Libyan Journal of Ecological & Environmental Sciences and Technology
(LJEEST)

LJEEST
ISSN: 2710-5237
www.srcest.org.ly/jou

DOI: HTTPS://DOI.ORG/10.63359/03TAXV67

Assessment of Quality Parameters of Industrial and Wastewater in Various Systems at Elobeid Petroleum Refinery

Mohammed Bahreldin Hussein[1*] Abdelhameid Abdelkareim Jobara[2], Abdalla Gobara Habieballa [3], Hamouda Adam Hamouda[1] and Awad Mohammed Babeker[4] and Awad Salim Ibrahim Holy[5]

ARTICLE INFO

Vol. 8 No. 2 August, 2026

Pages (45-50)

Article history:
Revised form 19 May 2026
Accepted 30 May 2026

Authors affiliation
[1]Department of Chemistry, Faculty of Science, University of Kordofan, Elobeid, 51111, Sudan
[2]Elobeid Petroleum Refinery Company, Elobeid, North Kordofan State-Sudan
[3]Department of Chemistry, Faculty of Education, Dalanj University, Dalanj, 53312 Sudan
[4]Department of Food Sciences and Technology, Faculty of Natural Resources and Environmental Studies, University of Kordofan, Elobeid, Sudan
[5]Department of Chemistry, Faculty of Education, West Kordofan University, El-Nuhud, 55511, Sudan
email@mail.com
Email: mohammedbahr66@gmail.com
Email:wadgobara35@gmail.com

Keywords:
Physicochemical Analysis, Quality Parameters, Boiler, Cooling and Waste Water.

ABSTRACT

This study aimed to assessment the quality parameters in industrial and waste water in various systems at Elobeid Petroleum Refinery *viz*; (Boiler, Cooling tower and Industrial waste water). All samples were collected during the period (December 2024-January 2025). The water samples were analyzed in the laboratories of Elobeid Petroleum Refinery. The instruments used in analysis include: Atomic Absorption Spectrophotometer, EC/TDS/T auto-ranging Bench meter, pH meter and ORP meter, Spectrophotometer (Hach USA DR/3900), DR/4000 and DR/6000, Reactor (Hach DRB200) and BOD Incubator. The parameters were assessed according to the national and international guidelines. The procedure was made to determine the characteristics of water conform or differ from the standard specification for manufacturing purposes, as well as to verify the effectiveness of the treating procedures to achieve these specifications. Boilers water was found suitable for low and medium-pressure systems, but it exceeds the limits of chloride (64.6 mg/l), total iron (0.16 mg/l), total hardness (8.8 mg/l), phosphate (0.27 mg/l) and dissolved oxygen (2.5 mg/l) under high-pressure conditions, posing risks of corrosion and scaling. Other parameters for this water such as TH, TDS and Total Alkalinity (TA) were found within the acceptable limits of American Society of Mechanical Engineers (ASME). Cooling tower water generally met General Services Administration (GSA) specifications, although high total alkalinity (255 mg/l) may promote carbonate scaling. Industrial wastewater was largely within Environmental Protection Agency (EPA) limits as Biological Oxygen Demand (BOD5), Chemical oxygen demand (COD), Total Organic Carbon (TOC), Phenols and Oil and Grease within acceptable limits of (EPA) with only a slight exceedance in TDS (510 mg/l). In conclusion the treatment processes for the refinery water are effective, but some of them were such as heavy metals removal, corrosion control, and high-pressure boiler water conditioning require further optimization. The study recommends: regular monitoring and advanced treatment interventions to ensure long-term compliance and environmental sustainability, adopting a comprehensive asset integrity risk management program, linking equipment risks to water quality parameters (chloride, iron, DO, and alkalinity), and identifying key performance indicators.

تقييم معايير جودة المياه الصناعية ومياه الصرف في الأنظمة المختلفة لمصفاة الابيض للبترول

محمد بحرالدين حسين [1*]، عبدالحميد عبدالكريم [1]، عبدالله جباره حبيب الله [3]، حمودة ادم حمودة [4]، عوض محمد بابكر [5]، عوض سالم حولى [6]

هدفت هذه الدراسة إلى تقييم معايير جودة المياه الصناعية ومياه الصرف الصحي في مختلف أنظمة مصفاة الابيض للبترول، وهي: (الغلايات، وأبراج التبريد، ومياه الصرف الصناعي). جُمعت جميع العينات خلال الفترة (ديسمبر 2024 – يناير 2025). تم تحليل عينات المياه في مختبرات مصفاة الابيض للبترول. وشملت الأجهزة المستخدمة في التحليل: مطياف الامتصاص الذري، وجهاز

قياس التوصيل الكهربائي، إجمالي المواد الصلبة الذائبة، الدرجة الكلية (EC/TDS/T) ذو النطاق التلقائي، وجهاز قياس الرقم الهيدروجيني(pH) ، وجهاز قياس جهد الأكسدة والاختزال(ORP) ، ومطياف ضوئي(Hach USA DR/3900 ، DR/4000، و(DR/6000، ومفاعل Hach DRB200)، وحاضنة الأكسجين الحيوي المستهلك .(BOD) وقُيّمت المعايير وفقًا للإرشادات الوطنية والدولية. تم اتباع الإجراءات لتحديد ما إذا كانت خصائص المياه مطابقة أو مختلفة عن المواصفات القياسية لأغراض التصنيع، بالإضافة إلى التحقق من فعالية إجراءات المعالجة لتحقيق هذه المواصفات. وُجد أن مياه الغلايات مناسبة لأنظمة الضغط المنخفض والمتوسط، إلا أنها تتجاوز الحدود المسموح بها للكلوريد (64.6 ملغم/لتر)، والحديد الكلي (0.16 ملغم/لتر)، والعسر الكلي (8.8 ملغم/لتر)، والفوسفات (0.27 ملغم/لتر)، والأكسجين المذاب (2.5 ملغم/لتر) في ظروف الضغط العالي، مما يُشكل مخاطر التآكل والترسبات. أما المعايير الأخرى لهذه المياه، مثل العسر الكلي، والمواد الصلبة الذائبة الكلية، والقلوية الكلية، فقد وُجدت ضمن الحدود المقبولة وفقًا لمعايير الجمعية الأمريكية للمهندسين الميكانيكيين (ASME)وبشكل عام، تُلبي مياه أبراج التبريد مواصفات إدارة الخدمات العامة (GSA) ، على الرغم من أن ارتفاع القلوية الكلية (255 ملغم/لتر) قد يُعزز تكوّن الترسبات الكربوناتية. كانت مياه الصرف الصناعي ضمن الحدود المسموح بها من قبل وكالة حماية البيئة الأمريكية (EPA) إلى حد كبير، حيث كانت قيم الطلب البيولوجي على الأكسجين (BOD5)، والطلب الكيميائي على الأكسجين(COD)، والكربون العضوي الكلي(TOC) ، والفينولات، والزيوت والشحوم ضمن الحدود المقبولة، مع تجاوز طفيف فقط في إجمالي المواد الصلبة الذائبة (510 ملغم/لتر). وخلصت الدراسة إلى أن عمليات معالجة مياه المصفاة فعالة، إلا أن بعضها، مثل إزالة المعادن الثقيلة، ومكافحة التآكل، ومعالجة مياه الغلايات عالية الضغط، يتطلب مزيدًا من التحسين. وتوصي الدراسة بما يلي: المراقبة الدورية وتدخلات المعالجة المتقدمة لضمان الامتثال طويل الأجل والاستدامة البيئية، واعتماد برنامج شامل لإدارة مخاطر سلامة الأصول، وربط مخاطر المعدات بمعايير جودة المياه (الكلوريد، والحديد، والأكسجين المذاب، والقلوية)، وتحديد مؤشرات الأداء الرئيسية.

INTRODUCTION

Water possesses a greater heat capacity than most other materials. This characteristic renders it an excellent raw material for boiler operations. Unlike open systems found in gas turbines, boilers operate within a closed system. Consequently, the water is recalculated throughout the system and remains isolated from the atmosphere. The water is reused and requires treatment to maintain efficient operations. Treatment of boiler water is essential for effective steam production. It is treated to avert scaling, corrosion, foaming, and priming. Boiler feed water plays a crucial role in boiler operations. The boiler water must maintain an alkaline pH rather than an acidic one to prevent damage to the tubes. Excessive conductivity in the feed water can occur when there are too many dissolved solids. These necessary treatments can be managed by a skilled operator and the appropriate use of treatment chemicals (Mischissin, 2012 ; Shokre, 2023; Inyang and Olughu 2025). To facilitate heat transmission, a portion of the water evaporates, absorbing latent heat and resulting in the cooling of the remaining water. This phenomenon is referred to as heat transfer. After the water cools, it is recalculated back into the process, allowing the cycle to continue (Milosavljevic and Heikkilä, 2007). The oil and gas industry is a vast and intricate sector, with its operations consuming and producing substantial amounts of water, leading to the generation of considerable quantities of petroleum wastewaters (PWWs) (Elmobarak et al., 2021). The energy sector's water usage may differ based on the fuel type, extraction technique, processing level, and the climate of the area being developed, as well as the available water resources (Eldos et al., 2022). PWWs originate from production activities such as vapour condensation, spent caustic, and process water. Furthermore, they can also arise from cooling towers, surface runoff, or spilled petroleum products (Ali et al., 2020). These various types of PWWs may be either combined or separated during treatment processes, depending on the water management strategies employed (Ali et al., 2021). The sources of water can differ in their components and characteristics. Typically, PWWs produced by refineries are highly concentrated with hydrocarbons and other primary constituents of petroleum. Nevertheless, the quantity and quality of the various types of PWWs depend on factors such as time, location, human activities, and governmental laws and regulations (Alsheyab and Kusch-Brandt, 2018). As a result, the composition and quantity of hazardous pollutants in PWWs can significantly fluctuate based on operational practices, the type and efficiency of treatment and processing equipment, and the regulatory protocols implemented to minimize waste (Jafarinejad, 2017). Characterizing the parameters of PWWs is essential for identifying management alternatives within the petroleum industry, facilitating the design of optimal collection and treatment practices reuse options, and environmental management strategies. Moreover, this information is valuable for conducting further investigations into the environmental impact of industrial wastewater and its contamination characteristics, including emerging pollutants and their toxicity (Al-haddad, et al., 2021), and Jafarinejad, 2017). In this study, three samples of industrial water were collected from the Elobeid petroleum refinery system: Boiler, Cooling tower and wastewater.

MATERIALS AND METHODS

1. Sample collection

Three samples of industrial water were obtained from the Elobeid petroleum refinery system: Boiler, Cooling Tower, and Industrial Waste Water, for the purpose of determining certain inorganic constituents and quality parameters. All samples were stored in dry, clean plastic containers and labeled with the relevant sample information.

2. Methods of analysis

The water samples were examined at the laboratory of the Elobeid petroleum refinery. A comprehensive analysis of the physic-chemical, organic, and biological properties was conducted for various water quality parameters, including Temperature, pH, Electrical Conductivity (EC), Total Dissolved Solids (TDS), Total Hardness (TH), Total Iron (TI), Total Suspended Solids (TSS), Total Solids (TS), as well as major cation such as Calcium ($Ca^{2+)}$ and Magnesium (Mg^{2+}), and anions including Chloride (Cl^{-}), Sulfate (SO_4^{2-}), Sulfite (SO_3^{2-}), Sulfide (S^{2-}), and Phosphate (PO_4^{3-}). Additionally, parameters such as Turbidity, Ammonia, Dissolved Oxygen, Biological Oxygen Demand (BOD), Total Organic Carbon (TOC), Chemical Oxygen Demand (COD), Oil & Grease, and Total Aerobic Bacteria were assessed using standard water examination procedures established by APHA and HACH, Standard methods (Table 1).

(Table 1). Standard methods for water analysis

STAM Method	Parameters	ASTM Method	Parameters
APHA 4500	pH	HACH 8226	Mg^{2+}mg/l
APHA 2510	EC µs/cm	HACH 8221	M.V mg/l
HACH 8207	TDS mg/l	HACH 8237	Turbidity mg/l
HACH 8006	TSS mg/l	HACH 8166	D.O mg/l
HACH 8008	T.I mg/l	APHA 5210 D	BOD_5 mg/l
HACH 8226	T.H mg/l	HACH 10173	TOC mg/l
HACH 8113	Cl^- mg/l	HACH 8000	COD mg/l
HACH 8151	$SO4^{2-}$mg/l	HACH 8155	NH3 mg/l
Colorimetric	S^{2-} mg/l	HACH Paddle Tester	Total Aerobic Bacteria CFU
HACH 8048	$PO4^{3-}$mg/l	HACH 8047	Phenols
HACH 8226	Ca^{2+}mg/l	EPA 1664	Oil & Grease

APHA: American Public Health Association, **HACH**: Company responsible for water quality
ASTM: American Society for Testing and Materials

RESULTS AND DISCUSSION

1. Results

The result of physical and chemical parameters obtained from the analysis of water samples are shown in (Table 2).

Table (2) Physiochemical properties of Elobeid Petroleum Refinery water

Parameters	**Boilers water**	**Cooling water**	**Waste water**
pH	9.2	8.6	8.4
EC µs/cm	411.0	609.8	1000.0
TDS mg/l	201.5	311.0	510.0
TSS mg/l	0.0	0.0	4.5
T.I mg/l	0.16	0.20	ND
T.H mg/l	8.8	ND	ND
Cl^- mg/l	64.6	93.72	ND
SO_3^{2-} mg/l	6.63	ND	ND
SO_4^{2-} mg/l	ND	0.0	ND
PO_4^{3-} mg/l	0.27	0.15	3.1
Ca^{2+} mg/l	6.0	128.5	ND
Mg^{2+} mg/l	2.8	56.7	ND
SiO_2 mg/l	0.25	0.11	ND
D.O mg/l	2.5	ND	5.8
M.V mg/l	ND	255	ND

ND=Not Detected

Table (3) Some Physiochemical properties of Elobeid Petroleum Refinery Wastewater

Parameters	Results	Parameters	Results
Temp°C	21.0	S^{2-} mg/l	0.03
Turbidity mg/l	5.5	NH_3 mg/l	0.025
BOD5 mg/l	42.55	Total Aerobic Bacteria CFU	<100
TOC mg/l	21.2	Phenols mg/l	0.028
COD mg/l	48.0	Oil & Grease mg/l	0.25

2. Discussions

The procedure was conducted to assess whether the characteristics of water align with or deviate from the standard specifications required for manufacturing purposes, in addition to evaluating the effectiveness of the treatment processes in meeting these specifications. The water used in boilers was deemed appropriate for low and medium-pressure systems; however, it surpassed the permissible limits for chloride (64.6), total iron (0.16 mg/l), total hardness (8.8 mg/l), phosphate (0.27 mg/l), and dissolved oxygen (2.5 mg/l), all of which were found to exceed the acceptable thresholds for boiler water.

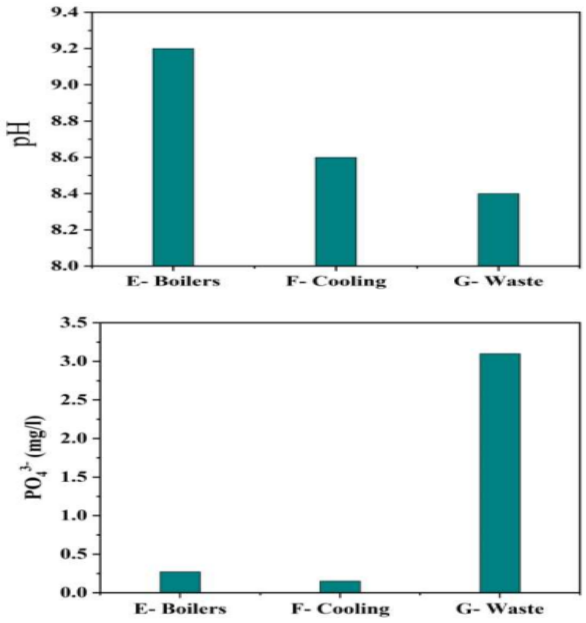

Figure 1. pH and PO_4^{3-} of Elobeid Petroleum Refinery Industrial waste water

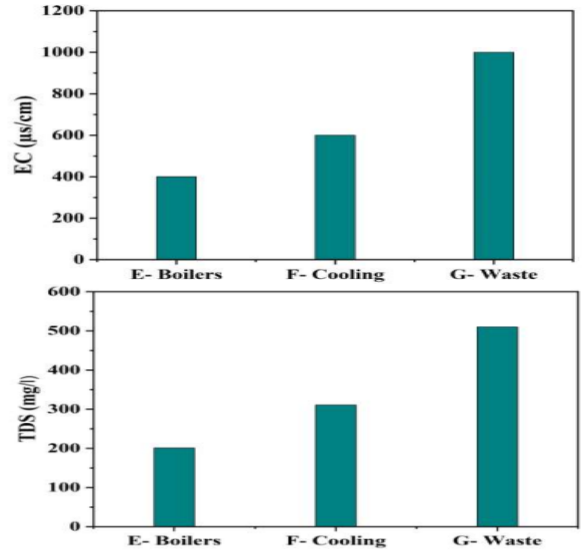

Figure 2. EC and TDS of Elobeid Petroleum Refinery Industrial waste water

Furthermore, the electrical conductivity (411.0 mg/l) and dissolved oxygen (2.5 mg/l) under high-pressure conditions also exceeded permissible limits, potentially leading to risks of corrosion and scaling. Other parameters for boiler water, including pH, TDS, Total Alkalinity (TA), Sulfide (S^{2-}), Silica, Calcium, and Magnesium, remained within acceptable limits. The water from cooling towers generally complied with GSA specifications, although the elevated total alkalinity (255 mg/l) could encourage carbonate scaling. Industrial wastewater was predominantly within EPA limits for Biological Oxygen Demand (BOD5), Chemical Oxygen Demand (COD), Total Organic Carbon (TOC), Phenols, and Oil and Grease; however, TDS (510 mg/l) was slightly above the acceptable limits.

The processes involved in treating refinery water are efficient; however, certain aspects, including corrosion control and high-pressure boiler water conditioning, necessitate additional optimization. Furthermore, ongoing monitoring and evaluation of the quality parameters may be required to tackle potential issues arising from the presence of these elevated parameters.

CONCLUSION

The current study conducted to assess the water quality parameters of the Elobeid Petroleum Refinery's water systems, which include boiler water, cooling tower water, and industrial wastewater, illustrates the success of treatment processes in enhancing water quality across various parameters. Boiler Water (E) largely complies with ASME standards for low and medium pressure boilers. Nevertheless, certain parameters such as chloride, total iron, dissolved oxygen, and minor levels of calcium and magnesium surpass the permissible limits for high-pressure boilers. These exceedances present risks including corrosion, scaling, and inefficiencies within the system. Continuous monitoring and effective treatment are essential. Cooling Tower Water (F) meets the General Services Administration (GSA) standards for most parameters, including pH, TDS, EC, total hardness, calcium, and magnesium. However, the elevated total alkalinity may lead to scaling and instability in pH levels. It is advisable to implement regular blow down, water softening, and alkalinity control to maintain optimal performance of the cooling system. Industrial Wastewater (G) indicates that the treated industrial effluent adheres to the majority of U.S. EPA standards, including acceptable levels of BOD_5, COD, phenols, oil and grease, sulfides, and ammonia. A slight exceedance in TDS (510 mg/l) indicates moderate salinity, which could impact the long-term suitability for discharge. The low microbial load and turbidity levels suggest effective pre-discharge treatment. However, ongoing efforts to reduce organic load and control heavy metals are crucial for environmental compliance. Nonetheless, persistent vigilance is required, especially in managing corrosion risks in boilers, preventing heavy metal contamination in groundwater utilized as feed water, and optimizing wastewater treatment to ensure environmental sustainability and adherence to regulatory standards.

RECOMMENDATIONS:

The study suggests: consistent monitoring and enhanced treatment strategies to guarantee long-term adherence and environmental sustainability, implementing a thorough asset integrity risk management program, correlating equipment risks with water quality indicators (chloride,

iron, DO, and alkalinity), and determining key performance indicators.

Acknowledgments

The authors express their gratitude and recognition to the director of Elobeid Petroleum Refinery for their support and encouragement. This research did not receive any specific funding from public, commercial, or non-profit organizations.

Authors Contributions:

Mohammed Bahreldin: Developed, organized, guided, and contributed significantly to various sections to enhance clarity and precision. Abaelhamid: Performed the laboratory experiments. Abdalla, Hamouda, and Awad: Reviewed the final manuscript.

Conflicts of Interest:

The authors declare that there are no conflicts of interest related to this article.

ORCID

https://orcid.org/0000-0002-1919-6176.
(Mohammed Bahreldin Hussein)
https://orcid.org/0009-0006-6725-0946
(Abdelhameid Abdelkareim Jobara)
https://orcid.org/0000-0002-8770-0936
(Abdalla Gobara Habieballa)
https://orcid.org/0000-0002-6967-7269
(Hamouda Adam Hamouda)
https://orcid.org/0009-0000-9838-381X
(Awad Mohammed Babeker)

REFERENCES

Mischissin. S. G. (2012). "University of Rochester - Investigation of Steam Turbine Extraction Line Failures" (PDF). Ar lington, VA. pp. 25–26

Shokre, A. (2023). "Principles, operational challenges, and perspectives in boiler feed-water treatment process". Environmental Advances. 48.

Inyang, U.E and C.O Olughu, (2025), The importance of boiler feed water and its treatment in a chemical plantWorld Journal of Advanced Research and Reviews, 27(01), 1624-

Milosavljevic, S. and P. Heikkilä, (2007) A comprehensive approach to cooling tower design," Appl. Therm. Eng., vol. 27,no. 3, pp. 374-379.

Elmobarak, W.F. B.H. Hameed, F. Almomani, A.Z. Abdullah, (2021), A review on the treatment of petroleum refinery wastewater using advanced oxidation processes, Catalysts 11 (7) 782, https://doi.org/10.3390/catal11070782

Eldos, H. I, K. Mariam, Z. Nabil, S. Suhur, M. A. Al-Ghouti, (2022), Characterization and assessment of process water from oil and gas production: A case study of process wastewater in Qatar.Case Studies in Chemical and Environmental Engineering 6 100210.https://doi.org/10.1016/j.cscee.2022.100210

Ali, N. M. Bilal, A. Khan, F. Ali, H.M. Iqbal, (2020), Effective exploitation of anionic, nonionic, and nanoparticle-stabilized surfactant foams for petroleum hydrocarbon contaminated soil remediation, Sci. Total Environ. 704 135391.

Ali, N., E.L. Gyllye, C. Duanmu, Y. Yang, A. Khan, F. Ali, H. Iqbal, (2021), Robust bioinspired surfaces and their exploitation for petroleum hydrocarbon remediation, Environ. Sci. Pollut. Control Ser. 1–15.

Alsheyab, M. S. Kusch-Brandt, (2018), Potential recovery assessment of the embodied resources in Qatar's wastewater, Sustainability 10 (9) 3055, https://doi.org/10.3390/su10093055.

Jafarinejad, S. (2017), Environmental impacts of the petroleum industry, protection options, and regulations, in: Petroleum Waste Treatment and Pollution Control, Elsevier, pp. 85–116, https://doi.org/10.1016/B978-0-12-809243-9.00003-1.

Al-haddad, A. M.E. Ahmed, H. Abdullah, R. Al-Yaseen, (2021), Anomalies in industrial wastewater quality data in Kuwait, Data Brief 35 106945, https://doi.org/ 10.1016/j.dib.2021.106945.

Jafarinejad, S. (2017), Pollution and wastes from the petroleum industry, in: Petroleum Waste Treatment and Pollution Control, Elsevier, pp. 19–83, https://doi.org/10.1016/B978-0-12-809243-9.00002-X.6/B978-0-12-809243-9.00002-X.

Appendixes:

Table (4) Specification of Boilers water

Parameters	ASME-LP (<300 psi)	ASME-MP (300–900 psi)	ASME-HP (>900 psi)
PH	10.5 – 11.5	10.5 – 11.5	9.0 – 11.0
TDS mg/l	< 3000 ppm	< 1000 ppm	< 500 ppm
Cl^- mg/l	< 200 ppm	< 50 ppm	< 10 ppm
EC µs/cm	<2000µS/cm	< 1000 µS/cm	< 100 µS/cm
T.H mg/l	0.0	0.0	0.0
Ca^{2+} mg/l	0.0	0.0	0.0
Mg^{2+} mg/l	0.0	0.0	0.0
T.I mg/l	< 0.1 ppm	< 0.05 ppm	< 0.01 ppm
TSS mg/l	10 – 15	10 – 15	10 – 15
SO_3^{2-} mg/l	20–40	20- 10	5.0
PO_4^{3-} mg/l	20 -60	20 – 60	N/A
SiO_2 mg/l	< 150 ppm	< 20 ppm	< 10 ppm
D.O mg/l	< 0.007 ppm	< 0.007 ppm	< 0.005 ppm

I. ASME: The American Society of Mechanical Engineers

Table (5) Specification of Cooling Tower water GSA General Services Administration

Parameters	GSA	Parameters	GSA
pH	7.3 – 9	Mg^{2+} mg/l	30-120
TDS mg/l	300-1200	SO_4^{2-} mg/l	<250
Cl^- mg/l	10 – 500	T.I mg/l	<4
E.C µs/cm	<2400	T.S.S mg/l	<10
T.H mg/l	500 – 1500	PO_4^{2-} mg/l	2-35
Ca^{2+} mg/l	80-240	SiO_2 mg/l	<150
M.V mg/l	70-180		

Table (6) Specification of Industrial Wastewater

Parameters	EPA-USA	Parameters	EPA-USA
Temp°C	<40	BOD5 mg/l	<50
pH	6-9	TOC mg/l	<30
TDS mg/l	500.0	COD mg/l	<100
EC µs/cm	2,500	S^{2-} mg/l	1.0
TSS mg/l	<100	NH_3 mg/l	<50
PO_4^{3-} mg/l	< 10	Total Aerobic Bacteria CFU	< 1000 CFU
D.O mg/l	N/A	Phenols mg/l	1.0
Turbidity mg/l	<100	Oil & Grease mg/l	<10

EPA-USA: Environmental Protection Agenc