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Monitoring and Evaluation of Corrosion Indices for Potable Water in Distribution System in Kuwait

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Ministry of Electricity & Water

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MONITORING AND EVALUATION OF CORROSION INDICES FOR POTABLE WATER IN DISTRIBUTION SYSTEM IN KUWAIT

Presented by

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Index of Slides

INTRODUCTION

- Drinking or potable water can be defined as water supplied to consumers that can be safety used for drinking and other purposes.
- Water quality cannot be effectively monitored without adequate laboratory facilities.
- In view of the scant natural fresh water resources, Kuwait has always had to look for other sources to secure potable water requirements. Much work has been done by the Ministry of Electricity and Water (MEW) to develop and secure the water resources in Kuwait.
- The Ministry has studied and explored many techniques for potable water production, but since the 1950's, potable water in Kuwait has been produced by the desalination of seawater for its fresh water supply.
- The Government of Kuwait adopted the use of Multi-Stage Flash (MSF) desalination plants. Distilled water produced in the MSF evaporators with very low concentrations of dissolved salts, gases and total alkalinity of less than 1mg $CaCO_3$/L.
- This type of very soft water has low buffer capacity and it's quite aggressive to materials in contact which result in corrosion problems.
- To improve the palatability of distilled water, the brackish water is blended with different blending ratio, to yield the minimum value total alkalinity of 60-80/l as $CaCO_3$.

- Also, when water temperature increases, the pH decreases correspondingly the corrosion rate will increase. Therefore, increase in pH and depress iron dissolution, thus prevent failure of pipes in the distribution system to improve palatability.
- Here, Corrosion control play an important aspect in safe drinking water supplies.
- Therefore, the main objectives of this study are to determine the best quality of drinking water according to the WHO guidelines, to reveal and control the corrosivity of the produced drinking water.
- Corrosion indices are important in monitoring of water supply distribution networks.
- Now, the goal is to produce a "Stable", non-corrosive water. For this treatment process we use to achieve the corrosion inhibition of iron pipes, by the recarbonation process which applied for the treatment of the distillate produced by the multistage flash evaporators in the plants.
- In order to achieve the most suitable method for minimizing the red water problem in Kuwait, the corrosivity of the produced drinking water is checked and controlled through the process of recarbonation in which the corrosion indices is being determined by using some chemical and physical parameters, as an indication of the corrosives are calculated during year 2013 for different areas in Kuwait.

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DISTILLATION PLANTS

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- Kuwait was the first country in the gulf area to adopt a new method of using flash type technique (MSF).
- In 1953, first (MSF) distillation plant was commissioned, with capacity 3/4 MGD and expanded to 15 MGD.
- In Kuwait, now there are seven distillation plants, each unit consist of a number of stages with different unit capacities according to each station.
- Now, total production reached to 522 MIGD, then this water is blended with brackish water in order to cover the consumption of potable water.
- The Production Capacity of each Distillation plant is outline below table:

DISTILLATION PLANT	PRODUCTION METHOD	PRODUCTION CAPACITY (MIG/D)
SHUWAIKH	MSF	19
SHUWAIKH	RO	30
SHUAIBA (SOUTH)	MSF	36
SHUAIBA (NORTH)	MSF	45
DOHA (EAST)	MSF	42
DOHA (WEST)	MSF	110
AZ-ZOUR (SOUTH)	MSF	110
AZ-ZOUR	MSF	30
SUBIYA	MSF	100
TOTAL	MSF	522

RECARBONATION SYSTEM

- In shuwaikh plant the recarbonation system was first started on Aug. 1990 then due to Iraqi invasion the operation was stopped and they restarted the work back in June 1995.
- In Shuaiba North and South Plant the system not yet installed.
- In Doha East Plant the system is not yet installed. But, in the Doha West Plant the two trains (stages) were first commissioned as follows:
  - Train A at 1996
  - Train B at 1997
- In Az Zour South Plant the recarbonation system was started with three stages as follows:
  - Stage 1 between 1995 &1996
  - Stage 2 at 1999
  - Stage 3 at 2001
- In Sabiya Plant the first available stages as follows for recarbonation operation:
  - Stage 1, 2 at Nov. 2006
  - Stage 3 at July 2007.

CHEMICAL TREATMENT

- Distilled water produce from Distillation Plants in
  - ✓ Shuwaikh(MSF,RO) , Doha (East and West) , Shuaiba (North & South)

Az-Zour and Subiya, is being mixed with underground water according to WHO standards.

- Brackish water produce from following wells.
- Sulaibiya , Shagaya , Al-Wafra , Umm-Qudair and Al-Atraf
- The operation takes place in the blending plants or lines.

- Fresh water is controlled according to WHO guidelines, applying chlorination process for disinfection of fresh water, maintains the water stability by sodium hydroxide injection under control limits.
- At last, the stable water from blending stations goes to storage reservoirs and the pumping stations.
- And, also Post chlorination's are applied at storage reservoirs area and at pumping stations for disinfection under control limits.

RECARBONATION PROCESS

- This studies suggested that the water treatment in Kuwait should be subjected to an increase of alkalinity, by using $CaCO_3$ to firm a coating layer to protect the water network from corrosion, which is known as the recarbonation process.
- The recarbonation process was established in 1987 and incorporated with Shuwaikh distillation plant.
- The recarbonation plant was designed to yield recarbonated water with a total alkalinity of 60-80 mg/l as $CaCO_3$.
- Distilled water from MSF distillation plants is acidified in an absorption tower using CO_2 gas.
- The acidified water is then augmented by bicarbonate ions using $CaCO_3$ in a number of limestone dissolution filters, where the following reaction takes place:

$$CaCO_3 + H_2O + CO_2 \longrightarrow Ca^{2+} + 2(HCO_3)^-$$

- The excess CO_2 presents in the recarbonated water filter is degasified in a stripping tower using air.
- After degasifying, the recarbonated distillate water is mixed in the plant by-pass distillate.
- Then the extraction of CO_2 from the non- condensable gases, released as a result of heating sea water to high temperatures, Would represent the most technically and economically feasible alternative.

- When sea water is heated to about 77^0C, the calcium bicarbonate will decompose according to the following reaction takes place:

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

- The liberated amount of CO_2 depended by thermal desalination process (MSF), then the extraction of CO_2 from the non-condensable gases, released as a result of heating seawater to high temperatures.
- The non-condensable gases are vented and withdrawn, using steam ejectors, to a vent gas condenser, where water vapor is condensed using a by-pass stream of the distilled water to be recarbonated.
- Almost, dry gases are evacuated from the vent gas condenser using a booster vacuum pump, and fed to a gas compressor.
- From the gas receivers, the gas stream containing CO_2 and air is fed to a gas purification filter filled with activated carbon to remove any volatile organic components (MEW, 1994).
- The Block Flow diagram of the Recarbonation Process as follows in Fig (1) respectively.

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FLOW CHART FOR THE RECARBONATION PROCESS

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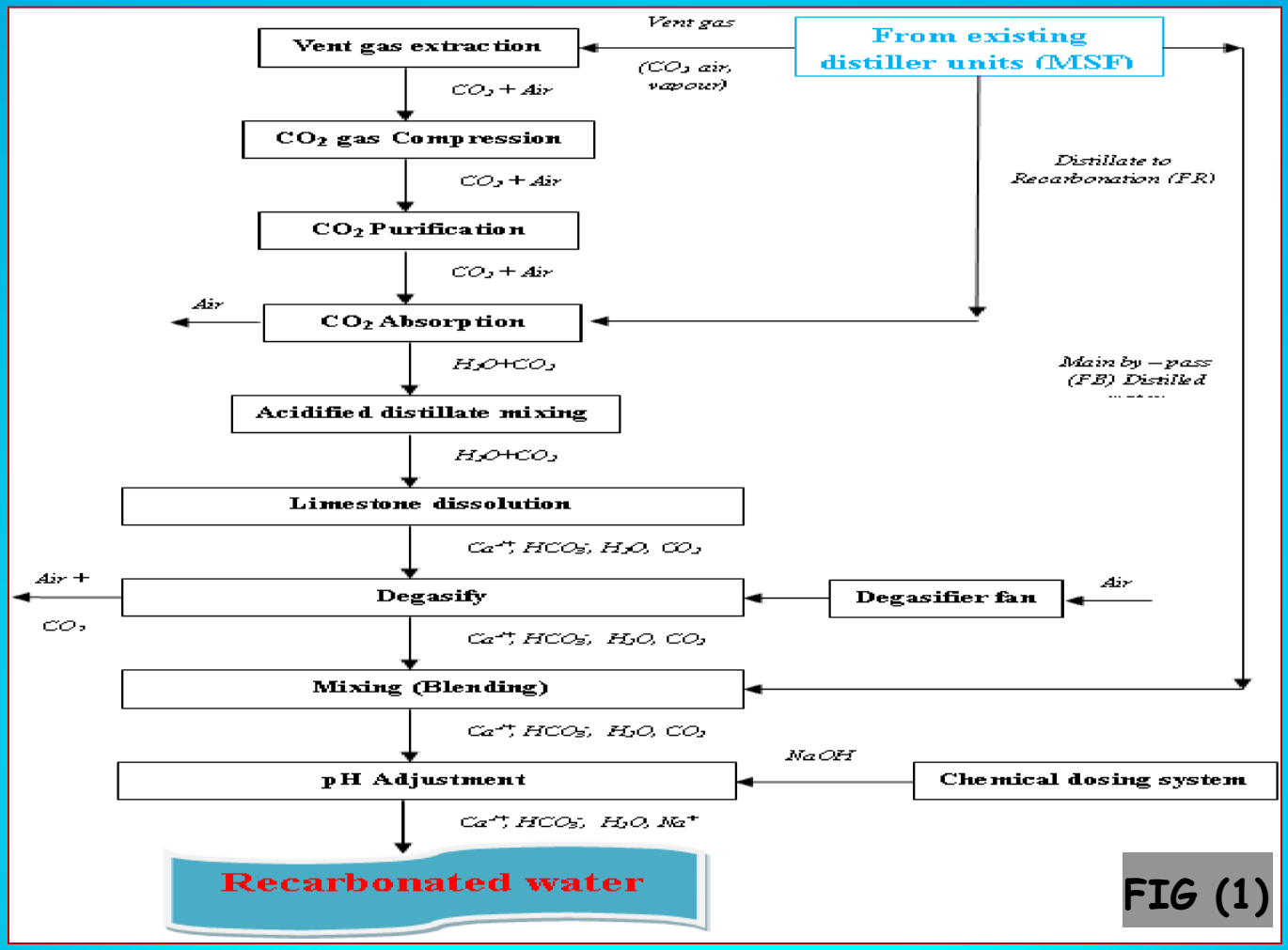

FIG (1)

CORRODION INDICES

- There are several indices can be useful for predicting corrosion. Three of the most commonly used corrosion indices in the waterworks industry are; **Saturation index**, **Ryznar index** and **Larson index**, which will be discussed in detail in the following paragraphs.
  - **Saturation index (SI)**
    - ✓ The index is based on the effect of pH on the solubility of $CaCO_3$ is known as the pH of saturation or ***pHs***.
    - ✓ At pHs, a protective scale will neither be deposited nor dissolved.
    - ✓ Therefore, the index indicates the tendency for corrosion to occur, and it is not a measurement of corrosivity.

      The index is defined by the following equation:

      SI = pH – pHs
- The results of the equation are interpreted as follows:
  - SI > 0; water is supersaturated and tends to precipitate a scale layer of $CaCO_3$
  - SI < 0; water is under-saturated, tends to dissolve solid $CaCO_3$ (Aggressive water)
  - SI = 0; water is saturated (in equilibrium) with $CaCO_3$; a scale layer of $CaCO_3$ is neither precipitate nor dissolved.

- **Ryznar index (RI)**
  - ✓ This empirical index uses the same parameters as the saturation index, but reversed the signs and doubled the pHs.

    The index is defined by the following equation:

$$RI = 2pH_s - pH$$

- The results of the equation are interpreted as follows:
  - RI < 7; water is supersaturated, tends to precipitate a scale layer of $CaCO_3$
  - R > 7; water is under-saturated, tends to dissolve solid $CaCO_3$ (Aggressive water).

- **Larson index (LI)**
  - ✓ The index is represent by the ratio between chloride and sulphate (as calcium carbonate) to the total alkalinity which attempts to measure the aggressive nature of these specific ions, and it does not refer to the solubility of calcium carbonate but rather to the faster rates of corrosion of metals because of conductivity affects.

    The index is defined by the following equation:

$$LI = (Cl^- + SO_4^{-2}) / T.Alk.$$

  - LI > 0.5 Possibility of corrosive action exists.

Method of Calculation for Corrosion Indices

- For the pH of saturation (pHs), method of calculation was done based on the equation (1)

$$pHs = pK_2 - pK_{sc} + p[Ca_t] + p[Alk_t] + 5pfm \dashrightarrow equ\ (1)$$

pK_2 = 107.88+0.031(T)-5151.79/(T)-38.92($\log_{10}$T)56371.9/(T^2)

(2^{nd} dissociation constant for carbonic acid)

pK_{sc} = 171.91+0.078(T)-2839.32/(T71.595$\log_{10}$T

(Solubility product constant for calcite)

Pfm = A [{sqrtI / (1+sqrtI)}-0.3*I]

(Activity coefficient for monovalent species)

Where, I (Ionic strength) = $1.6*10^{-5}$*Cond.

$A = 1.82*10^6(E*T)^{-1.5}$

E (dielectric constant) = {60954 / (T+116)}-68.937

- To apply parameters for pH_s equation, the units should be converted according to the following table:

pH	Temp (Kelvin)	Cond. (µS/cm)	Alk_t (geq/l)	Ca_t (gmol/l)	Cl^- (gmol/l)	SO_4^{-2} (gmol/l)

- The parameter for above calculations was applied from the following samples were collected every month during 2013, around different area in Kuwait country like shuwaikh, Kefan, Khaldiya, Shamiya, Abdullah Al Salem, Nuzha, Benid Al Ghar, Dasma, Qadsiya, Hawally and Mirqab respectively.
- Summarized calculation of Corrosion Indices for the year 2013 representing as follows:

	Saturation Index > 0	Ryznar Index > 7	Larson Index < 0.5
		YEAR 2013	
Min	-0.01	6.89	0.0002
Max	0.61	8.86	0.17
Avg	0.003	7.77	0.05

- Comparison of Corrosion indices before and after applying the recarbonation system.

Indices range	Before applying Recarbonation system, year 1995	After applying Recarbonation system, year 2013
Saturation	-1.3 to -0.8	-0.01 to 0.61
Ryznar	9.4 to 10	6.89 to 8.86
Larson	17.3 to 19.6	0.0002 to 0.17

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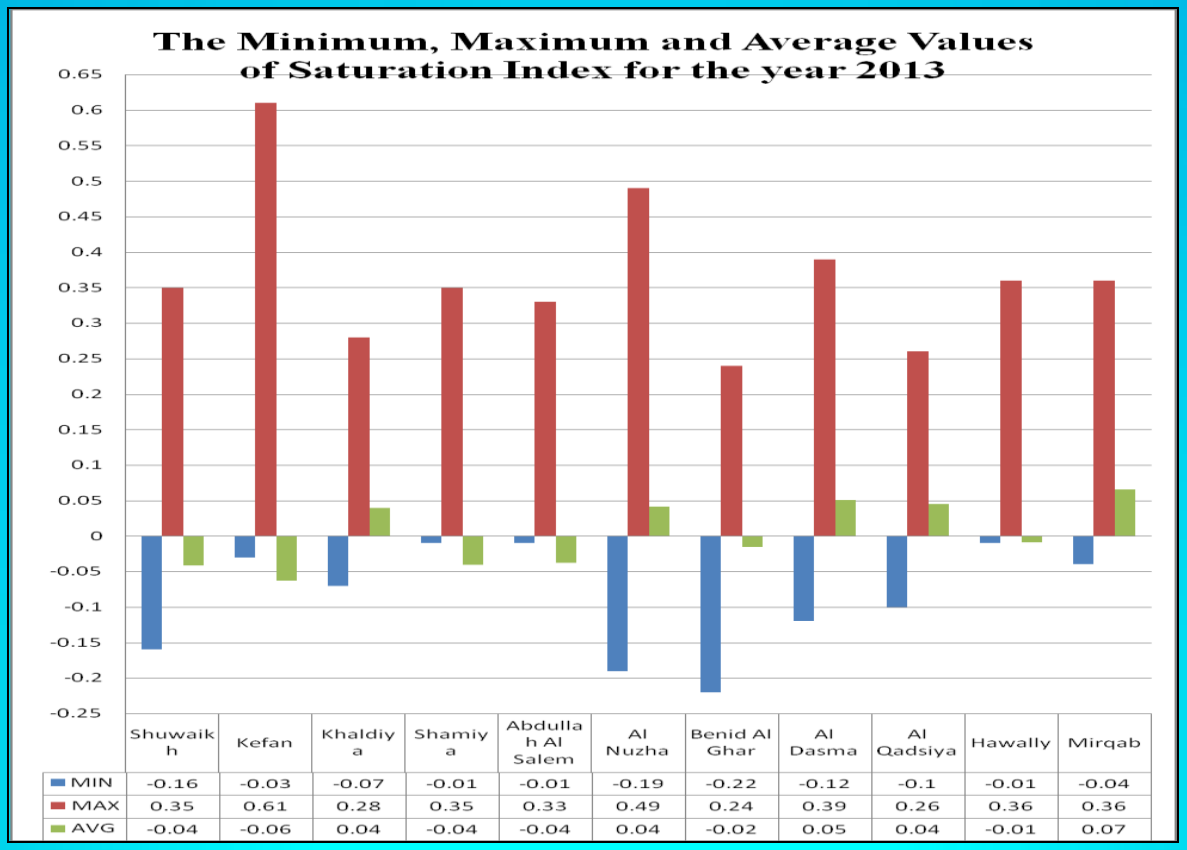
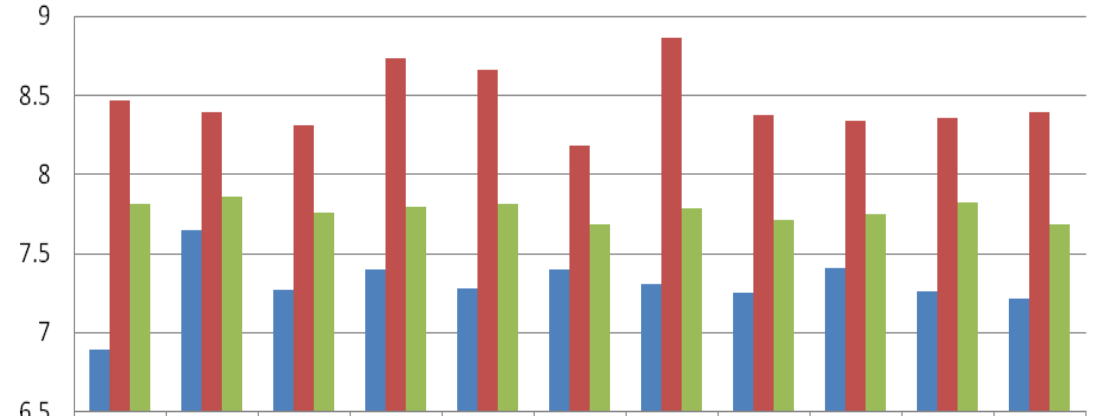
Maximum, Minimum & Average Bar Graph for Corrosion Indices during 2013



	Shuwaikh	Kefan	Khaldiya	Shamiya	Abdullah Al Salem	Al Nuzha	Benid Al Ghar	Al Dasma	Al Qadsiya	Hawally	Mirqab
MIN	-0.16	-0.03	-0.07	-0.01	-0.01	-0.19	-0.22	-0.12	-0.1	-0.01	-0.04
MAX	0.35	0.61	0.28	0.35	0.33	0.49	0.24	0.39	0.26	0.36	0.36
AVG	-0.04	-0.06	0.04	-0.04	-0.04	0.04	-0.02	0.05	0.04	-0.01	0.07

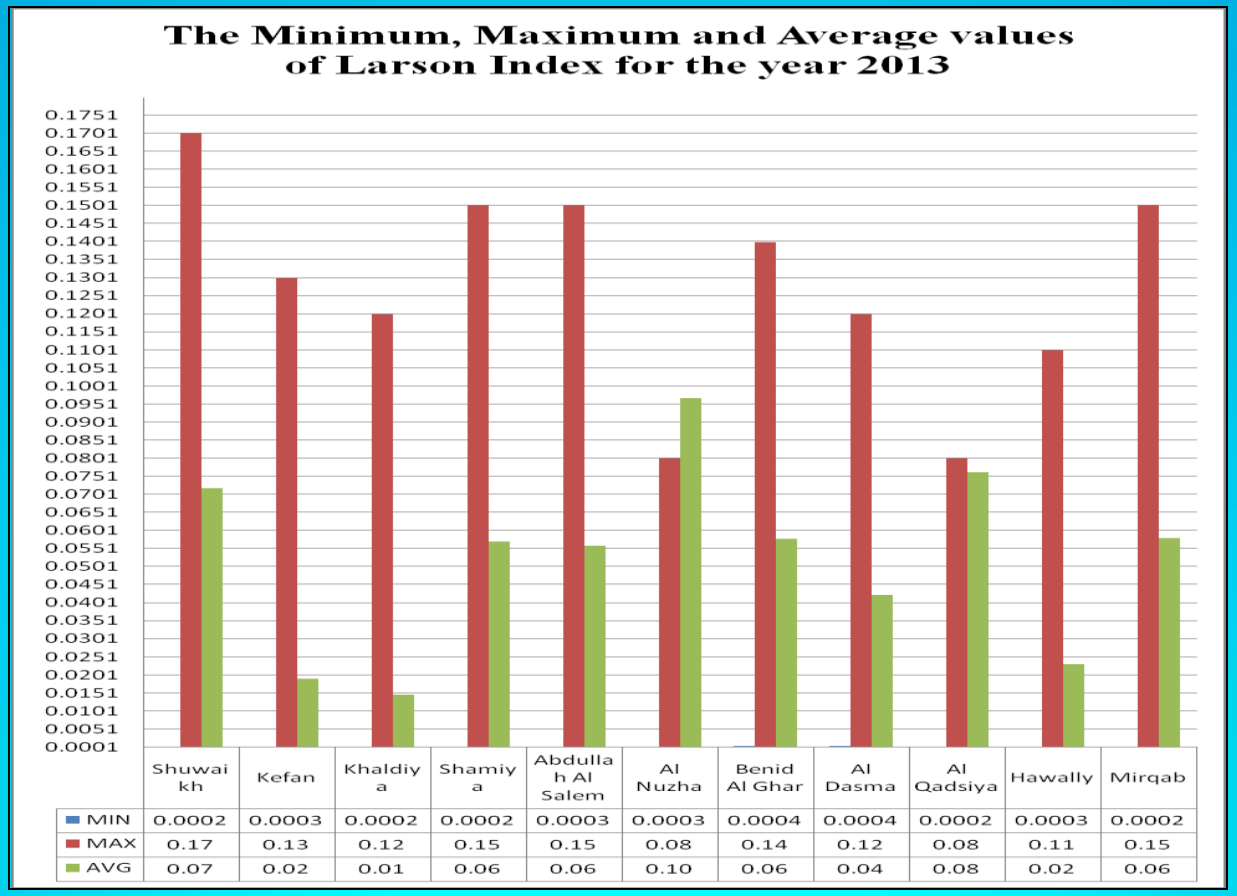
Bar Graph for Saturation Index During 2013

The Minimum, Maximum and Average values of Ryznar Index for the year 2013



	Shuwaikh	Kefan	Khaldiya	Shamiya	Abdullah Al Salem	Al Nuzha	Benid Al Ghar	Al Dasma	Al Qadsiya	Hawally	Mirqab
MIN	6.89	7.65	7.27	7.4	7.28	7.4	7.31	7.25	7.41	7.26	7.21
MAX	8.47	8.39	8.31	8.73	8.66	8.18	8.86	8.37	8.34	8.36	8.39
AVG	7.81	7.86	7.75	7.79	7.82	7.68	7.78	7.71	7.75	7.82	7.68

Bar Graph for Ryznar Index During 2013



	Shuwaikh	Kefan	Khaldiya	Shamiya	Abdullah Al Salem	Al Nuzha	Benid Al Ghar	Al Dasma	Al Qadsiya	Hawally	Mirqab
MIN	0.0002	0.0003	0.0002	0.0002	0.0003	0.0003	0.0004	0.0004	0.0002	0.0003	0.0002
MAX	0.17	0.13	0.12	0.15	0.15	0.08	0.14	0.12	0.08	0.11	0.15
AVG	0.07	0.02	0.01	0.06	0.06	0.10	0.06	0.04	0.08	0.02	0.06

Bar Graph for Larson Index During 2013

CONCLUSION

- In Kuwait, recarbonation process has been adopted as the remedial treatment.
- The recarbonation system is intended to increase the carbonate hardness in the potable water thereby minimizing corrosion in the water distribution system, thus eliminating to a great extent the "red water" problem.
- It also improves the palatability of the drinking water.
- To achieve these objectives recarbonation system makes use of released CO_2 from the MSF evaporators and adopts limestone dissolution with necessary PH control.
- This was regarded as reasonably effective and an economical solution as well.
- In addition, the corrosivity of the produced drinking water is checked and controlled through the process of recarbonation.
- The distribution system in Kuwait consists of main pumping stations, underground reservoirs, elevated storage towers, and distribution lines and subsidiary networks, as well as tanker filling stations from which water is supplied to areas without mains supply.
- For that, corrosion indices is being calculated during 2013 by using some chemical and physical parameters, as an indication of the corrosives

- Here three indices, Langlier Saturation Index (LSI), Ryznar Stability Index (RSI) and Larson-Skold Index (LS) are calculated during year 2013 for different areas which includes Shuwaikh, Kefan, Khaldiya, Shamiya, Abdullah Al Salem, Nuzha, Benid Al Ghar, Dasma, Qadsiya, Hawally and Mirqab in Kuwait country.
- As an overall, there was good improvement for year 2013 compared to the corrosion indices before applying recarbonation system in 1995, especially the **Saturation index reached (+0.61)** their desired value.
- And also, the Larson index reached a good value during 2013.
- But, the Ryznar index does not reached their desired value. (i.e.) Aggressive water. If, water is aggressive then it has some excess of carbon di oxide. And also called as carbon anhydride or carbonic acid.
- In order to reduce corrosion and corrosion by products, corrective action should be made in corrosive water supply network.
- Therefore, consequently the quality of potable water supplies must be carefully monitored in the distribution system and the concentration of $CaCO_3$ should be adjusted in some parts of the network depending upon the results of the indexes.

THANK YOU