World Journal of Pharmaceutical and Life Sciences
WJPLS
www.wjpls.org
SJIF Impact Factor: 7.409

# DETERMINATION OF SOME INORGANIC CONSTITUENTS AND TREATMENT OF ELOBEID PETROLEUM REFINERY FEED WATER

**Mohammed Bahreldin Hussein*[1], Abdelhameid Abdelkareim Jobara[2], Abdelwahab Abuelgasim Mohammed Adam[1]**

[1]Department of Chemistry, Faculty of Science, University of Kordofan, Elobeid, 55111, Sudan.
[2]Elobeid Petroleum Refinery Company, Elobeid, North Kordofan State-Sudan.

***Corresponding Author: Mohammed Bahreldin Hussein**
Department of Chemistry, Faculty of Science, University of Kordofan, Elobeid, 55111, Sudan.
**DOI:** https://doi.org/10.5281/zenodo.17224918

**Article Received on 11/08/2025** **Article Revised on 31/08/2025** **Article Accepted on 21/09/2025**

**ABSTRACT**
The aim of this study is determination of some inorganic constituents of Elobeid petroleum refinery feed water before and after treatment. Four samples of feed water were collected for this study, three samples from refinery wells; (A, B, and C) and one sample from Bara Basin (D). Parameters analyzed include; temperature, pH, electrical conductivity (EC), total dissolved solids (TDS), total hardness (TH), total alkalinity (TA) total iron (TI), total suspend solid (TSS), total solid (TS), major cations ($Na^+$, $K^+$, $Ca^{++}$ and $Mg^{++}$) and anions ($F^-$, $Cl^-$, $SO_4^{-2}$, $NO_3^-$, $NO_2^-$ and $PO_4^{3-}$). The heavy metals content of Bara Basin water were analyzed by using atomic absorption spectrometer. The results showed that the temperature values ranged from 25-28.3ºC and after treatment from 22.2-28.2ºC within acceptable limits. pH values from 6.7 to 7.4 and after treatment from 6.5 to 6.9 all samples in agreement with permissible level reported by World Health Organization WHO and Sudanese Standards and Metrology Organization SSMO. Electrical conductivity (EC) for all samples between 638.0 to 1075µs/cm and after treatment between 105.4 to 432.2µs/cm except samples A and C were out of permissible limits before treatment. The total dissolved solids (TDS) values for all samples ranging between 319.3 to 548.75mg/l and after treatment between 53.80 to 93.15 mg/l. All water sources within specifications of WHO an SSMO. The concentrations of sodium ($Na^+$) arranged between 11.5 to 17mg/l and after treatment between 0.0 to 0.1mg/l. All samples are below the permissible drinking water levels of WHO and SSOM (20 to 200 mg/l). The concentrations of Potassium ($K^+$) was 0.48 mg/l and after treatment was 0.23mg/l in Bara Basin sample. Calcium ($Ca^{++}$) ranging from 64.1 to 147.7mg/l and after treatment from 5.5 to 6.8 mg/l. All samples showed low concentration levels of calcium below the permissible drinking water levels of WHO 200mg/l. Magnesium ($Mg^{++}$) concentrations levels, ranged between 30.8 to 69.11 mg/l and after treatment 4.3-2.2 mg/l. Fluoride concentrations range of 0.76 to 0.88 mg/l and after treatment 0.25mg/l to 0.48mg/l almost all samples within the permissible limits. Chloride ranges from 36.3 to 166 mg/l and after treatment from 16.3 to 66.7 mg/l almost all samples are within permissible limits. The Sulphate concentration was observed between 42 to 102 mg/l and after treatment between 17 to 46 mg/l all samples within acceptable limits. Nitrate concentrations between 0.75 to 24.4 mg/l and after treatment between 0.22 to 3.7 mg/l. That means all samples within acceptable limits of WHO and SSMO. The Nitrite concentrations between 0.00 to 1.36 mg/l and after treatment between 0.00 mg/l to 0.32mg/l within acceptable limit WHO and SSMO. Phosphate concentrations between 0.20 to 3.92 mg/l and after treatment between 0.00 to 0.87 mg/l most samples within acceptable limits of WHO. In Bara basin water the concentrations of heavy metals; Barium (Ba), Manganese (Mn), Copper (Cu), Zinc (Zn) and Chromium (Cr) were (0.13, 0.01, 0.03, 0.01 and 0.006) within acceptable limits of WHO (0.13, 0.08, 2.0, 4.0 and 0.05) respectively. With exception of Nickel (Ni), Cadmium (Cd) and Lead (Pb) were (0.24, 0.02 and 0.27) higher than the permissible limit of WHO (0.07, 0.003 and 0.01) respectively.

**KEYWORDS:** Water quality, Petroleum refinery, Physiochemical analysis, Heavy metals, WHO and SSMO.

## 1. INTRODUCTION

Groundwater is one of the most important finite natural resource for fresh water on Earth.[1-3] Its importance has increased as people depend on it for agriculture, industry and domestic use.[4-8] Groundwater exploration and climate change in recent years have led to accelerated depletion of groundwater levels as well as deterioration of groundwater quality, especially in shallow aquifers.[9] Groundwater quality is as important as its quantity, and therefore it is essential to consider in depth the holistic approach towards its management.[10]

Presently the quality and quantity of water is important alarming environmental problems on at global and national levels. The pressure on water resources due to rapid urbanization, industrialization and agricultural development has resulted in high impact on quality and quantity of water. Massive uses and inappropriate management of groundwater are causing serious threat to the availability and quality of water.[11]

Water plays important role in petroleum refining operations, serving as a utility for cooling, steam generation, and process feed in various stages of production. The quality of this water, both prior to use (feed water) and after discharge (wastewater) has paramount importance in ensuring operational efficiency, equipment longevity, environmental compliance, and public health protection.

In the present study, four samples of feed water were collected and analyzed *via* standard procedures of water examination (APHA and HACH standard methods), and heavy metals were analyzed by atomic absorption spectrometer at Elobeid petroleum refinery Lab, then compared with WHO and SSMO standards.

## 2. MATERIALS AND METHODS

### 2.1. Sample collection

Three samples of groundwater were collected from refinery wells (A, B and C) and one sample from Bara basin (D) for determination of some inorganic constituents. All samples were packed in dry clean plastic container and labeled using gummed paper label, with collection date, location, and unique sample number.

### 2.2. Analysis of water samples

The water samples were analyzed at Elobeid Petroleum Refinery laboratory. The Physico-chemical analysis of groundwater was carried out for various water quality parameters such as Temperature, pH, Electrical conductivity(EC), Total Dissolved Solids (TDS), Total Hardness(TH), Total Alkalinity(TA), Total Iron(TI), Total Suspend Solid (TSS), Total Solid (TS) and major cations ($Na^+$, $Ca^{2+}$ and $Mg^{2+}$,) and anions ($F^-$, $Cl^-$, $SO_4^{-2}$, $PO_4^{-3}$, $NO_3^-$ and $NO_2^-$). as per standard procedures of water examination (APHA and HACH standard methods).

**Table 1: Standard Methods of water analysis.**

| Parameter | Standard Method | Parameter | Standard Method | Parameter | Standard Method |
|---|---|---|---|---|---|
| Temp(°C) | APHA 2550 | TS | APHA 2540-B | $NO_2^-$ | HACH 8153 |
| PH | APHA 4500 | TH | HACH 8226 | $F^-$ | HACH 8029 |
| EC | APHA 2510 | TI | HACH 8008 | $Cl^-$ | HACH 8113 |
| TDS | HACH 8207 | $Na^+$ | HACH 1429 | $SO_4^{-2}$ | HACH 8151 |
| TA | HACH 8221 | $Ca^{++}$ | HACH 8226 | $PO_4^{-3}$ | HACH 8048 |
| TSS | HACH 8006 | $Mg^{++}$ | HACH 8226 | $NO_3^-$ | HACH 8171 |

APHA 1992, 2008, 2014: American Public Health Association HACH: Name of company responsible for water quality

### 2.3. Determination of heavy metals

Bara basin Water was analyzed for the presence of heavy metals; Chromium, Nickel, Cadmium, Copper, Zinc, Lead and Barium by using an atomic absorption spectrometer (AAS Method)

**Table 2: National and international specifications of drinking water.**

| Parameter | WHO | SSMO | Parameter | WHO | SSMO |
|---|---|---|---|---|---|
| PH | 6.5-8.5 | 6.5-8.5 | $Ca^{+2}$ (mg/l) | 100.0 | N/A |
| E.C (µs/cm) | 400.0 | N/A | $Mg^{+2}$ (mg/l) | 50.0 | N/A |
| T.D.S (mg/l) | 600-1000 | 1000.0 | T.I (mg/l) | 0.3 | 0.3 |
| $Cl^-$ (mg/l) | 250.0 | 250.0 | T.H (mg/l) | 100-300 | 200.0 |
| F- (mg/l) | 0.7-1.2 | 1.5 | T.A (mg/l) | 20-200 | N/A |
| $SO_4^{-2}$ (mg/l) | 250.0 | 250.0 | T.S.S (mg/l) | 5.5 | N/A |
| $PO_4^{-3}$ (mg/l) | 0.3 | N/A | Turbidity (NTU) | 5.0 | 5.0 |
| $NO_3^-$ (mg/l) | 50.0 | 33.0 | Color (ADMI) | <15 | <15 |
| $NO_2^-$ (mg/l) | 3.0 | 2.0 | Temp (°C) | Acceptable | Acceptable |
| $Na^+$ (mg/l) | 200.0 | 250.0 | Taste | Acceptable | Acceptable |
| $K^+$ (mg/l) | 10-12 | N/A | Odor | Odorless | Odorless |

WHO 1993, 1996, 2003: World Health Organization SSMO 2016: Sudanese Standards and Metrology Organization

## 3. RESULTS AND DISCUSSION

### 3.1. Physochemical properties of Elobeid Petroleum Refinery feed water

#### 3.1.1. Temperature

Temperature is most important factor for biologically significant, that plays an important role in living organism for metabolic activities. The temperature ranged from (25.00 to 28.30) before treatment and (22.20 to 28.20) after treatment. Across all water sources, the temperature remained within acceptable limits stated by WHO and SSMO.

#### 3.1.2. PH-Value

PH of water significantly impacts its chemistry, toxicity, and health of aquatic ecosystems. It affects chemical reactions, the availability of nutrients, and the forms of pollutants, ultimately influencing the suitability of water for various uses, including drinking, industry and aquatic life. PH range from (6.7 to 7.4) before treatment and (6.5 to 6.9) after treatment indicating a neutral to slightly acidic/basic that means all samples shows value within permissible level reported by WHO, SSMO.

#### 3.1.3. Electrical conductivity

Electrical conductivity of water refers to its ability to conduct an electrical current. Pure water is a poor conductor, but the presence of dissolved salts and other inorganic chemicals increases conductivity. Factors like temperature and salinity also influence conductivity, with warmer and more saline water exhibiting higher conductivity. EC range from (638.0 to 1075µs/cm) before treatment and (105.4 to 432.2µs/cm) after treatment. As shown in table 2. All water sources before treatment were out permissible limits with exception of refinery (well C, Bara Basin D) within the permissible limits.

#### 3.1.4. Total Dissolve Solids

TDS ranging from (319.3 to 548.75 mg/l) before treatment and (53.80 to 93.15 mg/l) after treatment. That means all water sources within specifications of WHO and SSMO.

**Table 3: Physochemical properties of Elobeid Petroleum Refinery feed water**.

| No | Tem (℃) | | PH | | EC (µs/cm) | | TDS (mg/l) | |
|---|---|---|---|---|---|---|---|---|
| | Before | After | Before | After | Before | After | Before | After |
| A | 28.3 | 28.2 | 7.4 | 6.8 | 1075 | 105.4 | 548.75 | 53.8 |
| B | 28.1 | 27.6 | 7.3 | 6.9 | 638.0 | 105.4 | 319.3 | 63.8 |
| C | 25 | 22.2 | 7.25 | 6.8 | 1096.1 | 182.64 | 533.5 | 93.15 |
| D | 25.2 | 28 | 6.7 | 6.5 | 760.3 | 432.2 | 348.6 | 220 |

**Note:** A= Refinery well (1), B= Refinery well (2), C= Refinery well (3), D= Bara Basin

### 3.2. Chemical properties of Elobeid Petroleum Refinery feed water

#### 3.2.1. Total Iron

The permissible limit of iron is 0.3 mg/l as prescribed by WHO and SSMO. The iron concentration was observed between 0.03 to 0.33mg/l before treatment and 0.00 to 0.20 mg/l after treatment. That means all samples within acceptable limits of WHO and SSMO.

#### 3.2.2. Total Hardness

Water hardness is caused primarily by the presence of cations such as calcium and magnesium and anions such as carbonate, bicarbonate, chloride and sulphate in water. The value of Total hardness was observed between 105.2 to 196.7mg/l before treatment and 8.0 to 10.5mg/l after treatment. Almost all samples before treatment within permissible limits and after treatment below permissible limits of WHO of drinking water.

#### 3.2.3. Total Alkalinity

The Standard desirable limit of alkalinity in potable water is 120 mg/l. The maximum Permissible level is 600 mg/l. The value of Alkalinity of refinery feed water between 226 to 550mg/l before treatment and 35 to 88mg/l after treatment. All samples were below the permissible limits, given by WHO.

#### 3.2.4. Total Suspended Solids

Total Suspended Solids (TSS) is an important factor in water treatment, and removing them is crucial for both human health and environmental protection. TSS refers to the amount of solid particles that are suspended in water, and high levels can indicate pollution and potential health hazards. Effective TSS removal methods are essential for producing clean, safe water for various uses. TSS values were negligible or zero in most cases, showing clear water with minimal particulate matter.

#### 3.2.5. Total solids

Total Solids (TS) are dissolved solids plus suspended solids in water. In stream water, dissolved solids consist of calcium, chlorides, nitrate, phosphorus, iron, sulfur, and other ions particles that will pass through a filter with pores of around 2 microns (0.002 cm) in size. Suspended solids include silt and clay particles, plankton, algae, fine organic debris, and other particulate matter. These are particles that will not pass through a 2-micron filter. TS ranging from (119.3 to 548.75mg/l) before treatment and (53.80 to 93.15 mg/l) after treatment. All water sources within specifications of WHO an SSMO.

**Table 4: Chemical properties of Elobeid Petroleum Refinery feed water.**

| No | TI (mg/l) | | TH (mg/l) | | TA (mg/l) | | TSS (mg/l) | | TS mg/l) | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Before | After | Before | After | Before | After | Before | After | Before | After |
| A | 0.06 | 0.02 | 196.7 | 8.0 | 550 | 35.0 | 0.0 | 0.0 | 548.75 | 53.8 |
| B | 0.06 | 0.03 | 180.6 | 9.0 | 356 | 49.0 | 0.0 | 0.0 | 119.3 | 63.8 |
| C | 0.03 | 0.00 | 178.5 | 10.5 | 510 | 66 | 0.0 | 0.0 | 533.5 | 93.15 |
| D | 0.33 | 0.20 | 105.2 | 9.6 | 226 | 88.0 | 0.0 | 0.0 | 348.6 | 220 |

**Note:** A= Refinery well (1), B= Refinery well (2), C= Refinery well (3), D= Bara Basin

### 3.2.6. Cationic composition

Table (3). Show the cationic composition of Elobeid Petroleum Refinery feed water. The concentrations of sodium ($Na^+$) arranged between 11.5 to 17mg/l before treatment and 0.0 to 0.1mg/l after treatment. All samples are below the permissible drinking water levels of WHO (20 to 200 mg/l). Calcium ($Ca^{++}$) concentration ranging from 64.1 to 147.7mg/l before treatment and 5.5 to 6.8 mg/l after treatment. All samples showed low concentration levels of calcium below the permissible drinking water levels of WHO, (200mg/l). Magnesium ($Mg^{++}$) concentrations levels, is ranged between 30.8-69.11 mg/l before treatment and 4.3-2.2 mg/l after treatment magnesium not attached for WHO and SSMO Standard. The concentrations of Potassium ($K^+$) arranged between 0.48 mg/l before treatment and 0.23mg/l after treatment, in sample (D) Bara Basin. All Cationic within limits of WHO and SSMO.

**Table 5: Cationic Composition of Elobeid Petroleum Refinery feed water.**

| S.No | $K^+$(mg/l) | | $Na^+$(mg/l) | | $Ca^{+2}$(mg/l) | | $Mg^{+2}$(mg/l) | |
|---|---|---|---|---|---|---|---|---|
| | Before | After | Before | After | Before | After | Before | After |
| A | N/A | N/A | 11.5 | 0.11 | 128.3 | 5.8 | 69.11 | 2.2 |
| B | N/A | N/A | 11.7 | 0.13 | 122 | 6.8 | 58.6 | 3.2 |
| C | N/A | N/A | 14.5 | 0.1 | 147.7 | 6.6 | 30.8 | 4.2 |
| D | 0.48 | 0.23 | 17.0 | 0.0 | 64.1 | 5.5 | 44.9 | 4.3 |

**Note:** A= Refinery well (1), B= Refinery well (2), C= Refinery well (3), D= Bara Basin water

### 3.2.7. Anionic composition

#### 3.2.7.1. Fluoride

The WHO recommended value for Fluoride 0.7-1.2 mg/l. The high concentration of Fluoride due to weathering and circulation of water in rocks and soils, Fluorine is leached out and dissolves in ground water. Fluoride content of the groundwater samples ranges from 0.76 to 0.88 mg/l before treatment and 0.25mg to 0.48mg/l after treatment almost all samples within the permissible.

#### 3.2.7.2. Chloride

Chloride is important in detecting the contamination of groundwater. Its concentration increase rates of corrosion of metals in the distribution system. The permissible limits of chloride in drinking water is 250 mg/l. Chloride content of groundwater samples ranges from 36.3 to 166 mg/l before treatment and 16.3 to 66.7 mg/l after treatment almost all samples are within the permissible range.

#### 3.2.7.3. Sulphate

Sulphate occurs naturally in water as a result of leaching of gypsum and other common minerals. The permissible limits of Sulphate is 250 mg/l prescribed by WHO and SSMO. The Sulphate concentration was observed between 42 to 102 mg/l before treatment and 17 to 46 mg/l after treatment. That means all samples within acceptable limits.

#### 3.2.7.4. Nitrate

The permissible limits of Nitrate is 50 mg/l prescribed by WHO. The Nitrate concentration was observed between 0.75 mg/l to 24.4 mg/l before treatment and 0.22 mg/l to 3.7 mg/l after treatment. That means all samples within acceptable limits of WHO and SSMO.

#### 3.2.7.5. Nitrite

The permissible limits of Nitrite is 3.0 mg/l prescribed by WHO. The Nitrite concentration was observed between 0.00 to 1.36 mg/l before treatment and 0.00 to 0.32mg/l after treatment. That means all samples within acceptable limits WHO and SSMO.

#### 3.2.7.6. Phosphate

The permissible limit of Phosphate is 0.3mg/l prescribed by WHO. The Phosphate concentration was observed between 0.20 to 3.92 mg/l before treatment and 0.00 to 0.87 mg/l after treatment. Most samples within acceptable limit of WHO. With exception of Refinery well C. Phosphates in groundwater can have both beneficial and detrimental effects. On one hand, they can be essential nutrients for plant life and play a role in controlling the release of metals in drinking water systems. However, excessive phosphates can lead to eutrophication of surface water bodies, harming aquatic ecosystems.

**Table 6: Anionic Composition of Elobeid Petroleum Refinery feed water.**

| S.No | $F^-$ | | $Cl^-$ | | $SO_4^{-2}$ | | $NO_3^-$ | | $NO_2^-$ | | $PO_4^{-3}$ | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Before | After | Before | After | Before | After | Before | After | Before | After | Before | After |
| A | 0.82 | 0.35 | 166 | 16.3 | 82 | 17 | 0.75 | 0.22 | 0.07 | 0.0 | 0.20 | 0.0 |
| B | 0.77 | 0.29 | 36.3 | 18.6 | 102 | 21.0 | 3.0 | 0.7 | 0.00 | 0.0 | 0.20 | 0.0 |
| C | 0.88 | 0.25 | 161. | 28.2 | 42 | 17 | 24.4 | 3.7 | 0.06 | 0.0 | 3.92 | 0.87 |
| D | 0.76 | 0.48 | 102 | 66.7 | 72.0 | 46.0 | 6.6 | 1.2 | 1.36 | 0.32 | 0.32 | 0.22 |

**Note:** A= Refinery well (1), B= Refinery well (2), C= Refinery well (3), D= Bara Basin

### 3.2.7.7. Heavy Metals in Bara Basin Water

The measured concentrations of heavy metals; Barium (Ba), Manganese (Mn), Copper (Cu), Zinc (Zn) and Chromium (Cr) were (0.13, 0.01, 0.03, 0.01 and 0.006) within acceptable limits of WHO 0.13, 0.08, 2.0, 4.0 and 0.05 respectively. With exception of Nickel (Ni), Cadmium (Cd) and Lead (Pb) were (0.24, 0.02 and 0.27) higher than the permissible limit of WHO 0.07, 0.003 and 0.01 respectively.

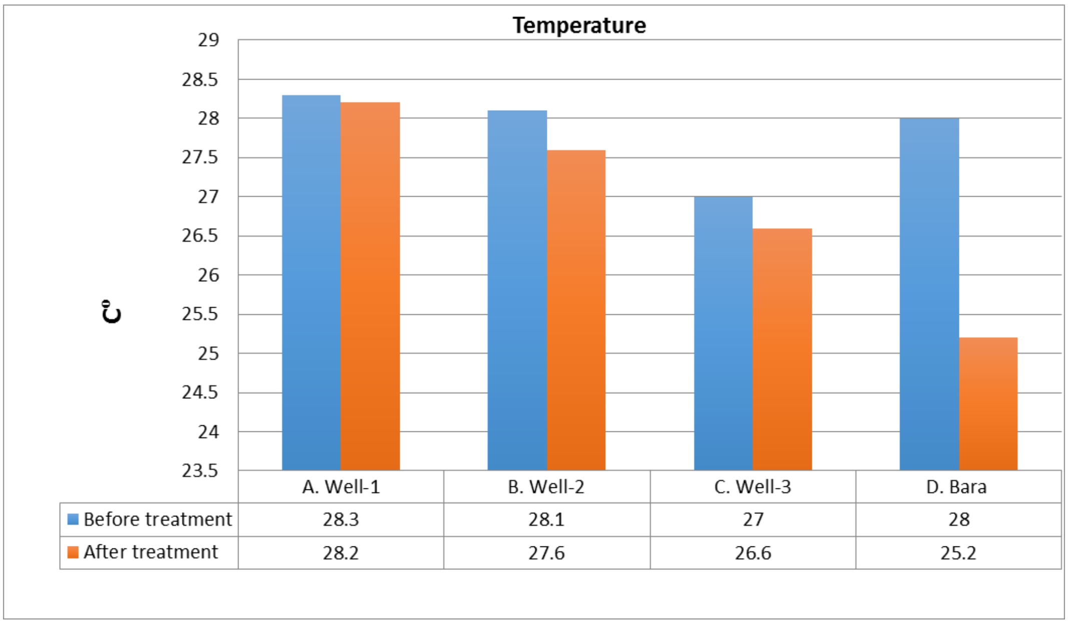


**Figure 1: Temperature of Elobeid Petroleum Refinery feed water.**

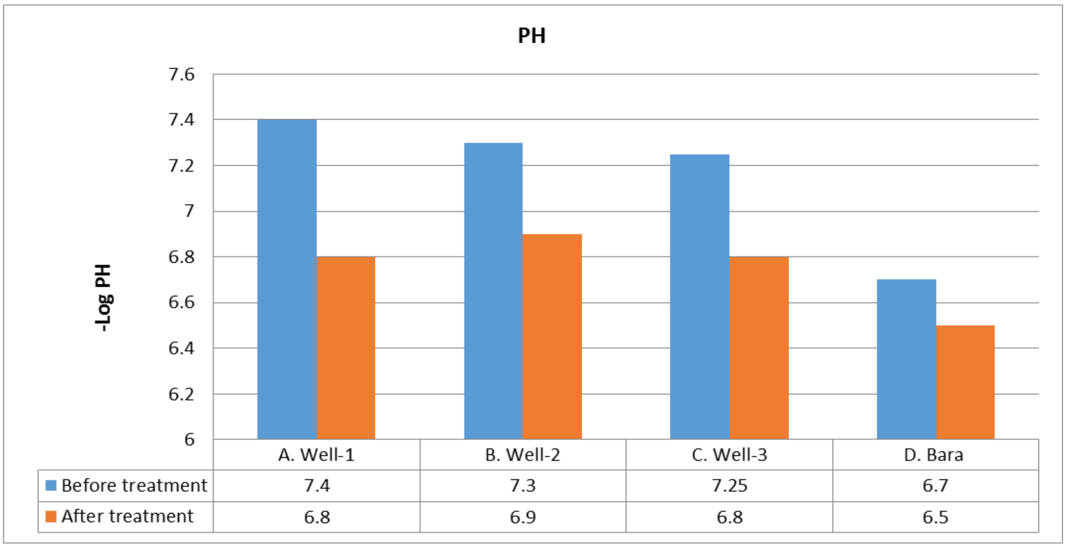


**Figure 2: PH of Elobeid Petroleum Refinery feed water.**

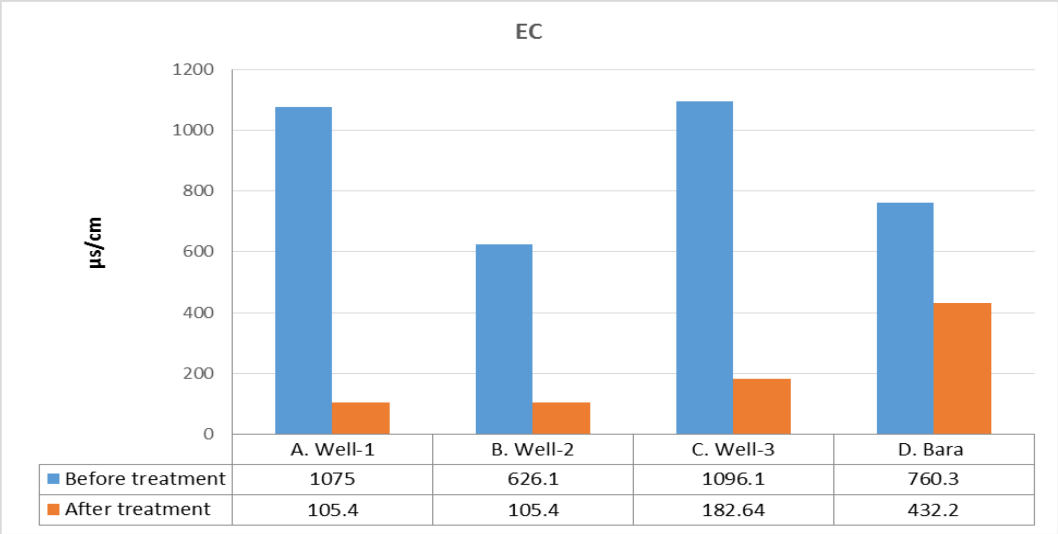


**Figure 3: EC of Elobeid Petroleum Refinery feed water.**

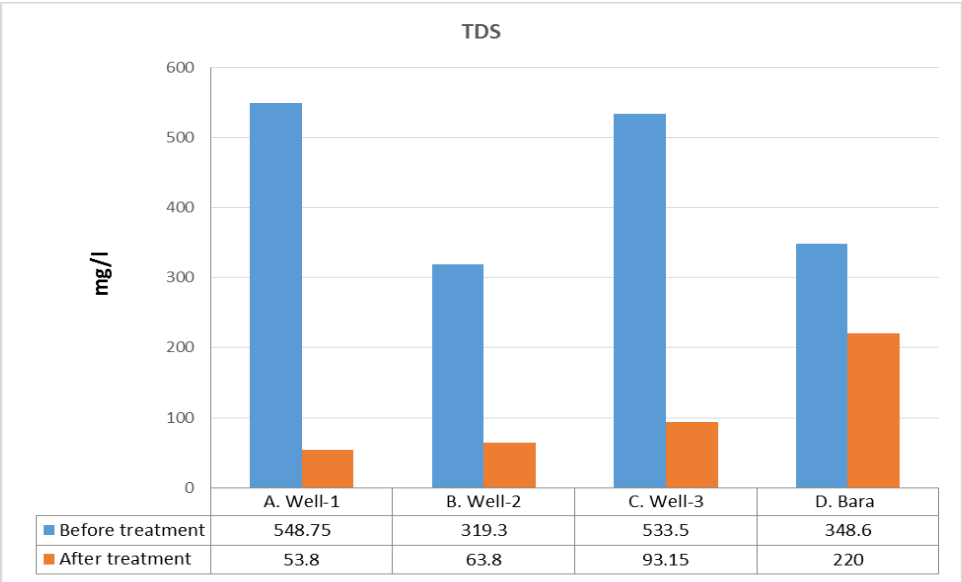


**Figure 4: TDS of Elobeid Petroleum Refinery feed water.**

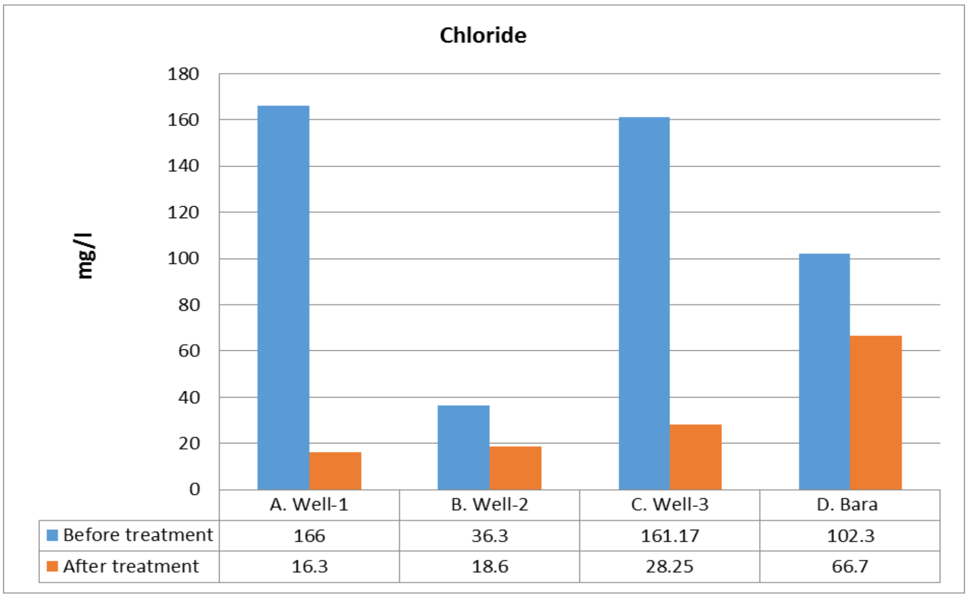


**Figure 5: Chloride of Elobeid Petroleum Refinery feed water.**

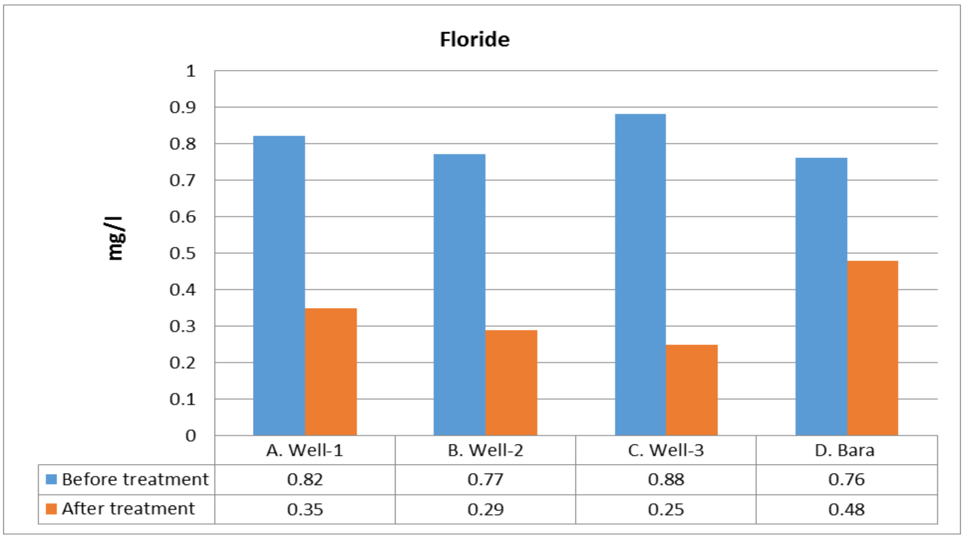


**Figure 6: Floride of Elobeid Petroleum Refinery feed water.**

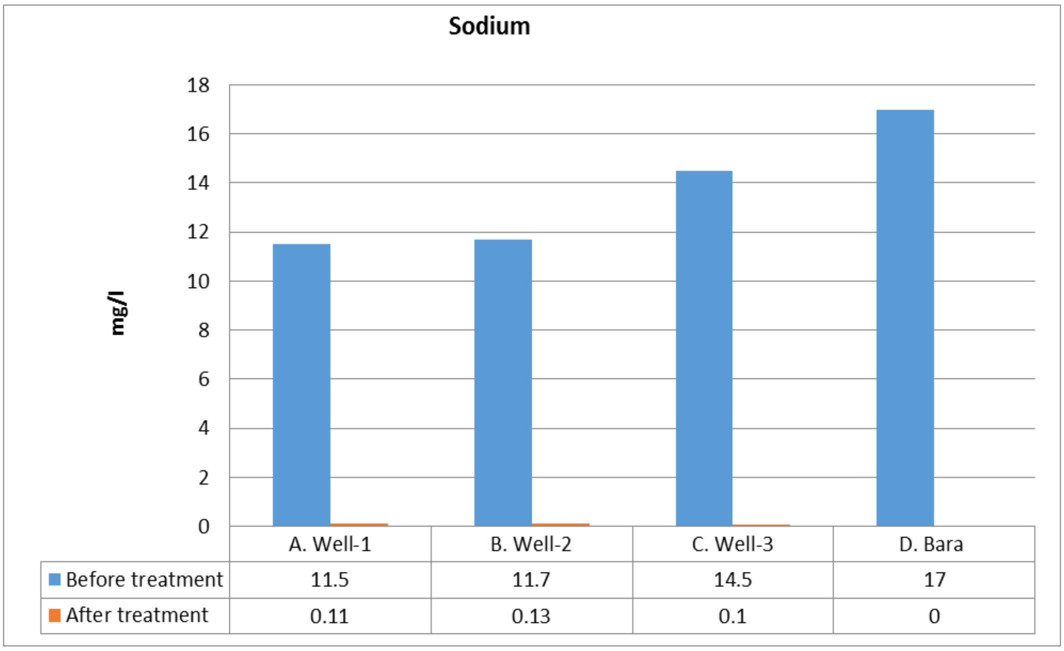


**Figure 7: Sodium of Elobeid Petroleum Refinery feed water.**

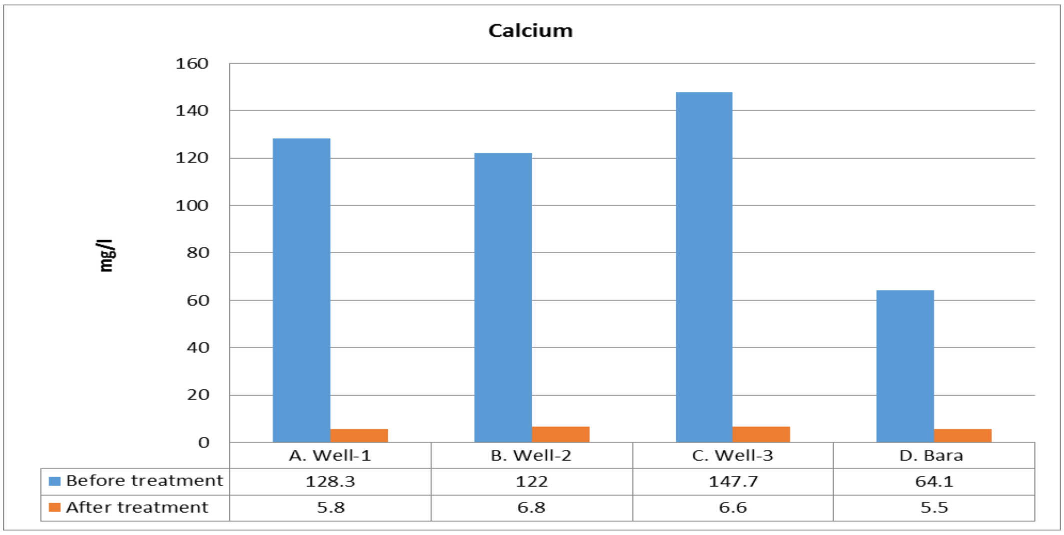


**Figure 8: Calcium of Elobeid Petroleum Refinery feed water.**

## CONCLUSION

The analysis and treatment process applied to Elobeid Petroleum Refinery feed water was effective for most quality parameters such as temperature, pH, electrical conductivity, total dissolved solids, total hardness, total alkalinity, total iron, total suspend solid, total solid, major ions and heavy metals. All samples, after treatment, within limits of WHO and SSMO standards. However, the persistent treatment and removal of hazardous heavy metals such as nickel, cadmium, and lead particularly in Bara Basin water is necessary. Further monitoring and extended treatment strategies are essential to ensure the safety of feed water used in petroleum refining processes, safeguard environmental integrity, and protect public health.

## ACKNOWLEDGEMENTS

Authors are thankful to the staff of the Department of Chemistry Faculty of Science University of Kordofan Sudan for their help and advice also our thanks extended to directorate of Elobeid Petroleum Refinery Company for support.

### Conflict of interests

All authors declare that they have no conflict of interest.

## REFERENCES

1. USGS. (2019). How Important Is Groundwater? *[Online]. Available at:https://www.usgs.gov/faqs/how-important-groundwater?qt-Newsscience-products=0#qt-news-science-products [Accessed 11 Jul. 2019]*.
2. Ahmad, M., Bastiaanssen, W.G. and Feddes, R. Sustainable use of groundwater for irrigation: A numerical analysis of the subsoil water fluxes. *Irrigation and Drainage: The Journal of the International Commission on Irrigation and Drainage*, 2002; 51: 227-241. https://doi.org/10.1002/ird.57
3. Avtar, R., Kharrazi, A. Exploring Renewable Energy Resources Using Remote Sensing and GIS-A Review. *Resources*, 2019; 8(3): 149. https://doi.org/10.3390/resources8030149
4. Avtar, R., Tripathi, S. and Aggarwal, A.K. Population-Urbanization-Energy Nexus: A Review. *Resources*, 2019; 8(3): 136. https://doi.org/10.3390/resources8030136
5. Avtar, R., Tripathi, S. and Kumar Aggarwal, A. Assessment of Energy–Population–Urbanization Nexus with Changing Energy Industry Scenario in India. *Land*, 2019; 8(8): 124. https://doi.org/10.3390/l and 8080124
6. Le, N.K., Jha, K.M., Jeong, J., Gassman, W.P., Reyes, R.M., Doro, L., Tran, Q.D. and Hok, L. Evaluation of Long-Term SOC and Crop Productivity within Conservation Systems Using GFDL CM2.1 and EPIC. *Sustainability*, 2018; 10(7): 2665. https://doi.org/10.3390/su10072665
7. Minh, H.V.T., Avtar, R., Kumar, P., Tran, D.Q., Ty, T.V., Behera, H.C. and Kurasaki, M. Groundwater Quality Assessment Using Fuzzy-AHP in An Giang Province of Vietnam. *Geosciences*, 2019; 9(7): 330. https://doi.org/10.3390/geosciences9070330
8. Minh, H.V.T., Kurasaki, M., Van Ty, T., Tran, D.Q., Le, K.N., Avtar, R., Rahman, M. and Osaki, M. Effects of Multi-Dike Protection Systems on Surface Water Quality in the Vietnamese Mekong Delta. *Water*, 2019; 11(5): 1010. https://doi.org/10.3390/w11051010
9. Neisi, A., Mirzabeygi Radfard, M., Zeyduni, G., Hamzezadeh, A., Jalili, D., Abbasnia, A., Yousefi, M. and Khodadadi, R. Data on fluoride concentration levels in cold and warm season in City area of Sistan and Baluchistan Province, Iran. *Data in Brief*, 2018; 18: 713-718. https://doi.org/10.1016/j.dib. 2018.03.083
10. Zahedi, S. Modification of expected conflicts between Drinking Water Quality Index and Irrigation Water Quality Index in water quality ranking of shared extraction wells using Multi Criteria Decision Making techniques. *Ecological Indicators*, 2017; 83: 368-379. https://doi.org/10.1016/j.ecolind. 2017.08.018
11. Nath S; Nafees, M. and Wani, A.M. Assessment of ground water quality at different sites Bara Tehsil, Allahabad, UP, International Journal of Farm Sciences, 2015; 5(1): 163-167.