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EVALUATING TREATMENT PROCESS OF PRODUCED WATER FROM OIL/GAS PRODUCTION PLATFORM WITH SCALE INHIBITOR

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ABSTRACT

Treatment of produced water from a crude oil production platform with a flow rate of 11,000 to 13,000 barrel per day (API 34° at 49°C) was carried out to determine optimum concentration of the injection rate of scale inhibitor before discharge overboard. The physico-chemical properties of the produced water were determined. A GBC Scientific Avanta Programmable A6080 Atomic Absorption Spectrometer (AAS) was used to determine the cations while Analytical Method was adopted to determine the concentration of anions, conductivity, alkalinity, hardness, suspended solids, and the pH of the produced water. Results showed that conductivity, alkalinity, hardness, suspended solids decrease with increase in the concentration of the scale inhibitor. At 0 ppm of scale inhibitor, hardness was 1100 mg ($CaC0_3$) per litre of produced water and at 8.6 ppm hardness reduced to 800 mg ($CaC0_3$) per litre of produced water indicating that increasing the dosage of the scale inhibitor prevents scale formation. However, optimum dosage value is required to minimize the cost of production processes.

Keywords: Produced water, Treatment, Scale formation inhibitor, Crude oil production.

Contribution/ Originality

This work applies the concept of kinetic equilibrium in converting anions and cations encountered in produced water from oil/gas wells which form scales causing corrosion to delineate pipeline problems associated with production platforms. Optimum scale inhibitor dosage was established in the evaluation. This perhaps could affect economic value of the production process.

1. INTRODUCTION

Produced water is a complex mixture of organic and inorganic compounds and the largest volume of byproduct generated during oil and gas recovery operations, [1]. Globally, produced

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water production is estimated at around 250 million barrels per day compared with around 80 million barrels per day of oil. Consequently, produced water to oil ratio is around 3: 1, that is to say water cut stands at about 70%. Produced water production has risen since decades ago and continues to rise because of consistent increase in crude oil exploitation in Nigeria. Produced water is driven up by maturing of oil fields but driven down by better management methods and introduction of new oil fields [2] [3]. The factors that affect the production volume of produced water production amongst others are: method of well drilling, location of well within homogeneous or heterogeneous reservoirs, different types of completion, types of separation techniques, water injection or water flooding for enhancing recovery, poor mechanical integrity and underground communication [4], [5], [6]. Some factors such as geological location of the field, its geological formation, lifetime of the reservoirs, and type of hydrocarbon product being produced affect the physical and chemical properties of produced water [7], [8]. Produced water characteristics depend on the nature of the producing| storage formation from which they are withdrawn, the operational conditions and chemicals used in process facilities. The composition of produced water from different sources varies by order of magnitude. However, produced water composition is qualitatively similar to oil / or gas production [9]; [10]; [11]. The major compounds of produced water include: dissolved and dispersed oil compounds, dissolved formation minerals, production chemical compounds, production solids (including formation solids, corrosion and scale products, bacteria, waxes, asphaltenes), and dissolved gases [12]. Treatment of produced water is an effective option for produced water management. Treatment of produced water has the potential to be a harmless and valuable product rather than a waste.

It is important to analyze the constituents of the produced water before beginning a water flood operation to avoid chemical reactions that may form precipitates. If necessary, treatment chemicals can minimize undesired reactions. Bacteria, algae, and fungi can be present in produced water or can be introduced during water handling processes at the surface. These are generally controlled by adding biocides or by filtration [13].

1.1. Oil/Water Separation

When reservoir fluids (gas/oil/water) are brought to the surface for separation and treatment, the pressure is reduced and this sometimes results in the formation of insoluble scales. In simple terms the reduction in pressure allows soluble bicarbonates to be converted to the carbonate ion with the release of CO_2 gas:

$$2HCO_3^- \longrightarrow CO_3^{2-} + CO_2 + H_2O \quad (1)$$

The carbonate ion combines with any calcium ions, for example, to form insoluble carbonate scales. Not only can this result in reduced flow rates (loss of revenue) but this can have an adverse effect on system integrity and needs to be addressed. Inhibition of scale formation can be achieved by dosing a scale inhibitor chemical to the reservoir fluids while these are still at high pressure

[14]. It is the aim of this study to ascertain the produced water treatment chemical performance and evaluate optimal chemical injection rate to reduce cost of chemical consumption and ensure effective performance of scale inhibitors. This is aimed at preventing scale formation in the produced water pipeline.

2. MATERIALS AND METHODS

2.1. Sample Collection and Preparation

The produced water was collected in a sterilized one litre sample bottle from the floatation cell outlet of a production platform in Niger Delta, Nigeria and taken to the laboratory in a cooler containing ice cubes wrapped in cellophane bag to reduce the temperature of the sample and to inhibit bacteria growth in the produced water as most bacteria grow best between 20⁰C to 30⁰C. Preservation of the sample was done in accordance with the stipulated standard in the annual book of ASTM and by American Society Testing and Materials.

2.2. Determination of Physico-Chemical Properties

Materials: Computer, GBC Scientific Avanta Programmable A6600 Atomic Absorption Spectroscopy (AAS) used for determination of the following cations in solution: Iron (Fe), Magnesium (Mg), Sodium (Na), Barium (Ba), Calcium (Ca), Lead (Pb), Mercury (Hg), and Cromium (Cr). Practical analytical methods were used to determine the following anions: Chloride (Cl^-) API-RP45, Sulphate (SO_4^{2-}) APHA-427C, Hydrogen Carbonate (HCO_3^-) API-RP45, Hydrogen Sulphide (H_2S) API-RP45, Carbon Dioxide (CO_2) API-RP45, Carbonate (CO_3^{2-}) API-RP45. Other test conducted include: Conductivity APHA 145, Hardness APHA 122B, Alkalinity APHA 403, pH API-RP45, Total Suspended Solid APHA 208D.

Procedure: The GBC Scientific Avanta A6080 AAS icon on the computer was double clicked to launch the page. Sub directory/folder for metals to be analyzed was created. The logged data were saved in the respective modules where they have been created. The test wavelength, module, flame, lamp current sensitivity was selected for the test to run. Acetylene/air burner was lit which produced a flame with temperature range 2100 - 2400⁰C. Produced water sample was introduced into the AAS nebulizer through an aspirator tube attached to the nozzle at one end and other submerged in the produced water in beaker at the other end. The flame from the burner heats up the AAS nebulizer which concerts the sample in it into a mist made of tiny droplets. The nebulizer sprays the liquid droplets on the hot flame which atomizes it. Then light from a hollow cathode lamp was aligned to the atomized metal in the spray chamber where the light energy of a given wavelength was absorbed to promote the electrons of the AAS calibration curve of standard concentration at equivalent absorbance to obtain the concentration of the metal ion interest.

Deuterium lamp (D2) adjustment and setting were used to prevent interference to the metal analyzed from the system and for background correction. Part of the precaution of the test was to ensure that the burner head was clean and free from debris. This was done with aid of a burner cleaning card. The results obtained were printed from the computer attached to the AAS. The following setting was maintained for the corresponding metals analyzed:

Table-1. AAS settings for metal ion determination

Element	Wavelength (Nm)	Slit Width (Nm)	Sensitivity (µg/Ml)	Lamp Current (Ma)	Gas Used
Ca	442.7	0.5	0.02	10	Air + acetylene
Ba	553.6	0.5	0.18	15.0	Same
Na	589.6	0.5	0.008	5	Same
Mg	202.6	1	0.003	3	Same
Mn	279.5	0.2	0.02	5	Same
Pb	217	1	0.06	5	Same
Fe	248.3	0.2	0.05	7	Same
Cr	357.9	0.2	0.05	6	Same

3. RESULTS AND DISCUSSIONS

Table 2 shows the results obtained from laboratory analysis of treatment of produced water using scale inhibitor Nalco 6080A chemical. Different injection rate of scale inhibitor ranging from 0ppm to 8.6ppm were used to determine the optimum concentration rate at various produced water flow rate for test period of 6 days at intervals of 24 hours. The results of the various physico-chemical parameters are presented in Table 2

Table-2. Results of the various physico-chemical parameters of the analysis.

Components	0ppm	2.1ppm	3.9ppm	5.5ppm	7.2ppm	8.6ppm
	24hrs	24hrs	24hrs	24hrs	24hrs	24hrs
	Field Test	Field Test	Field Test	Field Test	Field Test	Field Test
	13560bwpd	13389bwpd	13278bwpd	13580bwpd	13498bwpd	13293bwpd
Na (mg/l)	7870.6	7870.8	7880.6	7887.6	7888.4	7890.5
Ca (mg/l)	28.6	28.9	29.0	29.1	29.5	29.7
Fe (mg/l)	0.155	0.155	0.155	0.155	0.155	0.161
Mg (mg/l)	43.2	43.2	43.2	43.2	43.2	45.6
Pb (mg/l)	0.18	0.182	0.185	0.189	0.189	0.19
Cond (uS/cm)	24000	21750	18000	17560	17120	16350
Hardness (mg($CaCO_3$)/l)	11000	10980	10754	9500	970	800
Alkalinity (mg($CaCO_3$)/l)	25	23.5	23	23	21	20
pH	7.8	7.6	7.6	7.3	7.3	7.5
Cr (mg/l)	0.05	0.05	0.05	0.05	0.05	0.05
Ba (mg/l)	12.85	12.85	12.88	12.89	12.89	12.9
Hg (mg/l)	0.56	0.56	0.56	0.56	0.57	0.56
Suspended solid	460	456	450	432	423	410

Chloride Cl (mg/l)	12853	12854	12854	12854.9	12856	12857.5
Carbonate CO_3 (mg/l)	0.08	0.08	0.08	0.08	0.08	0.08
Sulphate SO_4 (mg/l)	10.5	10.6	10.6	10.8	10.85	11
Bicarbonate (mg/l)	786	865	870	873	873	875
CO_2 (mg/l)	10.9	10.9	10.9	10.9	10.9	11
Sulphide (mg/l)	0.04	0.04	0.04	0.04	0.04	0.04

Note: bwpd means barrel of water per day

Figures 1, 2 show the concentration of cations in the treated produced water at various injection rate of the scale inhibitor. The concentrations of the cations increase as the injection rate of the scale inhibitor is increased from 0 ppm to 8.6 ppm, whereas for magnesium, the concentration remains constant between 0ppm to 5.5 ppm and increases rapidly from 5.5ppm to 8.6 ppm. This increase in concentration is necessary to inhibit scale formation reactions. The concentration of the scale inhibitor injection rate was increased from 5.5 ppm to 8.6 ppm to prevent scaling tendencies in produced water to inhibit scale formation reaction such as:

$$Ca^{2+} + 2(HCO_3) \longrightarrow Ca(HCO_3)_2 \qquad (2)$$

$$Ca(HCO3)_2 \longrightarrow CaCO_3 + CO_2 + H_2O \qquad (3)$$

$$Ba^{2+} + SO4^{2-} \longrightarrow BaSO_4; \qquad (4)$$

$$Ca^{2+} + SO4^{2-} \longrightarrow CaSO_4. \qquad (5)$$

Thus, increase in the injection rate of the scale inhibitor eliminates formation of $BaSO_4$ and $CaSO_4$ scales in the produced water pipeline facilities.

Fig. 3 and 4 show the variation of the concentration of anions with the concentration of the scale inhibitor injection rate. The concentrations of chloride, bicarbonate and sulphate ions increase as the concentration of the scale inhibitor injection rate increases whereas the concentrations of sulphide, carbonate, chromium, and carbon dioxide remain practically constant. In the analysis of the produced water with 0 ppm of scale inhibitor, the anions concentrations were less than the anions concentrations in the produced water in which scale inhibitor chemical was injected. The scale inhibitor in solution inhibits the salt crystals formation reactions between anions and cations in the produced water. In samples without scale inhibitor, metallic cations reacted with the anions in solution to form salt which is responsible for the increase in hardness, conductivity, alkalinity, suspended solid and pH.

Fig.5 depicts the variation of the concentration of heavy metals (chromium, mercury and lead) with the concentration of scale inhibitor injection rate. The concentration of lead increases as the dosage of the scale inhibitor increase whereas the concentrations of chromium and iron remain constant. Heavy metal concentration in produced water depend on age of the well and formation geology.

Fig. 6 and7 show the variation of Conductivity, Hardness, suspended solid, alkalinity and pH with concentration of scale inhibitor. These physico-chemical parameters decrease with increase in the concentration of the scale inhibitor except the pH which remains fairly constant. The initial increase in the Conductivity, Hardness and suspended solid and alkalinity concentration emanate from scale formation reactions.

4. CONCLUSION

Treatment of produced water from a crude oil production platform with a flow rate of 11,000 to 13,000 barrel per day was carried out to determine optimum concentration of the injection rate of scale inhibitor before discharge overboard. The physico-chemical properties of the produced water were determined. A GBC Scientific Avanta Programmable A6080 Atomic Absorption Spectrometer (ASS) was used to determine the cations while Analytical Method was used to determine the concentration of anions, conductivity, alkalinity, hardness, suspended solids, and the pH of the produced water. Increase in the injection rate of Nalco 6080 from 0ppm to 8.6ppm resulted in the reduction of the conductivity by 32% (24,000 to 16,350 us/cm), Hardness by 93% (11,000 to 8000 mg(CaCO3) per litre of produced water, pH by 4% (7.8 to 7.5), Suspended solids (460 to 410) and Alkalinity (25 to 20 mg(CaCO3)/l). The chloride content of 12,857mg/l is higher than the recommended value of the Directorate of Petroleum Resources (DPR) a regulatory body in Nigeria and therefore need further treatments. This work explains the controlling mechanism of inhibitor application to reduce scale formation on structures transporting produced water. The benefit is that environmental impact of the produced water, inhibitor is minimized. The results obtained should be a guide to oil and gas operators to protect not only the environment but also to reduce hazard of equipment failures.

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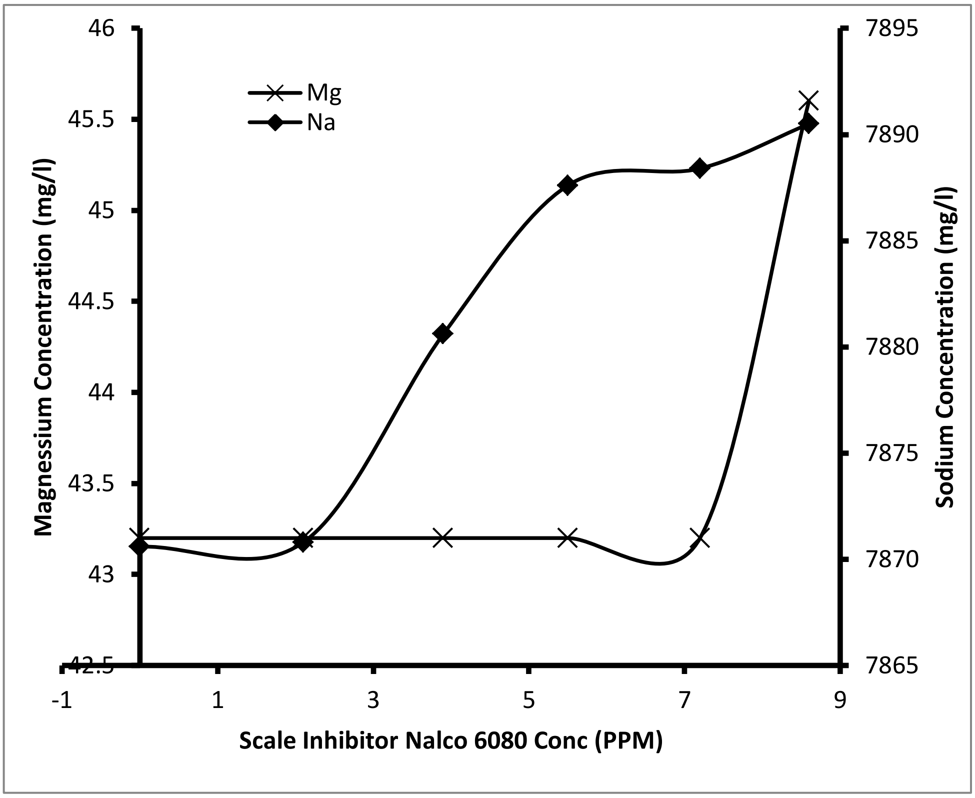

Fig-1. Variation of concentration of sodium and magnesium with concentration of scale inhibitor

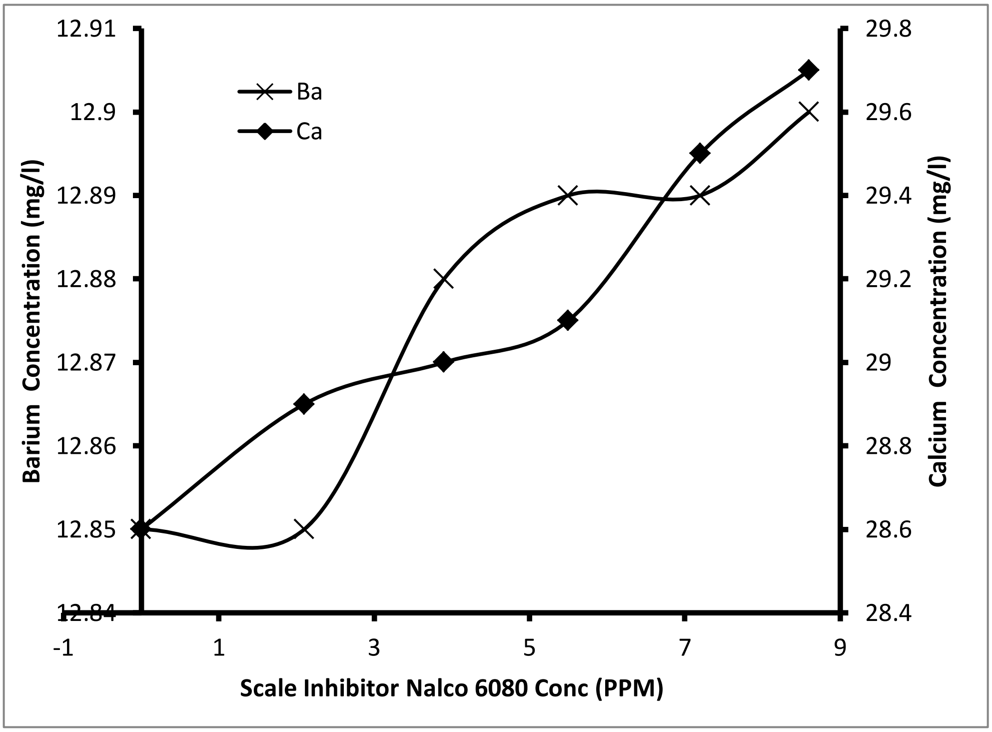

Fig-2. Variation of concentration of barium and calcium with concentration of scale inhibitor

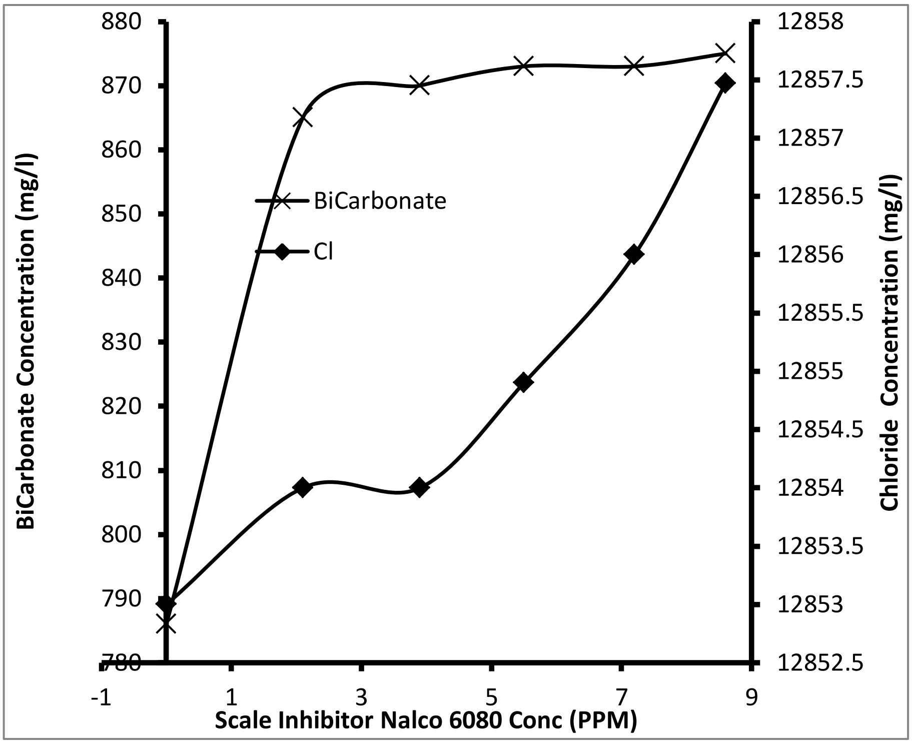

Fig-3. Variation of concentration of chloride and bicarbonate ion with concentration of scale inhibitor

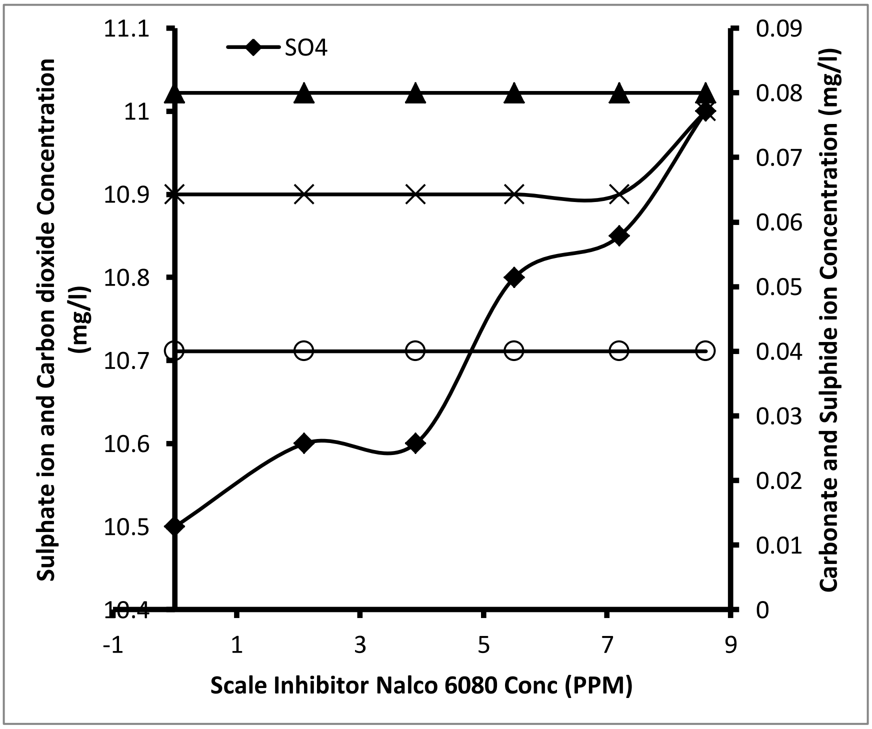

Fig-4. Variation of concentration of sulphate, carbon dioxide, carbonate and sulphide ion with concentration of scale inhibitor

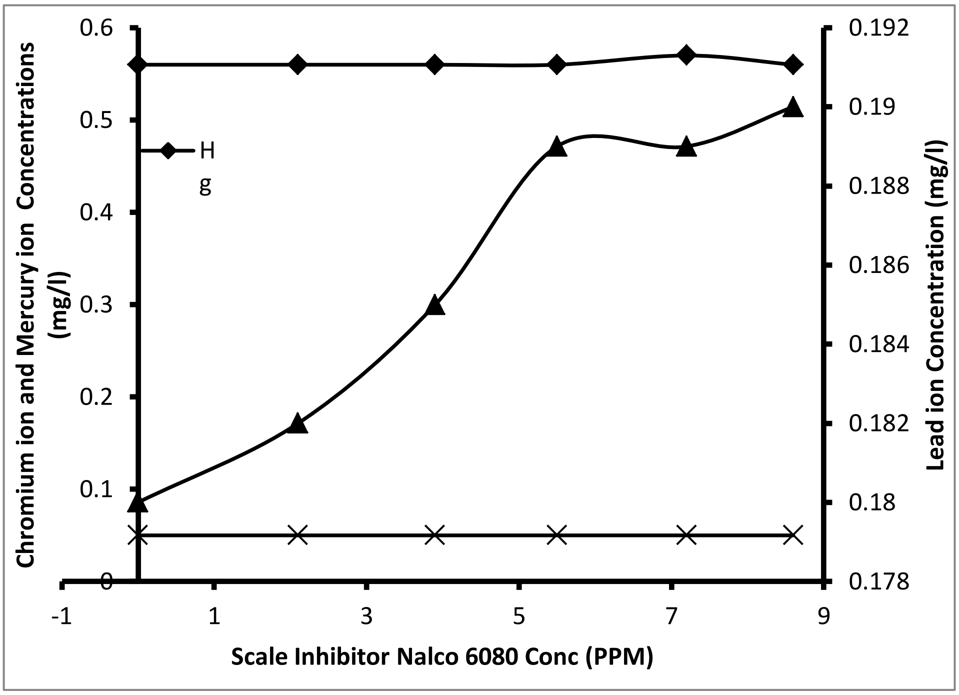

Fig-5. Variation of concentration of mercury, lead and chromium ion with concentration of scale inhibitor

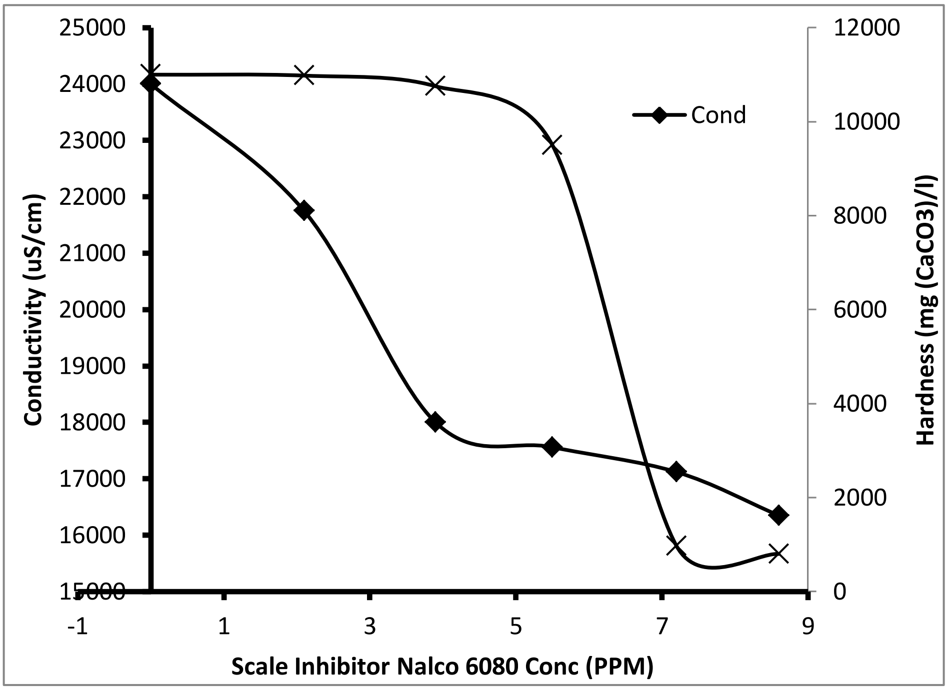

Fig-6. Variation of conductivity and hardness with concentration of scale inhibitor

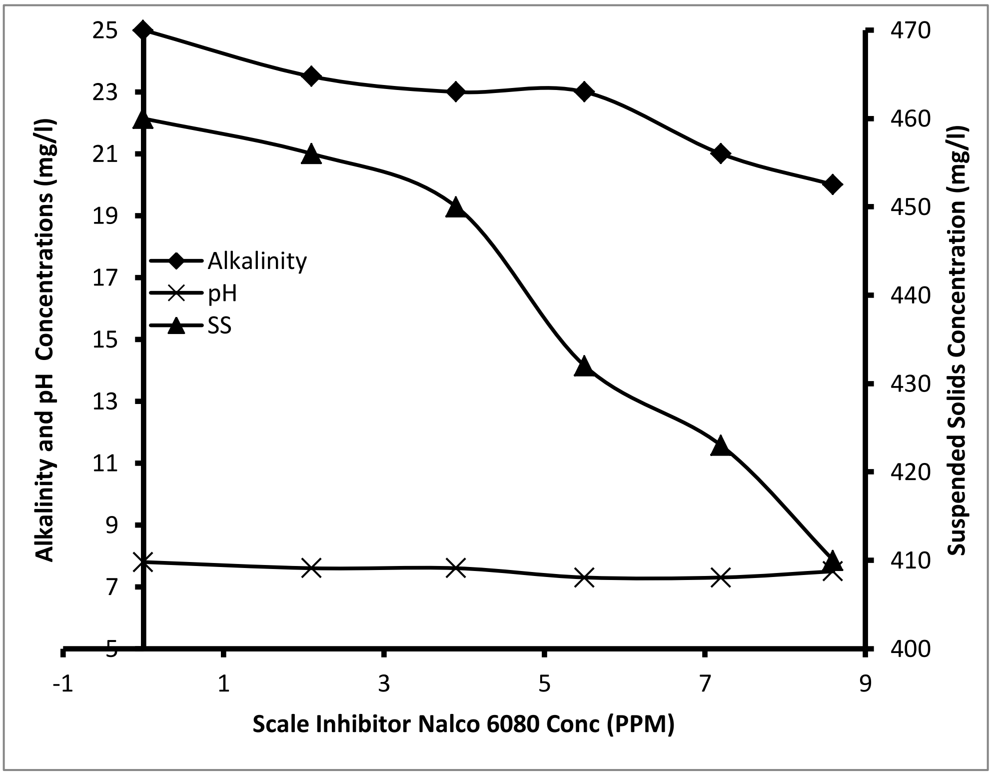

Fig-7. Variation of concentration alkalinity, suspended solids and pH with concentration of scale inhibitor