivity (corrosivity) in groundwater and its seriousness in this region.

2. EXPERIMENTAL STUDIES.

2.1. MATERIALS AND ANALYTICAL METHODS.

The samples of groundwater for analyses were taken from 28 deep wells and 1 spring located in 22 places in Wadi Ashati. Water taken from wells in these places is generally used for domestic as well as irrigation purposes without any treatment. Only water taken from four places was treated and in these cases samples of raw and treated water were analyzed. The groundwater for analyses was taken from the following places:

- Eshkeda, Abu Garda, Gera, Brack (HIT), Brack-Zulwaz, Afiya, Zwaya, Tamzawa, Geogam East, Geogam West, Agar, Mahruga, Mahruga Blad, Mahruga Ayoun, Gorda, Desah, Tarout, Mashashiya, Gotta, Bergen, Zahra, Wenzreek, Tmessan, Mansura and Idri.

To determine aggressivity (corrosivity) of groundwater from Wadi Ashati the following physicochemical parameters were analyzed:

- temperature, pH, conductivity, alkalinity, acidity, total hardness, calcium, magnesium, chlorides, sulfates, total dissolved solids (TDS).

All physicochemical analyses of groundwater were carried out according to analytical procedures outlined in Standard Methods [6]. The content of free CO_2 as well as calcium hardness were calculated on the basis of the results obtained. The content of aggressive CO_2 was read out from the Lehmann and Reuss Tables. Relevant physicochemical characteristics of groundwater from Wadi Ashati are listed in Table 2.

These physicochemical parameters were used in the study in two ways: First, to assess groundwater quality according to international water quality standards and secondly, to estimate internal corrosion potential.

2.2. PHYSICOCHEMICAL EXAMINATION OF GROUND WATER QUALLITY IN WADI ASHATI AREA - DISCUSSION OF RESULTS.

Physicochemical examination of groundwater from Wadi Ashati showed a wide range of fluctuations in relation to main water quality parameters as follows (Table.2).

pH

pH of tested water ranged from slightly acidic (6.4, Gogam East) upto neutral (7.46 Zwaya), within the acceptable range for drinking water (6.5 - 8.5) but most of pH values were below 7.0 indicating rather acidic waters.

Conductivity

Conductivity of water fluctuated from 625 uS/cm (Mahruga Ayoun) to 1660 uS/cm (Tarout) but most of the water samples had conductivity within the narrow range 900-1000 uS/cm. All water samples taken from the places between Bergen and Idri had highest values of conductivity exceeding in every case 1000 uS/cm. These values showed that groundwater taken from the western end of Wadi Ashati contained considerable amounts of dissolved salts. It was reflected in other water quality parameters (chlorides, sulfates etc). Therefore, the highest permissible level of conductivity for drinking water (1000 uS/cm) which was reached and in many cases exceeded for groundwater from Wadi Ashati gave evidence of its corrosivity. As is well known, water having conductivity above 1000 uS/cm appears to be highly corrosive.

Carbon di-oxide

All groundwater samples taken from Wadi Ashati area were rich in dissolved free CO_2. The amounts of free CO_2 dissolved in water ranged from 5.3 mg/l (Zwaya) upto 118.8 mg/l (Tarout) but on average were 40.50 mg/l. Most of free CO_2 was aggressive CO_2 which is mainly responsible for the corrosive character of water. According to drinking water quality standards, the concentration of aggressive CO_2 should be equal to zero.

Calcium and Magnesium

Two major cations occurring in natural water ranged also in broad limits. Calcium concentrations ranged from 9.6 mg/l (Mahruga Blad, Gotta 1) upto ten times higher concentration 96.0 mg/l for Tarout. Increased concentrations of calcium were observed near the west end of Wadi Ashati between Bergen and Idri (30-80 mg/l) but most of the samples had concentrations of calcium below 20 *mg/l. Increased concentrations of calcium were reflected in higher values of conductivity as well as total hardness of groundwater. Magnesium concentrations were usually lower than calcium ranging from 2.9 mg/l (Afiya) upto 48.4 mg/l (Mansura). According to drinking water quality standards, concentrations of magnesium should not exceed 30 mg/l if there are sulfates in concentrations above 250 mg/l. Owing to these requirements water from Bergen, Zahra and Mansura seems to be unacceptable for drinking purposes when taking into account incresed concentration of magnesium in the presence of large quantities of sulfates.*

Total hardness

This important water quality parameter ranged for all tested samples from 60 mg $CaCO_3$/l (Gotta) upto 410 mg $CaCO_3$/l (Mansura) but in 15 out of 29 samples of groundwater from Wadi Ashati total hardness was within the range 60-100 mg/l, indicating soft water more dangerous for water distribution system than moderately hard water. According to water quality standards total hardness below 100 mg/$CaCO_3$/l is undesirable as it increases corrosivity of water.

Chlorides

The level of chlorides in groundwater taken from wells between Eshkeda and Gorda was slightly differentiated within the range of 130 - 190 mg/l. The highest concentrations of chlorides were observed in the western part of Wadi Ashati starting from Bergen to Idri reaching the highest value, 544 mg/l in Idri.

Sulfates

The concentration of sulfates in groundwater fromWadi Ashati area occurred in broad limits starting from 7.8 mg/l (Brack (HIT) up to 375 mg/l (Tarout). High concentrations of sulfates exceeding drinking water quality requirements - 250 mg/l appeared in groundwater from Bergen, Zahra, Mansura and Tarout.

Total dissolved solids (TDS)

The content of TDS in groundwater from Wadi Ashati are fluctuated from the lowest value, 195 mg/l for Agar upto the highest value, 1192 mg/l in Idri. It could be easily seen that water samples taken from the area between Bergen - Idri had the highest values of TDS, just under 1000 mg/l or exceeding it. Similarly, the sample taken from Tarout also had high content of TDS, 996 mg/l. These valules of TDS exceeded the desirable level of TDS for drinking water, 500 mg/l, and reached or were above the maximum permissible level, 1000 mg/l. The remainder of the samples had the content of TDS below the desirable level or exceeded this level slightly.

Additionally, physicochemical examination of treated groundwater taken from four places in Wadi Ashati area (Table.2) showed slight improvement in water quality because of increase in pH and decrease in such parameters as conductivity and aggressive CO_2.

Briefly, on the basis of the physicochemical analyses carried out to assess corrosivity of water from Wadi Ashati area it could be concluded that the quality of water varied considerably. Groundwater taken from wells between Eshkeda and Gotta except Tarout could be acceptable for drinking purposes, while water taken from the western end of Wadi Ashati from Bergen to Idri was rather undesirable for human consumption.

3. ASSESSMENT OF GROUNDWATER AGGESSIVITY (CORROSIVITY) IN WADI ASHATI AREA.

3.1. CORROSION INDEXES.

In order to assess more quantitatively the ability of water to be more or less aggressive special corrosion indexes which included several simple water quality parameters were calculated. They allow one to compare more precisely particular corrosivities of waters. However, these indexes are not direct measures of water aggressivity but they indicate only the tendency of water to be corrosive or noncorrosive. Corrosion indexes used in this study were:

- *Langelier Index (LI), also called Saturation Index*
- *Ryznar Index (RI), also called Stability Index*
- *Aggressiveness Index (AI)*
- *Halogen-sulfate/alkalinity ratio*

The first three indexes are based on the solubility of calcium carbonate. These indexes focus on predicting the ability of water to deposit $CaCO_3$ films in water distribution systems because upto now controlled deposition of $CaCO_3$ films is still the predominant method of corrosion prevention. And so far no single index was proved to be entirely satisfactory for corrosion contorl.

The Langelier Index (LI) was calculated according to the following formula [7,8,9]:

$$LI = pH_a - pH_s$$

where

pH_a = actual pH of water

pH_s = pH at which water is in equilibrium with $CaCO_3$.

If LI > 0, water has tendency to form scale.

If LI < O, water exhibits aggressive properties (corrosive water), the greater the negative value, the greater the aggresiveness of water.

Table 2A - PHYSICOCHEMICAL COMPOSITION OF GROUNDWATER FROM WADI ASHATI AREA

	TYPE OF WATER			RAW WATER															
	WATER SOURCE	Eshkeda	Abu Garda	Gera (1)	Gera (2)	Brack Hit(1)	Brack Hit(2)	Zulwaz	Afiya	Zwaya	Tamaza-wa	Gogam East	Gogam West	Agar	Mahru-ga	Mahruga	Mahruga Blad	Mahrug Ayom
	Sample No.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
TEMPERATURA °C (°F)		25/77	30/86	27/80	29/84	29/84	32/90	29/84	33/91	32/90	30/86	30/86	28/82	29/84	29/84	23/73	32/90	29/84
pH		6.80	6.65	6.70	6.70	6.64	6.78	6.75	6.68	7.00	7.46	6.70	6.40	6.70	6.63	6.92	6.52	6.82
CONDUCTIVITY us/cm		910	960	1000	940	795	760	900	910	920	1120	900	970	920	950	870	660	625
ALKALINITY, mg $CaCO_3$/1		112.0	102.0	108.0	104.0	99.0	106.0	103.0	96.0	107.0	.88.0	88.0	87.0	92.0	87.0	102.0	92.0	88.0
ACIDITY, mg $CaCO_3$/1		40.0	52.0	44.0	46.0	48.0	36.0	42.0	47.0	29.0	6.0	39.0	81.0	38.0	43.0	26.0	90.0	38.0
FREE CO2, mg CO2/1		35.2	45.8	38.7	40.5	42.2	31.7	37.0	41.4	25.5	5.3	34.3	71.3	33.4	37.8	22.9	79.2	33.4
AGGRESSIVE CO_2,mg CO_2/1		24.7	33.9	27.9	29.6	31.5	23.1	27.3	31.2	18.4	3.4	23.3	52.5	25.9	29.8	17.2	56.5	26.3
CALCIUM, mg/1		16.0	20.0	32.0	17.6	17.6	12.0	12.8	16.0	32.0	34.8	14.0	19.2	14.0	10.8	12.0	9.6	11.2
MAGNESUM, mg/1		12.0	13.5	12.1	13.0	11.2	10.7	12.6	10.6	2.9	16.2	12.6	15.0	15.7	9.7	12.3	9.7	10.6
TOTAL HARDNESS,mg $CaCO_3$/1		90.0	106.0	130.0	98.0	90.0	74.0	84.0	84.0	92.0	154.0	87.0	110.0	100.0	67.0	81.0	64.0	72.0
CALCIUM HARDENESS,mg$CaC0_3$/1		40.0	50.0	80.0	44.0	44.0	30.0	32.0	40.0	80.0	87.0	35.0	48.0	35.0	27.0	30.0	24.0	28.0
TOTAL DISSOLVED SOLIDS, mg/1		570.0	716.0	686.0	555.0	357.0	363.0	225.0	297.0	327.0	619.0	401.0	340.0	282.0	195.0	300.0	364.0	381.0
CHLORIDES, mg/1		182.0	182.0	173.0	160.0	170.0	175.0	153.0	157.0	178.0	187.0	150.0	175.0	157.0	144.0	141.0	129.0	131.0
SULFATES, mg/1		4.0	51.0	81.0	35.5	7.5	8.0	291.0	37.5	17.5	64.0	21.0	55.0	55.0	17.0	25.0	60.0	71.0

Table 2B - PHYSICOCHEMICAL COMPOSITION OF GROUNDWATER FROM WADI ASHATI AREA

		RAW WATER												TREATED WATER WATER SOURCES			
		Gorda	Desah	Tarout	Masha-shiya	Gotta (1)	Gotta (2)	Bergen	Zahra	Wenz-reek	Tmes-san	Mansura	Idri	Brack	Zwaya Hit (1)	Bergen	Wenzree
TYPE OF WATER	Sample No.	18	19	20	21	22	23	24	25	26	27	28	29	5T	10T	24T	26T
TEMPERATURA °C (°F)		24/75	28/82	29/84	28/82	26/79	29/84	32/90	29/84	28/82	29/84	25/77	29/84	21/70	28/82	30/86	28/82
pH		6.54	6.68	6.46	6.55	6.45	6.42	6.88	6.95	6.72	6.88	7.28	6.60	6.95	7.16	7.41	6.88
CONDUCTIVITY us/cm		870	1150	1660	750	675	940	1150	1170	1250	1350	1350	1490	780.0	951.0	1120	1130
ALKALINITY, mg $CaCO_3$/1		100.0	122.0	126.0	75.0	89.0	85.0	125.0	130.0	110.0	127.0	144.0	144.0	127.0	90.0	112.0	105.0
ACIDITY, mg $CaCO_3$/1		95.0	65.0	135.0	44.0	87.0	100.0	32.0	34.0	61.0	81.0	66.0	106.0	32.0	15.0	30.0	25.0
FREE CO2, mg $CO2/_1$		83.6	57.2	118.8	38.7	75.6	88.0	28.1	29.9	53.7	71.3	58.0	93.3	28.1	13.2	26.4	22.0
AGGRESSIVE CO_2,mg CO_2/1		56.0	38.0	70.0	31.0	54.6	63.0	18.0	18.0	38.0	44.9	34.2	53.0	23.1	10.1	18.0	15.8
CALCIUM, mg/1		18.4	40.0	96.0	10.4	9.6	18.4	69.6	69.6	20.0	52.0	84.0	31.2	20.0	20.0	72.0	16.0
MAGNESUM, mg/1		14.0	17.9	26.6	8.7	8.7	14.0	36.3	36.3	16.9	5.8	48.8	24.7	12.1	15.7	33.9	17.9
TOTAL HARDNESS,mg $CaCO_3$/1		104.0	174.0	350.0	62.0	60.0	104.0	324.0	324.0	120.0	154.0	410.0	180.0	110.0	115.0	324.0	114.0
CALCIUM HARDENESS,mg$CaC0_3$/1		46.0	100.0	240.0	26.0	24.0	46.0	174.0	174.0	50.0	130.0	210.0	78.0	50.0	50.0	180.0	40.0
TOTAL DISSOLVED SOLIDS, mg/1		480.0	661.0	996.0	358.0	358.0	476.0	908.0	908.0	781.0	956.0	1183	1192	339.0	478.0	973.0	782.0
CHLORIDES, mg/1		161.0	201.0	243.0	127.0	131.0	170.0	220.0	220	355.0	478.0	335.0	544.0	170.0	166.0	223.0	338.0
SULFATES, mg/1		75.0	140.0	375.0	62.0	30.0	61.0	245.0	245.0	26.7	23.7	262.0	31.0	10.0	47.0	250.0	25.0

If LI = O, water is in equilibrium, water is non-corrosive and non-scale depositing.

The Ryznar Index (RI) permits a more quantitative measure of corrosiveness of water and was calculated by the formula:

$RI = 2pH_s - pH_a$ [7,8,9,10]

The properties of water can be predicted on the basis of this index [10] as shown in Table 2.

The use of RI with the LI helps to predict more accurately the scaling or corrosive tendencies of water.

RI Value	Tendency of water
4.0 - 5.0	Highly scale-forming
5.0 - 6.0	Slightly scale-fprming
6.0 - 7.0	Slightly scale-forming of or little corrosion
7.0 - 7.5	Corrosive
7.5 - 9.0	Highly corrosive
9.0 and over	Very highly corrosive

Table 3 : The Corroive scale forming properties of water in the relation tp the Ryzner index

The Agreessiveness Index (AI) is mainly used for determining the aggressivity of water transported through asbestos - cement and concrete pipelies. This index was calculated by the formula:

$AI = pH + \log (A \times H)$ [7, 9]

where :

A = total alkalinity (mg $CaCO_3/l$)

H = calcium hardness (mg $CaCO_3/l$)

Water with:

AI > 12.0 is nonaggressive

AI = 10.0 - 11.9 is moderately aggressive

AI < 10.0 is highly aggressive

Water with AI < 10.0 is found to be very corrosive to almost all materials in typical water systems including the plumbing in consumer's home. [7]

The last of the indexes used to measure aggressivity of water was halogen-sulfate/alkalinity ratio, calculated according to the formula:

$$\frac{(Cl^- + SO_4^{-2}\ (meq/l))}{Alkalinity\ (meq/l)}$$

Values of this index, 0.1 - 0.2 indicate freedom from corrosion but significantly higher ratios show aggressive waters [6]. All these indexes were used to assess aggressivity of each water sample. The results obtained are presented inFigures 2,3,4 and 6.

3.2 DISCUSSION OF CORROSIVITY RESULTS.

The Langelier Index (LI)

In all the tested samples of groundwater Langelier Index had negative values indicating that water had corrosive properties. The magnitude of these values changed from 0.23 (Mansura) upto 2.20 (Gotta 1) but most of the water samples had values from -1.0 to -1.60 (Fig.2). On the basis of the values obtained, the most corrosive water originated from Gotta (1) while Mansura had the least corrosive water. As could be predicted water with high TDS content, total hardness and calcium had less corrosive character than soft water. The Langelier Index calculated for treated waters showed a slight decrease in corrosivity compared to raw waters.

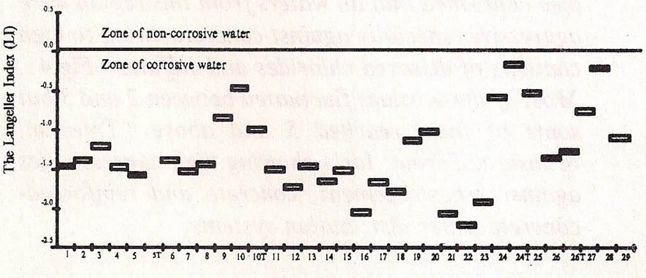


Fig 2 - The Langelier Index (LI) Values of groundwater from Ashati Area

CHEMICAL COMPOSITON OF TWO TYPICAL ANALYSES OF WATER FROM THE DEVONIAN AND CAMBRO-ORDOVICIAN SANDSTONES (5).

The Ryznar Index (RI)

Calculated values of the Ryznar Index for all water samples showed that almost all waters from Wadi Ashati were corrosive. The differences among them depended upon the degree of corrosivity. Some of them were highly corrosive but most of them were very highly corrosive. (Fig.3). The highest corrosivity was exhibied by waters. coming from Mashashiya, Gotta, Mahruga and Agar while relatively mild corrosivity was shown by waters from Bergen, Mansura and Zahra. Also in this case, calculated values of the Ryznar Index showed a slight decrease in corrosivity of treated waters except water from Zwaya.

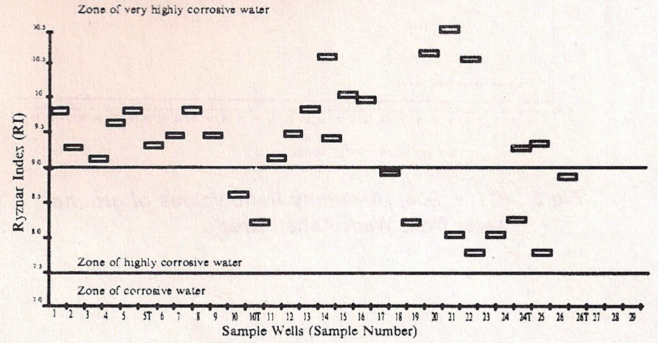


Fig 3 - Ryznar Index (rI) values of groundwater from wadi Ashati Area

The Agreessiveness Index (AI)

According to the Aggressiveness Index values nearly all the tested waters were moderately aggressive (AI = 10 - 12) but several of them could be classified as highly aggressive (Fig.5). These waters originated form Mashashiya, Gotta, Mahruga Blad, Agar and Gogam East. This index supported conclusions drawn on the basis of previously calculated indexes (LI, RI). Also in this case computed values of AI for treated waters were higher than for raw water indicating that the latter is more corrosive.

The Halogen-sulfate / alkalinity Ratio

This ratio, used additionally to assess aggresive characteristics of water from Wadi Ashati area, also confirmed that all waters from this region were aggressive especially against concrete owing to high contents of dissoved chlorides and sulfates (Fig.4). Most of these values fluctuated between 2 and 3 but some of them reached 5 and above (Tmessan, Mansura, Tarout, Idri) showing high aggressivities against asbestoscement, concrete and reinforced-concrete water distribution systems.

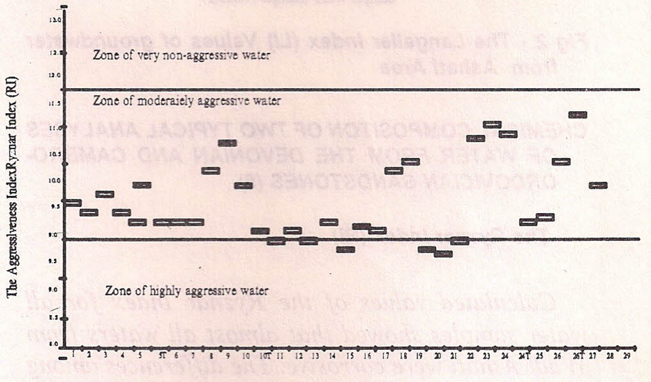


Fig-4 The Aggressiveness Index values of groundwater wadi ashati area

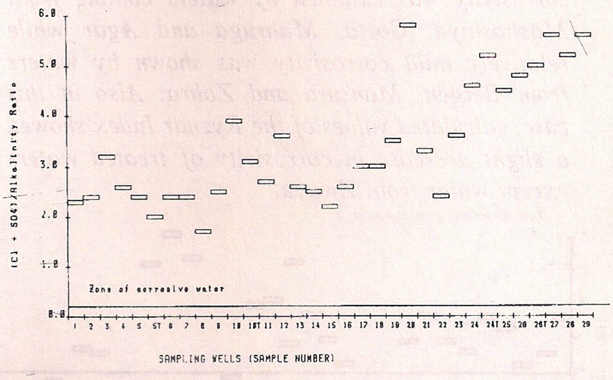


Fig 5 : (C1 + S04) /Alkalinity Ratio values of ground water from Wadi Ashati Area

4. CONCLUSIONS.

The preliminary survey of water resources in Wadi Ashati area carried out in this study with respect to its corrosivity made it possible to draw the following general conclusions:

(a) The quality of raw groundwater from Wadi Ashati area used for human consumption is significantly differentiated from well acceptable to undesirable for drinking purposes, therefore, its quality needs to be improved by proper treatment.

(b) All groundwaters from Wadi Ashati area belong to highly or very highly corrosive categories of water which require to be treated in order to reduce their corrosiveness.

(c) Assessing corrosivity of water should be included in routine water quality programmes

(d) Further research work should be carried out in order to get more detailed information about quality and quantity of water resources in this region.

5. REFERENCES.

1. *Al-Meshal - Edition No. 44 Libyan Petorleum Journal.*

2. *Theme introduction-Curbing corrosion Jour. AWWA, 57 (February 1983)*

3. *Committee Report - Determining internal corrosion potential in water supply systems. Jour. AWWA., 83 (August 1984)*

4. *Kirmeyer G.J., Logsdon G.S. - Principles of internal corrosion and corrosion monitoring. Jour. AWWA, 78 (February1983)*

5. *Dubay L. - Groundwater in Wadi Ashati, Fezzar - A case history of resource development. The Geology of Libya, Vol. II. Acad. Press 1980.*

6. *Standard Methods for the Examination of Water and Wastewater. 14th Edition, 1975 APHA - AWWA - WPCF.*

7. *Millette J. R. et al. - Aggressive water: Assessing the extent of the problem. Jour. AWWA, 262 (May, 1980)*

8. *Betz Handbook of Industrial Water Conditioning 8th Edition, 1980, USA*

9. *Rossum J.R., Merril D.T. - An evaluation of the calcium carbonate saturation indexes. Jour. AWWA, 95 (February, 1983)*

10. *Water Treatment Handbook, Degre mont, 1973, France.*

Acknowledgements

The authors are grateful to Mr. F. Koku and Mr. Y. Saad of the technial staff of Enviromental Research unit at higher institute of technology (HIT) for technical assistanc in sampling of water and in analyzing the water quality parameters; Dr. R. Sadek, Enviromental research unit (HIT) for his constructive criticism, useful suggestions as well as for help in editing and computer printing and plotting and Dr.. M. Monippally (HIT) for helpful review of the manuscript.