

Efficiency of Different Water Treatment Technologies in Reducing Physicochemical Contaminants: A Case Study of Raipur Division, Chhattisgarh

Payal Sourabh Samadar¹, Dr. Anita Kabi²

¹Research Scholar, Department of Chemistry, Bharti Vishwavidhyalaya, Durg (C.G.)

²Assistant Professor, Department of Chemistry, Bharti Vishwavidhyalaya, Durg (C.G.)

Abstract:

Water treatment technologies differ substantially in their ability to remove suspended, dissolved and organic contaminants. This study comparatively evaluates five treatment approaches—conventional treatment (M1), activated carbon (M2), reverse osmosis (M3), ultraviolet treatment (M4) and biosand filtration (M5)—using twelve physicochemical water-quality parameters. The supplied treatment dataset reports mean post-treatment concentrations and percentage removal for turbidity, electrical conductivity (EC), total dissolved solids (TDS), biochemical oxygen demand (BOD), chemical oxygen demand (COD), total hardness, alkalinity, chloride, sulphate, nitrate, fluoride and iron. Reverse osmosis produced the highest overall mean removal efficiency (87.89%), followed by conventional treatment (33.71%), activated carbon (33.55%), biosand (29.86%) and UV (12.46%). RO achieved 80% or greater removal for turbidity, EC, TDS, BOD, total hardness, alkalinity, chloride, sulphate, nitrate, fluoride and iron, while COD removal was 77.99%. Conventional treatment showed strong removal of turbidity and iron; activated carbon performed particularly well for BOD, COD and iron; and biosand filtration showed strong turbidity and iron removal. UV produced limited changes in physicochemical parameters, consistent with its primary role as a disinfection process rather than a dissolved-solute removal process. The study demonstrates that treatment selection should be based on the contaminant profile and treatment objective, and that combined treatment trains may be preferable when both physicochemical and microbiological risks must be controlled.

Keywords: Water treatment; Raipur Division; reverse osmosis; activated carbon; biosand filtration; ultraviolet; physicochemical parameters; contaminant removal.

1. Introduction

Safe water supply requires effective control of particulate matter, dissolved salts, organic matter, nutrients and trace contaminants. Conventional treatment processes such as coagulation, flocculation, sedimentation and filtration are widely used for reducing suspended and particulate contaminants. Activated carbon relies primarily on adsorption and can be useful for selected dissolved organic compounds and taste- and odour-producing substances. Biosand filtration combines physical filtration and biological processes and is particularly relevant for turbidity and microbial improvement. Ultraviolet

treatment is principally a microbial-disinfection process, whereas reverse osmosis is a pressure-driven membrane process capable of reducing many dissolved inorganic constituents.

The present study focuses on Raipur Division, Chhattisgarh, and compares five treatment approaches using a common set of physicochemical indicators. The principal aim is to quantify the reported removal performance of each technology and identify treatment-specific strengths. The analysis is based strictly on the supplied summary dataset; raw replicate measurements, sampling dates, source-water concentrations and statistical replicate information were not provided and are therefore not fabricated.

2. Objectives

The objectives were (i) to compare five water-treatment technologies using physicochemical parameters; (ii) to quantify percentage removal for each parameter; (iii) to compare overall mean removal efficiency; (iv) to identify parameters for which individual treatment technologies were particularly effective; and (v) to discuss the implications for treatment selection in the Raipur Division context.

3. Materials and Methods

The comparative dataset included five treatment methods: M1 Conventional, M2 Activated Carbon, M3 Reverse Osmosis, M4 UV and M5 Biosand. Twelve parameters were evaluated: turbidity, EC, TDS, BOD, COD, total hardness, alkalinity, chloride, sulphate, nitrate, fluoride and iron. Treatment performance was represented by the reported mean concentration after treatment and the reported removal percentage. Removal efficiency is conventionally calculated as: $\text{Removal (\%)} = [(C_i - C_f)/C_i] \times 100$, where C_i is the initial concentration and C_f is the final concentration. Because the supplied material contains the calculated removal percentages but not the original raw observations, the reported removal percentages were used directly.

4. Results

The complete dataset is summarized in Tables 1 and 2. RO produced the lowest post-treatment value for all twelve parameters in the supplied data and had the highest overall mean removal efficiency.

Table 1. Mean post-treatment concentrations

Parameter	M1 Conventional	M2 Activated Carbon	M3 RO	M4 UV	M5 Biosand
Turbidity (NTU)	3.07	4.23	1.15	10.51	2.01
EC (µS/cm)	650.46	634.96	80.00	690.21	670.78
TDS (mg/L)	470.10	460.44	60.00	490.29	481.10
BOD (mg/L)	2.46	1.93	1.08	4.84	3.17
COD (mg/L)	16.80	10.37	7.07	28.84	19.96
Total Hardness (mg/L)	251.41	282.41	29.05	300.10	275.39
Alkalinity (mg/L)	190.94	206.53	40.11	215.09	204.55

Chloride (mg/L)	125.94	120.78	14.43	130.03	127.29
Sulphate (mg/L)	95.60	97.91	11.24	107.52	100.08
Nitrate (mg/L)	22.46	21.90	2.99	24.73	22.02
Fluoride (mg/L)	0.89	0.87	0.10	0.94	0.92
Iron (mg/L)	0.11	0.17	0.06	0.60	0.16

Table 2. Percentage removal efficiency

Parameter	M1 Conventional	M2 Activated Carbon	M3 RO	M4 UV	M5 Biosand
Turbidity (NTU)	78.19	70.00	91.85	25.40	85.76
EC (μ S/cm)	7.85	10.05	88.67	2.22	4.98
TDS (mg/L)	6.07	8.00	88.01	2.04	3.87
BOD (mg/L)	55.00	64.67	80.30	11.66	42.01
COD (mg/L)	47.73	67.74	77.99	10.27	37.88
Total Hardness (mg/L)	17.81	7.68	90.50	1.90	9.97
Alkalinity (mg/L)	12.19	5.02	81.56	1.09	5.93
Chloride (mg/L)	4.14	8.06	89.02	1.02	3.11
Sulphate (mg/L)	12.13	10.00	89.67	1.17	8.01
Nitrate (mg/L)	10.27	12.52	88.04	1.21	12.00
Fluoride (mg/L)	5.43	8.18	89.06	0.93	2.93
Iron (mg/L)	81.95	72.20	89.88	3.55	74.69

Table 3. Overall mean removal efficiency

Treatment	Mean removal (%)	Descriptive position
M3 RO	87.89	Rank 1
M1 Conventional	33.71	Rank 2
M2 Activated Carbon	33.55	Rank 3
M5 Biosand	29.86	Rank 4
M4 UV	12.46	Rank 5

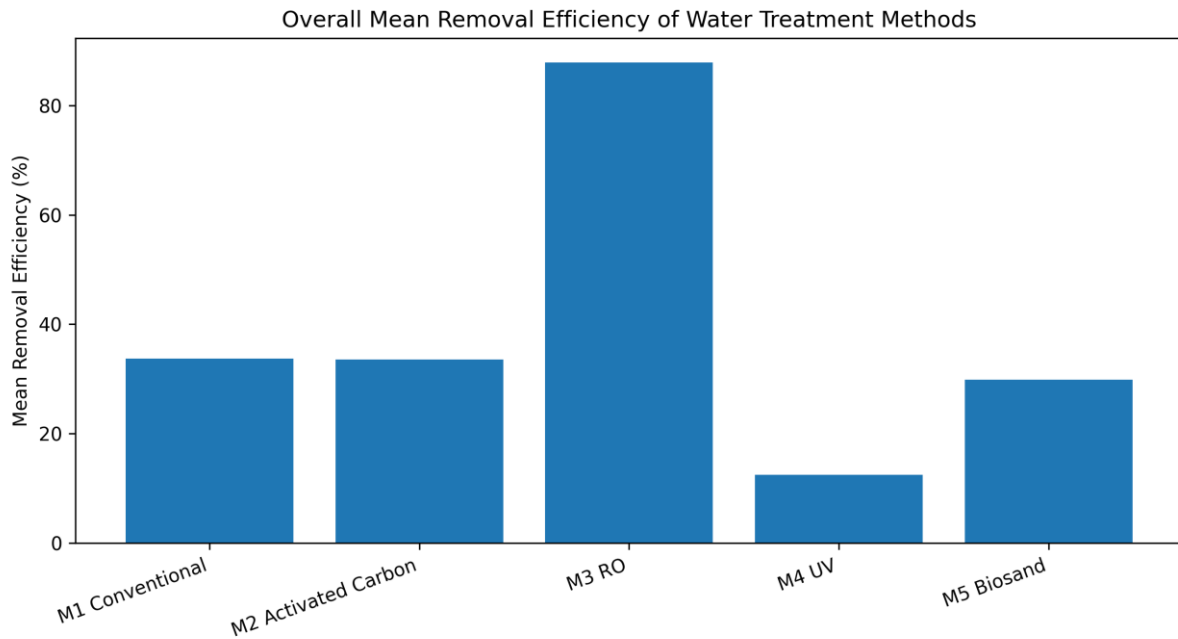


Figure 1. Overall mean removal efficiency of the five treatment methods.

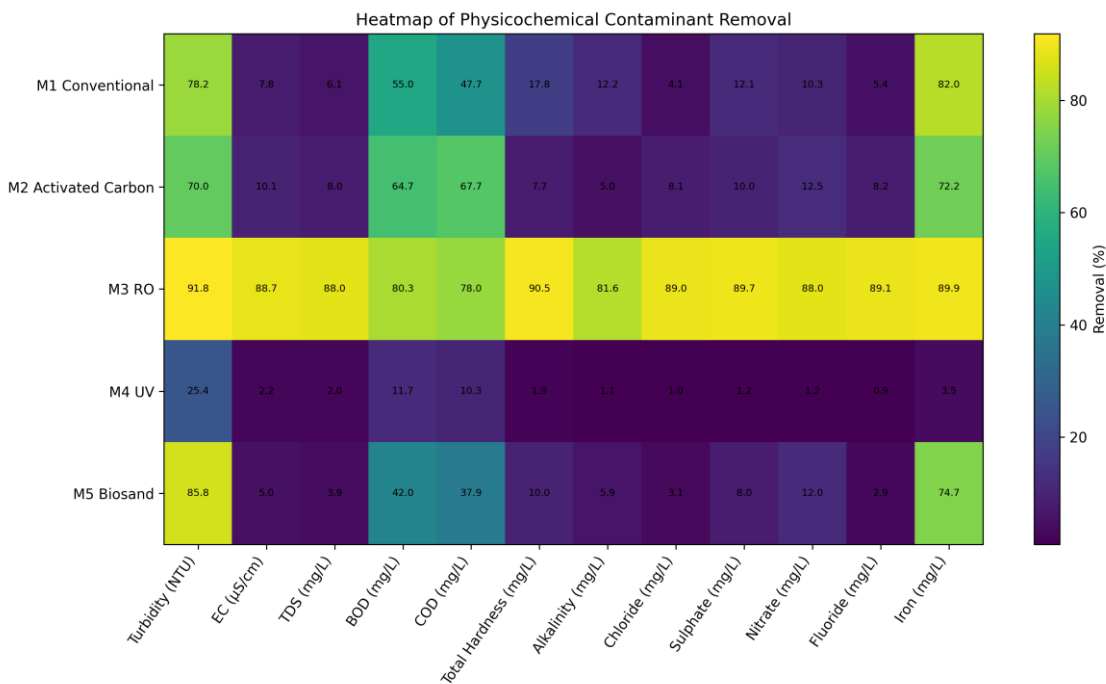


Figure 2. Heatmap showing parameter-wise removal efficiency.

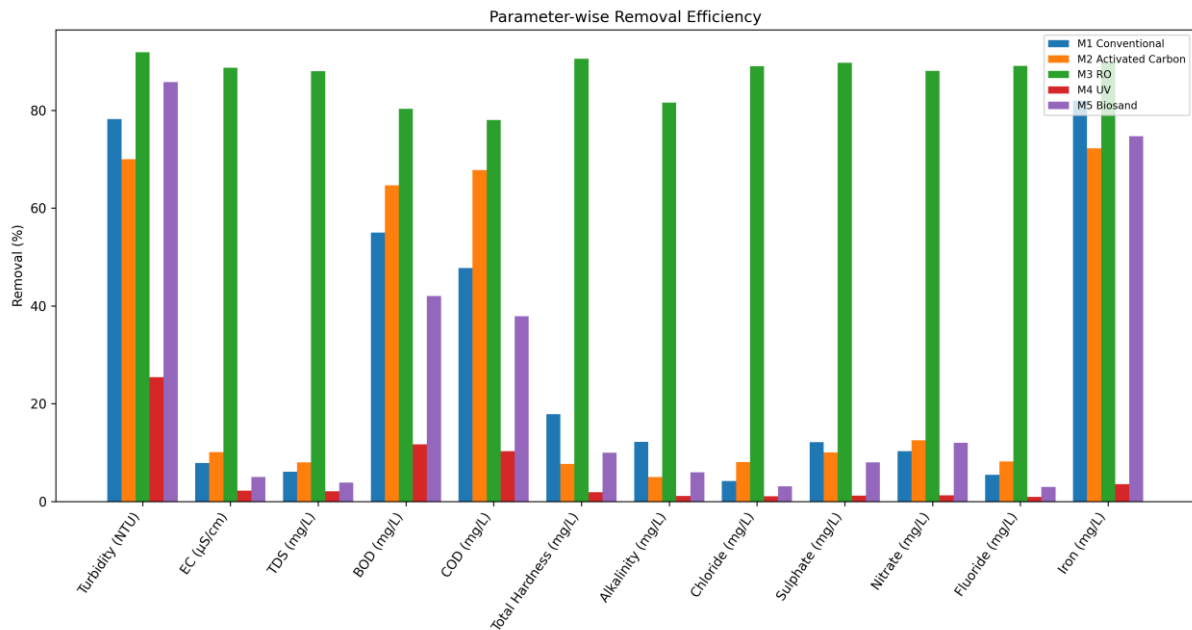


Figure 3. Comparative removal efficiency across physicochemical parameters.

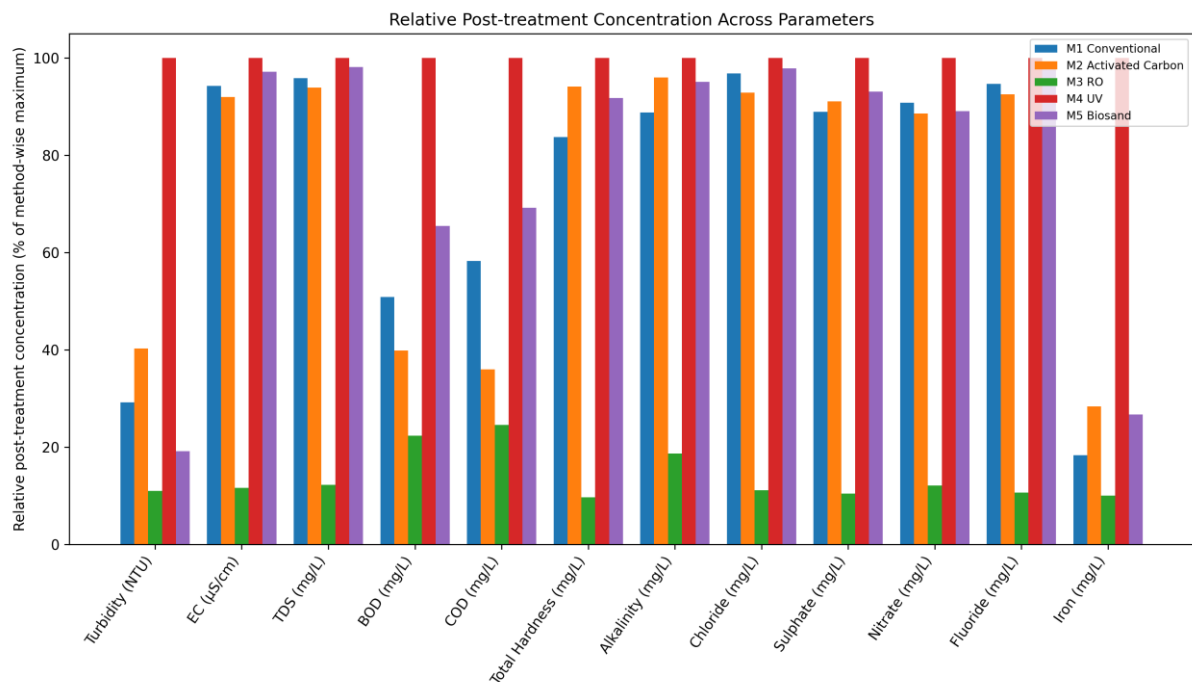


Figure 4. Relative post-treatment concentrations

5. Discussion

Reverse osmosis was the dominant treatment for broad physicochemical removal, with an overall mean removal of 87.89%. Its strongest results occurred for turbidity (91.85%), total hardness (90.50%), iron (89.88%), sulphate (89.67%), fluoride (89.06%), chloride (89.02%), EC (88.67%), nitrate (88.04%) and TDS (88.01%). This pattern is consistent with the function of membrane treatment in reducing dissolved constituents.

Conventional treatment achieved a mean removal of 33.71% and was particularly effective for turbidity

(78.19%) and iron (81.95%). Activated carbon had a mean removal of 33.55%, with comparatively high BOD (64.67%), COD (67.74%) and iron (72.20%) removal. Biosand filtration had a mean removal of 29.86% and performed especially well for turbidity (85.76%) and iron (74.69%).

UV had the lowest physicochemical removal at 12.46%. This should not be interpreted as poor disinfection performance: UV is primarily intended to inactivate microorganisms rather than remove dissolved salts, hardness or major ions. WHO evaluations of household water-treatment technologies explicitly assess UV among technologies intended for microbial contaminant control.

The results therefore support a treatment-train concept rather than assuming that all technologies are direct substitutes. Filtration can reduce turbidity and particulate matter; activated carbon can provide adsorption of selected compounds; RO can address dissolved constituents; and UV can provide a disinfection barrier. The final design should depend on source-water characteristics, microbiological quality, operating costs, energy availability, membrane fouling, concentrate management and required end-use quality.

6. Interpretation

Turbidity (NTU)

The highest reported removal for Turbidity (NTU) was achieved by M3 RO at 91.85%. The corresponding mean post-treatment concentrations were M1 Conventional 3.07, M2 Activated Carbon 4.23, M3 RO 1.15, M4 UV 10.51, M5 Biosand 2.01.

EC ($\mu\text{S}/\text{cm}$)

The highest reported removal for EC ($\mu\text{S}/\text{cm}$) was achieved by M3 RO at 88.67%. The corresponding mean post-treatment concentrations were M1 Conventional 650.46, M2 Activated Carbon 634.96, M3 RO 80.00, M4 UV 690.21, M5 Biosand 670.78.

TDS (mg/L)

The highest reported removal for TDS (mg/L) was achieved by M3 RO at 88.01%. The corresponding mean post-treatment concentrations were M1 Conventional 470.10, M2 Activated Carbon 460.44, M3 RO 60.00, M4 UV 490.29, M5 Biosand 481.10.

BOD (mg/L)

The highest reported removal for BOD (mg/L) was achieved by M3 RO at 80.30%. The corresponding mean post-treatment concentrations were M1 Conventional 2.46, M2 Activated Carbon 1.93, M3 RO 1.08, M4 UV 4.84, M5 Biosand 3.17.

COD (mg/L)

The highest reported removal for COD (mg/L) was achieved by M3 RO at 77.99%. The corresponding mean post-treatment concentrations were M1 Conventional 16.80, M2 Activated Carbon 10.37, M3 RO 7.07, M4 UV 28.84, M5 Biosand 19.96.

Total Hardness (mg/L)

The highest reported removal for Total Hardness (mg/L) was achieved by M3 RO at 90.50%. The corresponding mean post-treatment concentrations were M1 Conventional 251.41, M2 Activated Carbon 282.41, M3 RO 29.05, M4 UV 300.10, M5 Biosand 275.39.

Alkalinity (mg/L)

The highest reported removal for Alkalinity (mg/L) was achieved by M3 RO at 81.56%. The corresponding mean post-treatment concentrations were M1 Conventional 190.94, M2 Activated Carbon 206.53, M3 RO 40.11, M4 UV 215.09, M5 Biosand 204.55.

Chloride (mg/L)

The highest reported removal for Chloride (mg/L) was achieved by M3 RO at 89.02%. The corresponding mean post-treatment concentrations were M1 Conventional 125.94, M2 Activated Carbon 120.78, M3 RO 14.43, M4 UV 130.03, M5 Biosand 127.29.

Sulphate (mg/L)

The highest reported removal for Sulphate (mg/L) was achieved by M3 RO at 89.67%. The corresponding mean post-treatment concentrations were M1 Conventional 95.60, M2 Activated Carbon 97.91, M3 RO 11.24, M4 UV 107.52, M5 Biosand 100.08.

Nitrate (mg/L)

The highest reported removal for Nitrate (mg/L) was achieved by M3 RO at 88.04%. The corresponding mean post-treatment concentrations were M1 Conventional 22.46, M2 Activated Carbon 21.90, M3 RO 2.99, M4 UV 24.73, M5 Biosand 22.02.

Fluoride (mg/L)

The highest reported removal for Fluoride (mg/L) was achieved by M3 RO at 89.06%. The corresponding mean post-treatment concentrations were M1 Conventional 0.89, M2 Activated Carbon 0.87, M3 RO 0.10, M4 UV 0.94, M5 Biosand 0.92.

Iron (mg/L)

The highest reported removal for Iron (mg/L) was achieved by M3 RO at 89.88%. The corresponding mean post-treatment concentrations were M1 Conventional 0.11, M2 Activated Carbon 0.17, M3 RO 0.06, M4 UV 0.60, M5 Biosand 0.16.

7. Conclusion

The comparative assessment demonstrates substantial differences among water-treatment technologies. Reverse osmosis showed the highest overall physicochemical removal efficiency (87.89%) and the lowest reported post-treatment concentration for each of the twelve investigated parameters. Conventional treatment, activated carbon and biosand filtration each showed useful parameter-specific performance, whereas UV produced limited physicochemical removal as expected for a primarily disinfection-oriented process.

For Raipur Division, treatment selection should therefore be based on the actual contaminant profile of the source water. Where dissolved salts, hardness, nitrate, fluoride and major ions are dominant concerns, membrane treatment may provide substantial benefit. Where turbidity and particulate contamination are more important, filtration-based processes can be effective. Activated carbon and UV may serve as complementary treatment barriers. Future work should incorporate raw-water measurements, microbial indicators, replicate-level data, treatment operating conditions, cost analysis and inferential statistics to establish treatment performance with greater experimental certainty.

REFERENCES:

1. Ahmed, F., et al. (2020). Physicochemical characteristics of groundwater in mining areas, *Environmental Pollution*, 258, 113358.
2. Kumar, P., et al. (2021). "Assessment of groundwater quality in agricultural regions affected by pesticide use." *Environmental Science and Pollution Research*, 28(4), 4585-4594.
3. Ravi, S., et al. (2022). "Urbanization and groundwater contamination: A review of heavy metal contamination sources." *Science of the Total Environment*, 755, 142417.
4. Mohan, V., et al. (2023). "Influence of water extraction on groundwater quality in semi-arid regions." *Hydrology and Earth System Sciences*, 27(4), 1785-1798.
5. Singh, S., et al. (2017). "Groundwater contamination due to heavy metals from mining and industrial waste." *Environmental Monitoring and Assessment*, 189(8), 389-398.
6. World Health Organization. (2016). Results of Round I of the WHO Household Water Treatment Evaluation Scheme.
7. Chaudhary, S., et al. (2018). "Agricultural sources of heavy metal contamination in groundwater." *Journal of Agricultural and Food Chemistry*, 66(3), 597-605.
8. Akhtar, N., Ishak, M. I. S., Ahmad, M. I., Umar, K., Md Yusuff, M. S., Anees, M. T., Qadir, A., & Almanasir, Y. K. A. (2021). Modification of the Water Quality Index (WQI) process for simple calculation using the Multi-Criteria Decision-Making (MCDM) method: A review. *Water*, 13(7), 905.
9. World Health Organization. (2019). Results of Round II of the WHO Household Water Treatment Evaluation Scheme.
10. Bongoua-Devisme, A. J., & Balland-Bolou-Bi, C. (2018). Assessment of heavy metal contamination degree of municipal open-air dumpsite on surrounding soils: Case of dumpsite of Bonoua, Ivory Coast. *International Journal of Engineering Research and General Science*, 6(5), 28-42.
11. World Health Organization. (2026). WHO international scheme to evaluate household water treatment technologies: results of Rounds III and IV.
12. Ghalit, M., Yousfi, E. B., Zouhairi, M., & El Khadir, G. (2017). Hydrochemical characterization of groundwater in the Nekor basin located in the North-East of the Rif of Morocco. *Moroccan Journal of Chemistry*, 5, 272-284.
13. Pati, M. C., & Rout, S. P. (2018). Water quality status of Rushikulya River Basin, Odisha, India. *Asian Journal of Research in Chemistry*, 11(3), 221-231.
14. U.S. Environmental Protection Agency. Overview of Drinking Water Treatment Technologies.