Journal of Petroleum Research and Studies

Open Access
No. 31, June 2021, pp.15-29

P- ISSN: 2220-5381
E- ISSN: 2710-1096

DOI: http://doi.org/10.52716/jprs.v11i2.512

Decreasing the Tendency of Water to Form Scale and Corrosion in Cooling Towers – South Refineries Company (SRC) – Iraq

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Received 9/2/2020, Accepted 21/9/2020, Published 20/6/2021

Abstract

Scale formation and corrosion phenomena are major technical problems at Basra Refinery/ South Refineries Company (SRC). These technical problems are concentrated in cooling towers which are used to supply cooling water to the processing units. The Scales and corrosion products precipitate inside cooling units, heat exchangers and pipeline networks affecting negatively efficiency of refinery's equipment. In this work, a real plant data was collected from four cooling towers which is supplied the coolant to the crude distillation units of the refinery and also from the raw water supplier. The collected data was fitted by Langelier model to predict the tendency of cooling water for scale forming and activation of corrosion. The obtained result shows that the cooling water has a tendency to form scale ($CaCO_3$ Precipitation) at cooling tower units. Also the feed water has the same tendency for scale forming.

After analyzing the LSI (Langelier Saturation Index) results, the research team recommends the particular company to overcome this problem by installing a Reverse Osmosis (RO) plant for treating raw water to decrease the concentrations of total dissolved solids (TDS) which result scale and corrosion in the parts of cooling tower as an option to solve the problem.

Keywords: SRC, $CaCO_3$ Precipitation, RO, LSI, TDS, Corrosion.

1. Introduction

Cooling towers are heat exchangers used to dissipate large heat loads to the atmosphere [1]. They are used in a variety of settings including process cooling, power generation cycles, and air-conditioning cycles. All cooling towers used to remove heat from an industrial processor chemical reaction [2]. Proper design of cooling tower system helps in reducing operational and maintenance problems as well as environmental impacts arising from system operation [3].

To control corrosion and scale, maintain the water chemistry of the recirculating water within the parameters listed in Table (1) [4]. The specific measures required vary from system to system and are dependent on the chemistry of the make-up water, the metallurgy of the piping and heat transfer devices exposed to the recirculating water, and all temperatures at which the system will be operating. Bleed/blow-down, the continuous flow of a small portion of the recirculating water to a drain is used to control the concentration of dissolved solids. On rare occasions, this may be adequate to control scale and corrosion. Usually, the chemical scale and corrosion inhibitors are necessary, which raise the allowable level of dissolved solids without the risk of scale and corrosion. Keep the chemically treated water within the guidelines given in Table (1). In cases where bleed/ blow-down alone is being employed for corrosion and scale control without chemical treatment your water treatment specialist may recommend more conservative limits than those shown in Table (2) [5].

Table (1) Quality Guidelines for Treated Circulating Water

Property of water	**Recommended Levels for Various Materials of Construction**			
	Galvanized Steel	Thermosetting Hybrid Polymer	Stainless Steel Type 304	Triamor Corrosion Protection System or Type 316 Stainless Steel
PH	6.5 to 9.0	6.5 to 9.2	6.5 to 9.0	6.5 to 9.5
Total Suspended Solids	25ppm	25ppm	25ppm	25ppm
Total Dissolved Solids (TDS)	1500ppm	2050ppm	2050ppm	2500ppm
Conductivity	2400 μs/cm	3300 μs/cm	3300 μs/cm	400 μs/cm
Alkalinity as $CaCO_3$	500ppm	600ppm	600ppm	600ppm
Calcium Hardness as $CaCO_3$	50-600ppm	50-750ppm	50-750ppm	50-750ppm
Chlorides	250ppm	300ppm	300ppm	750ppm
Sulfates	250ppm	350ppm	350ppm	750ppm
Silica	150ppm	150ppm	150ppm	150ppm

Table (2) Common Scale in Cooling Water Systems

Most Common	**Less Frequent**
Calcium Carbonate	Iron Oxide
Calcium Sulphate	Zinc Phosphate
Calcium Phosphate	Calcium Fluoride
Magnesium Silicate	Iron Carbonate
Silica	Aluminum Oxide

2. Description of Corrosion and Scale Problems at Basrah Refinery / South Refineries Company (SRC):

Basrah refinery (BR) is one of most refineries subsidiary South Refineries Company (SRC) located in Basrah in the south of Iraq. In Basrah refinery, water is used for the cooling towers installed in the refinery as a heat transfer medium. Feed Water supplied to the installed (BR) cooling towers is received from only single source (Alarab River). The feed water is treated in Almoftya Water Treatment Station, where the water passes by different stages of treatment before entering to the Basrah refinery. The main stages of treatment in the station are:

- Mechanical Filtration.
- Coagulation – Flocculation.
- Sand Filtration.
- Dosing of chlorine gas.

Figure (1) shows the schematic diagram of water treatment process in Almoftya Water Treatment Station. The water losses in cooling towers are replenished which is called makeup water. At present, (BR) Cooling tower efficiency enhanced by the addition of certain water treatment chemicals to increase the solubility of calcium salts, mitigate corrosion, minimize fouling and control the growth of microbiological organisms like algae, bacteria, mold and fungi, as shown in Fig. Makeup water feeds to (BR) cooling units submits to some treatments to be improved quality, but it is not enough to make the water safe to be used in cooling towers.

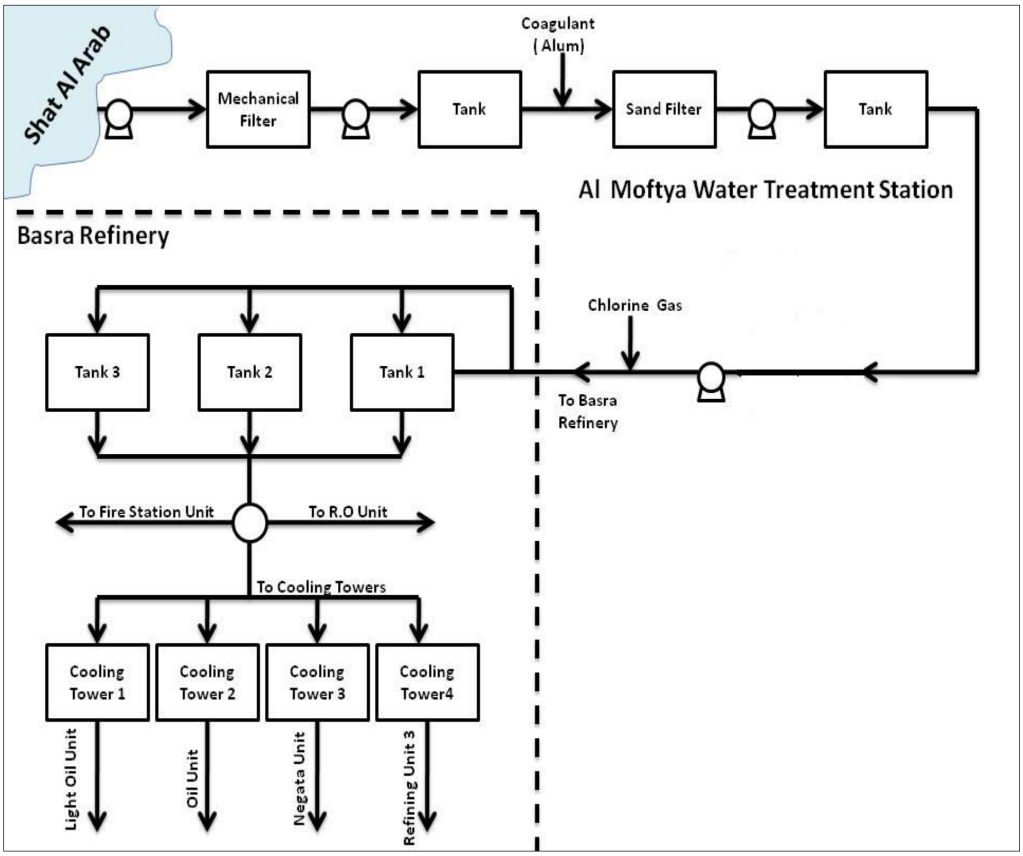

Fig. (1) Water Treatment Process in Almoftya Station

3. Present Situation of cooling towers at SRC

Based the Field data collected from **SRC** cooling towers of Basrah Refinery in different times and compared these data with the optimal required specifications of cooling towers showed, that:

- The concentrations of total dissolved salts (TDS) are higher than the acceptable limits of water used in cooling towers and that can cause scale problem.
- PH value of water is seemed to be with acceptable limits (6.5-8.5).

The Cooling tower efficiency of BR enhanced by the addition of certain makeup water treatment chemicals to increase the solubility of calcium salts, mitigate corrosion, minimize fouling and controls the growth of microbiological organisms like algae, bacteria, mold and fungi, as shown in Fig. However, addition of these improvers has not effect on quality of water where fouling and scales are causing problems in heat exchangers and pipelines, also corrosion products is found in the circulating water as well as finding of microbiological growth.

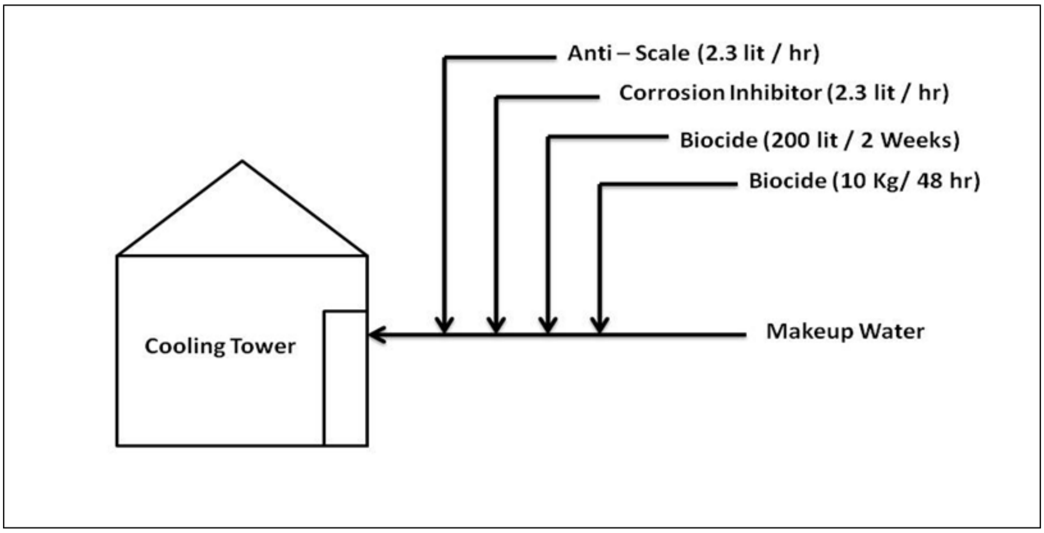

Fig. (2) Chemicals adding to makeup water at (BR)

4. Results and Discussion

In the current work, the field data was provided by **SRC**/Basrah Refinery related to the water quality that used in cooling towers. The average data of water cooling towers calculated is shown in Table (3).

Table (3) Average calculated concentrations of cooling towers water data reported in SRC

Cooling* Towers	pH	Conductivity us. cm^{-1}	Total Hardness as $CaCO_3$ mg/l	HCO_3 mg/l	SiO_2 mg/l	Turbidity NTU	T.D.S mg/l
OLD	7.6	6630	924	249	11.75	17.4	5206
NIGATTA	8.0	9811	403	322.6	10.7	8.76	7805
OILS	8.0	12887	286	228	9.0	8.1	5014
IMPROVEMENT Of GASOLINE/3	6.7	1917	50.5	144	9.4	7.7	1454
FEED	6.9	7556	259	214	8.25	12.1	4892

*The names of cooling towers at the first column in the table are as reported in the documents of BR and it will be written down by these names in all items of this research.

4.1. Data Analysis by Langelier Model

Langelier equation is the ordinary procedure using to predict occurrence of calcium carbonate scale. The PH value of saturation with $CaCO_3$ (pH_s) is illustrated as bellow:

$$pH_s = (pK_2 - pK_S) - pCa^{++} p_{alk} \quad \text{where:}$$

pK_2 =Constant

pK_S = Constant

pCa^{++} = negative logarithm of *calcium concentration (ppm)*

p_{alk} = *negative logarithm of total alkalinity (meq/liter)*

When the concentration of TDS is more than 5000mg/l, Langelier index will be affected. Stiff and Davis have simplified estimated calculation to use the equation in saline water as bellow [6]:

$$pH_s = pCa^{++} + p_{alk} + k$$

k =Constant and its value depends on TDS and temperature.

The final langelier equation is:

$LSI = pH - pH_S$

Where:

LSI = langelier Saturation Index

PH = Real PH value of water (measured)

pH_S = pH saturation (calculated)

4.2. Prediction of Scale and Corrosion of Water

Applying of langelier Saturation Index on collected field data leads to predict the behavior of cooling water by comparing the results of LSI values with standard limitations, the standard limitations of LSI can be concluded as Table (4) [7]:

Table (4): Tendency of water based on LSI value

LSI	Indication
LSI<Zero	Water is under saturated with respect to calcium carbonate. Under saturated water has a tendency to remove
LSI=Zero	Water is considered to be neutral. Neither scale forming nor scale removing.
LSI >Zero	Water is supersaturated with respect to calcium carbonate and scale forming may occur

Source: (langelier saturation index - Lenntech, www.lenntech.com)

4.3. Applying of LSI on Water used in cooling towers of SRC

Applying of **LSI** model on collected field cooling water data reported from **SRC** / Basrah Refinery Tables (5, 7, 9, 11, 13), gives the following results which are obtained in Tables (6, 8, 10, 12, 14 respectively).

Table (5) Water Analysis of Sample (1)

Sample Date 26/5/2015	**Water Analysis**					
Test	**Unit**	***OLD****	***NIGATTA***	**OILS**	**FEED**	***IMPROVE-MENT Of GASOLINE/* 3**
PH	……….	7.8	8.3	8.4	8.0	7.7
Conductivity	us-cm^{-1}	4120	5740	4950	3900	982
Total Hardness as $CaCO_3$	mg/l	1048	1390	1120	928	137
Ca^{+2}	mg/l	236	315	276	199	27
Mg^{+2}	mg/l	112	147	105	105	16
Na^{+}	mg/l	613	771	663	557	115
SO_4^{-2}	mg/l	706	994	882	672	175
$HCO3^{-}$	mg/l	234	234	234	204	39
Fe	mg/l	1.5	2.6	0.9	2.5	3.1
Suspended solid	mg/l	10.7	13	26	18	23
SiO_2	mg/l	7	9	7	7	3
C.O.D ($K_2Cr_2O_7$ method)	mg/l	48	34	16	26	Nil
B.O.D$_5$	mg/l	35	19	12	13	Nil
Oil in water	mg/l	13.0	Nil	Nil	---	Nil
Turbidity	N.T.U	11	5	8	21	27
K^{+}	mg/l	10	15	15	10	30
T.D.S	mg/l	2877	3895	3218	2626	560
PO_4^{-3}	mg/l	3.8	8.9	1.36	---	4.9
O_2	mg/l	2.4	8.0	6.6	6.7	7.5
AcidophIllic	colony/ ml	10^5	10^5	10^3	10^4	10^4
T.anerobic	colony/ ml	10^5	10^5	10^4	10^4	10^5
S.R.B	colony/ ml	10^3	10^5	10^2	10^2	10^2

Table (6) Applying of LSI Model on Sample (1) Data

C.W	**PHs**	**LSI**	**Description**
OLD	6.7	**1.1**	scale forming but non corrosive
NIGATTA	6.7	**1.6**	scale forming but non corrosive
OILS	6.7	**1.7**	scale forming but non corrosive
FEED	6.8	**1.2**	scale forming but non corrosive
IMPROVE-MENT Of GASOLINE	8.1	**-0.45**	slightly corrosive but non –scale forming

Table (7) Water Analysis of Sample (2)

Sample Date				
9/6/2015				
Test	**Unit**	**OLD**	**NIGATTA**	**FEED**
PH	………..	7.8	8.2	7.9
Conductivity	us-cm^{-1}	4300	6190	3720
Total Hardness as $CaCO_3$	mg/l	1058	1508	890
Ca^{+2}	mg/l	242	322	199
Mg^{+2}	mg/l	111	171	96
Na^{+}	mg/l	615	1032	435
SO_4^{-2}	mg/l	630	900	592
Cl^{-}	mg/l	962	1612	861
$HCO3^{-}$	mg/l	224	331	195
Fe	mg/l	2.2	0.95	0.96
Suspended solid	mg/l	39	9.0	4.0
SiO_2	mg/l	12	13	10
C.O.D ($K_2Cr_2O_7$ method)	mg/l	75	420	15
B.O.D_5	mg/l	56.5	26.6	14.1
Oil in water	mg/l	37	34	-
Turbidity	N.T.U	19	7.4	6.9
K^{+}	mg/l	15	15	10
T.D.S	mg/l	2813	4396	2399
PO_4^{-3}	mg/l	5.6	1.7	1.18
O_2	mg/l	2.6	2.2	5.3
AcidophIllic	colony/ml	10^3	10^2	10^2
T.anerobic	colony/ml	10^5	10^5	10^4
S.R.B	colony/ml	10^2	10^2	10^2

Table (8) Applying of LSI Model on Sample (2) Data

C.W	**PHs**	**LSI**	**Description**
OLD	6.7	**1.1**	*scale forming but non corrosive*
NIGATTA	6.5	**1.7**	*scale forming but non corrosive*
OILS	-------	**------**	------------------------------------
FEED	6.8	**1.1**	*scale forming but non corrosive*
IMPROVE-MENT Of GASOLINE	------	**------**	------------------------------------

Table (9) Water Analysis of Sample (3)

Sample Date 18/8/2015	Water Analysis					
Test	*Unit*	*OLD*	*NIGATTA*	*OILS*	*FEED*	*IMPROVE-MENT Of GASOLINE /3*
PH	………..	7.6	7.9		7.8	7.9
Conductivity	us-cm^{-1}	11280	15100		10500	3860
Total Hardness as $CaCO_3$	mg/l	1922	2516		1804	360
Ca^{+2}	mg/l	348	450		312	66
Mg^{+2}	mg/l	256	339		249	47
Na^{+}	mg/l	2398	3185		2129	522
SO_4^{-2}	mg/l	932	1428		1048	812
Cl^{-}	mg/l	3748	4978		3328	816
$HCO3^{-}$	mg/l	244	280		195	102
Fe	mg/l	1.03	2.2		0.72	3.6
Suspended solid	mg/l	19	21		7.0	3.0
SiO_2	mg/l	12	10		9	6
C.O.D ($K_2Cr_2O_7$ method)	mg/l	91	122		41	75
$B.O.D_5$	mg/l	32	43		18	15
Oil in water	mg/l	8.5	21		-	NIL
Turbidity	N.T.U	6.0	6.5		3.8	4.5
K^{+}	mg/l	20	30		20	5
T.D.S	mg/l	7958	10700		7290	2379
PO_4^{-3}	mg/l	5.1	10.2		-	3.5
O_2	mg/l	1.8	2.9		5.3	7.4
AcidophIllic	colony/ml					
T.anerobic	colony/ml					
S.R.B	colony/ml					

Table (10) Applying of LSI Model on Sample (3) Data

C.W	PHs	LSI	Description
OLD	6.8	**1.0**	Scale forming but non corrosive
NIGATTA	6.7	**1.2**	Scale forming but non corrosive
OILS	-----	-----	-------------------------------------
FEED	6.9	**0.91**	Scale forming but non corrosive
IMPROVE-MENT Of GASOLINE/3	7.6	**0.30**	Slightly scale forming and corrosive

Table (11) Water Analysis of Sample (4)

Sample Date 17/11/2015					
Test	**Unit**	**OLD**	**OIL S**	**Feed**	**IMPROVE-MENT Of GASOLINE /3**
PH	………..	7.4	7.7	7.1	7.2
Conductivity	us-cm^{-1}	9610	7700	9670	1990
Total Hardness as $CaCO_3$	mg/l	1572	1244	1522	240
Ca^{+2}	mg/l	317	252	308	52
Mg^{+2}	mg/l	190	150	183	27
Na^{+}	mg/l	1750	1301	1722	316
SO_4^{-2}	mg/l	1000	908	1204	170
Cl^{-}	mg/l	2734	2033	2692	495
$HCO3^{-}$	mg/l	244	195	240	136
Fe	mg/l	0.82	0.7	1.3	0.7
Suspended solid	mg/l	25	17	12	2
SiO_2	mg/l	13	10	12	8
C.O.D ($K_2Cr_2O_7$ method)	mg/l	95	31.9	31.6	61
$B.O.D_5$	mg/l	56	21.5	7.9	32.8
Oil in water	mg/l	29	2.4	-	32
Turbidity	N.T.U	7.7	3.6	16.8	5.2
K^{+}	mg/l	15	10	15	5
T.D.S	mg/l	0.9	4859	6376	7.5
PO_4^{-3}	mg/l	0.4	0.2	-	0.2
O_2	mg/l	7.0	7.8	6.0	0.6
AcidophIllic	colony/ml	6263	10^{2}	10^{5}	10^{5}
T.anerobic	colony/ml	10^{5}	10^{2}	10^{5}	10^{5}
S.R.B	colony/ml	10^{5}	10^{3}	10^{3}	10^{5}

Table (12) Applying of LSI Model on Sample (4) Data

C.W	**PHs**	**LSI**	**Description**
OLD	6.8	**0.63**	*Scale forming but non corrosive*
NIGATTA	-----	-----	------------------------------------
OILS	6.9	**0.80**	*Scale forming but non corrosive*
FEED	6.8	**0.31**	*Slightly scale forming and corrosive*
IMPROVE-MENT Of GASOLINE/3	7.4	**-0.24**	*Slightly corrosive but non scale forming*

Table (13) Water Analysis of Sample (5)

Sample Date 3/11/2015					
Test	**Unit**	***OLD***	***NIGATAT***	***OILS***	***FEED***
PH	………	7.5	7.8	7.8	7.7
Conductivity	us-cm^{-1}	4430	6860	5760	4520
Total Hardness as $CaCO_3$	mg/l	920	1400	1120	900
Ca^{+2}	mg/l	196	304	208	180
Mg^{+2}	mg/l	105	156	146	109
Na^{+}	mg/l	711	1154	942	739
SO_4^{-2}	mg/l	435	924	752	712
Cl^{-}	mg/l	1111	1803	1473	1155
$HCO3^{-}$	mg/l	239	213	198	195
Fe	mg/l	1.6	1.7	1.4	1.0
Suspended solid	mg/l	8	12	8	5
SiO_2	mg/l	11	13	10	8
C.O.D ($K_2Cr_2O_7$ method)	mg/l	68	26	21	21
$B.O.D_5$	mg/l	24	12	9	5.7
Oil in water	mg/l	35	17	14	-
Turbidity	N.T.U	19	20	14	8.0
K^{+}	mg/l	10	15	10	10
T.D.S	mg/l	2820	4582	3740	3109
PO_4^{-3}	mg/l	2.3	7.6	6.8	7.2
O_2	mg/l	3.7	5.4	1.5	-
AcidophIllic	colony/ml	0.4	0.3	0.3	0.2
T.anerobic	colony/ml	10^3	10^4	10^4	10^4
S.R.B	colony/ml	10^5	10^5	10^5	

Table (14) Applying of LSI Model on Sample (5) Data

C.W	PHs	LSI	Description
OLD	**6.7**	**0.80**	Scale forming but non corrosive
NIGATTA	**6.7**	**1.1**	Scale forming but non corrosive
OILS	**6.8**	**0.98**	Scale forming but non corrosive
FEED	**6.8**	**0.87**	Scale forming but non corrosive
IMPROVE-MENT Of GASOLINE	-----		----------------------------------

5. Conclusions

The obtained results collected by applying LSI model on cooling water analysis data show that the tendency of water to form scale ($CaCO_3$ Precipitation) at units (**OLD, NIGATTA, OILS**). Also, the feed water has the same tendency for scale forming. Applying of **LSI** model on data analysis of cooling water for (**IMPROVEMENT of GASOLINE**) shows the tendency of water to be slightly corrosive without forming of scale. Bad quality of water parameters is noticed from high levels of calcium and alkalinity, which leads to high value of **PHs** (PH at saturation), causes scale forming and corrosion.

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