https://doi.org/10.52676/1729-7885-2025-4-100-106
УДК 658.264

ASSESSMENT OF WATER TREATMENT QUALITY AT THE WATER TREATMENT COMPLEX OF TPP-1 IN THE CITY OF SEMEY

A. R. Khazhidinova[1*], **A. S. Khazhidinov**[2], **S. L. Elistratov**[3]

[1] *Shakarim University, Semey, Kazakhstan*
[2] *Center of Nuclear Medicine and Oncology, Semey, Kazakhstan*
[3] *Novosibirsk State Technical University, Novosibirsk, Russia*

* *E-mail for contacts: khazhidinova1991@mail.ru*

Reliable and efficient operation of thermal power plants is impossible without high-quality water treatment. This is particularly important for facilities that use natural water sources characterized by high turbidity, suspended solids, and dissolved gases. This study examines the three-stage water treatment system used at the Semey TPP-1. The aim was to evaluate the effectiveness of each stage of water purification: mechanical filtration, sodium-cation softening, and thermal degassing. The study included instrumental assessment of water quality before and after each treatment stage, visual inspection of the equipment, and analysis of operational documentation. The results demonstrate a high level of purification: anthracite-loaded mechanical filters reduce turbidity by more than 95%, sodium-cation exchange units lower hardness from 12 mg-eq/L to 0.05 mg-eq/L, and the deaerator reduces dissolved oxygen concentration to ≤ 0.05 mg/L. It is shown that adherence to technological parameters – such as filter loading levels, regeneration regimes, and backwashing intensity – directly affects purification efficiency and equipment durability. The findings confirm that the quality of treated water meets regulatory requirements for boiler feedwater. Based on the measurement results, a quantitative assessment was made of the performance efficiency of each unit in the water treatment system. These results can be used in the design and modernization of water treatment systems at similar thermal power facilities and provide practical value for developing engineering competencies in operating power equipment and water-chemical regimes.

Keywords: *water treatment, mechanical filter, anthracite, sodium cation exchange filter, deaerator, water quality.*

INTRODUCTION

Water treatment is one of the key elements in ensuring the reliable and efficient operation of thermal power facilities. The quality of water used in thermal power facilities directly affects the provision of electricity, hot water supply, and heating to the population. Furthermore, an adequate level of water treatment is essential for the preservation of equipment [1–4]. Malfunctions in the water treatment process can lead to significant technological and economic losses. Figure 1 shows the potential consequences of inadequate water purification at thermal power plants.

Multi-stage water treatment systems are widely used at thermal power plants. These typically include mechanical filtration, ion exchange, thermal deaeration, and, in some cases, membrane technologies. Each stage plays a specific role in removing suspended solids, hardness salts, dissolved gases, and organic compounds [5].

In recent years, a number of studies have been published addressing water treatment issues at thermal power facilities, including water hardness, suspended solids content, and the application of various filtration and ion-exchange methods [6–8]. For instance, Zaharia and Stanciulescu [7] examined water treatment processes with emphasis on sludge formation and disposal, while Fajri et al. [6] analyzed river water hardness in relation to demineralization processes at a thermal power plant. Tsubakizaki et al. [8] discussed general approaches to water quality control in thermal power plants. However, these studies mainly focus on specific aspects or generalized schemes. Comprehensive assessments of the performance of existing water treatment systems under the conditions of specific plants remain insufficiently covered, which highlights the necessity of the present study on the example of TPP-1 in Semey.

The aim of this study is to analyze the design, operating principles, and efficiency of the water treatment equipment in use at TPP-1 in the city of Semey, taking into account the quality of the raw water and the requirements for feedwater parameters in thermal power systems.

The water intake for TPP-1 is sourced from the Irtysh River. The quality of water in the Irtysh River often does not meet established standards, as it contains a significant amount of impurities and suspended substances, necessitating strict control of boiler water treatment. As it passes through the intake structure, the hardness of the water increases.

The water treatment system at TPP-1 is a three-stage process, with each stage performing a specific function in achieving the required water quality. It includes:

1) A mechanical filter for removing suspended and insoluble mechanical impurities;
2) First- and second-stage sodium-cation exchange filters for water softening;
3) A deaerator that removes dissolved gases.

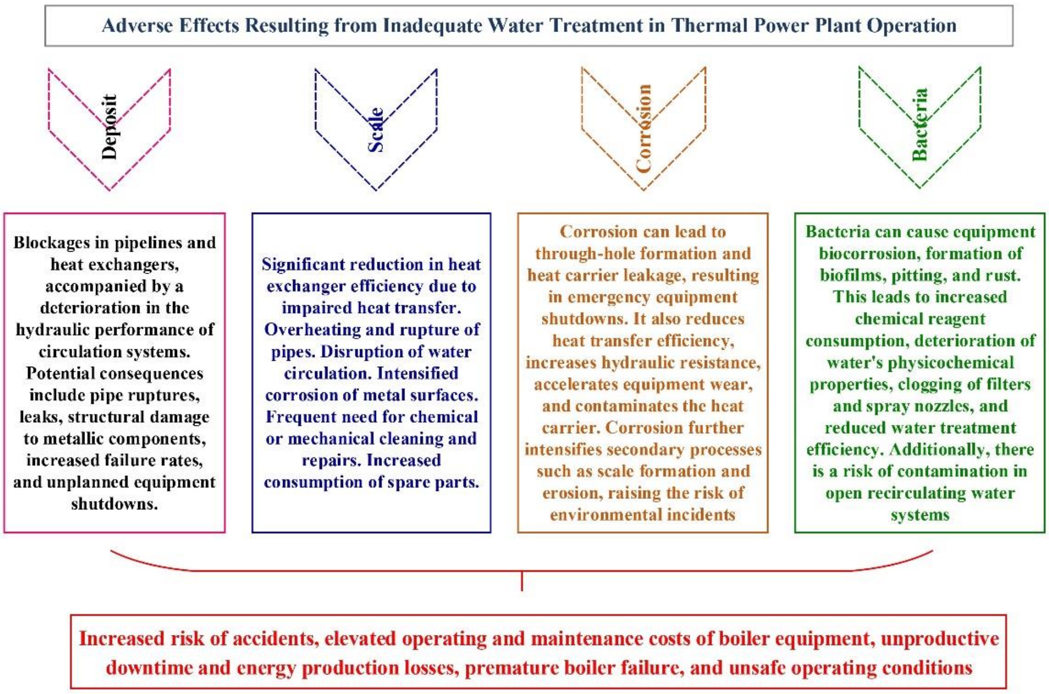

Figure 1. Potential consequences of inadequate water treatment at thermal power plants

The novelty of this study lies in the fact that, for the first time, a comprehensive analysis of the water treatment system operation at TPP-1 in the city of Semey was carried out under real operating conditions based on data obtained directly at the plant. Unlike general descriptions of standard water treatment schemes, this study examines the actual quality of water at the intake point and its changes after each treatment stage, taking into account the local hydrochemical characteristics of the Irtysh River basin and the specific features of the intake facilities. This approach makes it possible to identify the most critical purification stages and to assess their efficiency under the actual operating conditions of the plant.

METHODS

The study of the water treatment process was conducted at the operating water treatment complex of the TPP-1 thermal power plant in the city of Semey, which provides feedwater treatment for the water-steam path of the boiler equipment. The aim of the research was to assess the effectiveness of the main stages of water purification under real operating conditions.

The methodology included an engineering and technological survey of the water treatment scheme, analysis of operational documentation, visual inspection of the equipment, as well as instrumental measurements of water quality indicators before and after passing through individual treatment stages.

The quality indicators of technical water were determined in accordance with state standards (GOST) and standard laboratory procedures used at thermal power plants. Turbidity was measured in accordance with the national standard ST RK ISO 7027–2007 “Water quality. Determination of turbidity” using a HACH 2100N turbidimeter [9]. The concentration of suspended solids was determined in accordance with the standard ST RK 3865–2023 “Industrial waters of thermal power plants. Determination of suspended solids by gravimetric method” [10].

Total hardness, as well as calcium and magnesium concentrations, were determined by manual complexometric titration with EDTA (Trilon B) in accordance with GOST 31954-2012 in the laboratory of TPP-1 [11]. Dissolved oxygen was measured manually by the Winkler iodometric method in accordance with the standard ST RK 2518–2014 “Water quality. Methods for determination of dissolved oxygen” [12]. Free CO_2 was determined manually by acid–base titration in accordance with GOST 23268.5-78 [13].

Particular attention was paid to evaluating the sequence of purification processes, the reliability of equipment operation, and the degree to which the water quality characteristics complied with established standards.

Water quality parameters were monitored using standard sampling devices installed at the inlet and outlet of the main process units: mechanical filters, sodium-cation exchange filters of stages I and II, and the atmospheric deaerator.

The sampling points included pipelines for sample collection, shut-off valves, and pressure gauge devices, allowing for real-time control of pressure drops before and after the treatment equipment.

The data were analyzed in comparison with regulatory requirements for feed and makeup water quality in heat supply systems, as well as with the parameters necessary to ensure corrosion and scale formation safety in the water-steam circuit of the boilers.

RESULTS AND DISCUSSION

Figure 2 shows the schematic diagram of a mechanical water filter. The mechanical filter is a structurally simple and reliable device designed for the primary removal of mechanical impurities from water [14]. The description of the filter in this study is based on actual inspection data from the equipment at TPP-1 in Semey, and the reference to Zhao et al. [14] is cited exclusively as an example to illustrate the general characteristics and operating principles of similar filters. The filter is constructed as a vertical cylindrical structure made of monolithic reinforced concrete. The rigidity and strength of the concrete housing allow the filter to operate under variable hydraulic loads and pressure differentials typical of industrial water treatment systems.

The filtering medium used is anthracite – a high-carbon filtration material characterized by abrasion resistance, chemical inertness, and a large specific surface area. The values “900” and “500” shown in Figure 2 indicate the height of the anthracite layer and the distance to the upper distribution pipe, in millimeters. The grain size and bed height of the anthracite are selected to ensure an optimal filtration rate while achieving a high degree of suspended solids removal.

The design of the mechanical filter includes the option for backwashing, during which accumulated contaminants are removed from the filter bed by reversing the flow of water. The absence of chemical reagents at this stage significantly reduces the overall cost of water treatment [14].

During operation, the raw water is fed into the upper part of the filter (Figure 2). To prevent air lock formation and ensure uniform flow distribution, special air release and pressure equalization slots are integrated into the upper section of the structure. This design solution helps avoid uneven filtration, thereby improving the efficiency of the device [6]. After passing through the anthracite layer, the filtered water flows into the lower part of the filter, from where it is directed to the next treatment stage – the first-stage sodium cation exchange filter.

Table 1 presents the water quality indicators before and after passing through the mechanical filter.

Table 1. Water quality indicators before and after the mechanical filter

Water Quality Parameters	Before treatment	After treatment
Turbidity, NTU	45÷65	0,6
Suspended solids concentration, mg/L	130÷210	<5

The analysis of the obtained results indicates a high degree of water purification from mechanical contaminants in mechanical filters – over 96% for both parameters. Effective removal of suspended solids at this stage significantly increases the lifespan of subsequent filters, prevents their fouling, and reduces the consumption of reagents during regeneration.

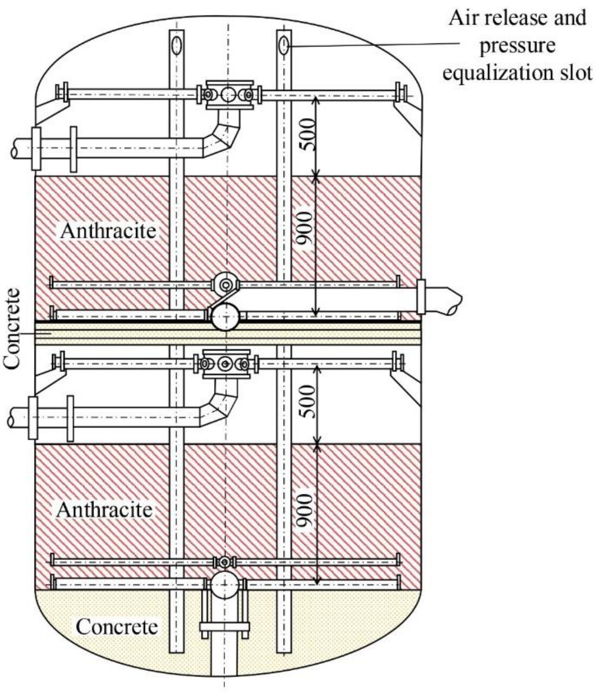

Figure 2. Diagram of the mechanical filter

Mechanical filtration is not capable of removing dissolved substances such as salts, metals, and organic compounds. For their removal, sodium cation exchange filters are used [15].

The design of the sodium cation exchange filters of stages I and II is identical [15]. Both filters operate on the same principle and have a similar structure. Possible differences may concern operational parameters, such as the volume of the filtering media or regeneration modes; however, these do not affect the basic structural scheme of the equipment (Figure 3).

The working bed of the filter consists of a layer of ion-exchange material, the height of which is determined by the design level Hsl – the maximum allowable bed level in operating condition (indicated in the diagram as the bottom level of the filter media layer). A free space is provided above the bed for regeneration. During backwashing, the layer expands, and this expansion must not exceed 30% of Hsl, as shown in the figure. This limitation prevents material loss and ensures uniform flow distribution. Maintaining these levels is crucial for the stable operation of the filter, the efficiency of ion-exchange processes, and the extended service life of the media [16].

Raw water is supplied to the filter under pressure and passes through the layer of cation exchange media from top to bottom, during which the water softening process occurs through ion exchange: calcium and magnesium ions are replaced by an equivalent amount of sodium ions.

The working cycle of the filter includes the following stages: softening, loosening, regeneration, and rinsing [16].

The softening cycle ends when the hardness of the water at the outlet exceeds 0.1 mg-eq/L, indicating that the ion-exchange capacity of the media has been exhausted and regeneration is required.

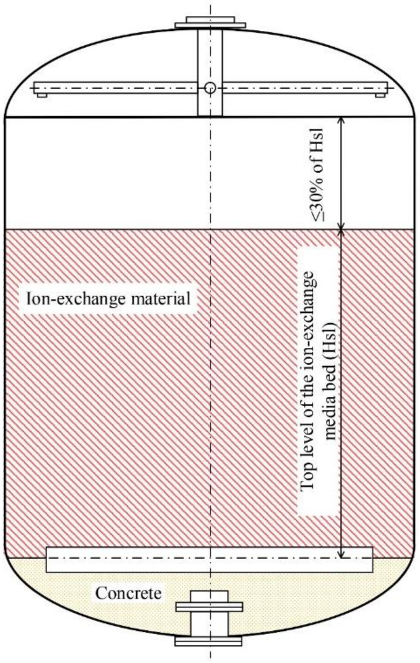

Figure 3. Diagram of the sodium cation exchange filter

Loosening, which lasts 15 to 30 minutes at an intensity of 3 to 4 L/m²·s, is carried out to eliminate compaction of the ion-exchange media and restore its filtration properties.

Regeneration is performed using a 5 to 8% sodium chloride (NaCl) solution to restore the exchange capacity of the cation exchange resin by saturating it with sodium ions. After regeneration, the ion-exchange material is rinsed from top to bottom to remove excess regenerant solution and by-products formed during the recovery process [16].

Table 2 presents the water quality parameters before and after passing through the sodium cation exchange filters.

Table 2. Water quality parameters before and after sodium cation exchange filtration

Water Quality Parameters	Before treatment	After treatment
Total hardness, mg-eq/L	12	0.05
Calcium (Ca^{2+}), mg/L	40÷100	≤ 1
Magnesium (Mg^{2+}), mg/L	10÷30	≤ 0.5

The analysis results indicate the high efficiency of the sodium cation exchange filters used in the water treatment system. The total hardness of the raw water was 12 mg-eq/L, which classifies it as hard and potentially hazardous for the operation of thermal equipment due to the risk of scale formation. After passing through the filters, this parameter was reduced to 0.05 mg-eq/L, indicating the near-complete removal of calcium and magnesium ions.

Such a degree of water softening meets the requirements of ST RK 2248–2012 "Quality standards for feedwater and steam", according to which the total hardness of feedwater must not exceed 0.1 mg-eq/L [17].

After passing through the sodium cation exchange filters, the softened water is directed to an atmospheric deaerator for the removal of dissolved gases, primarily oxygen and carbon dioxide. The schematic of the atmospheric deaerator is shown in Figure 4.

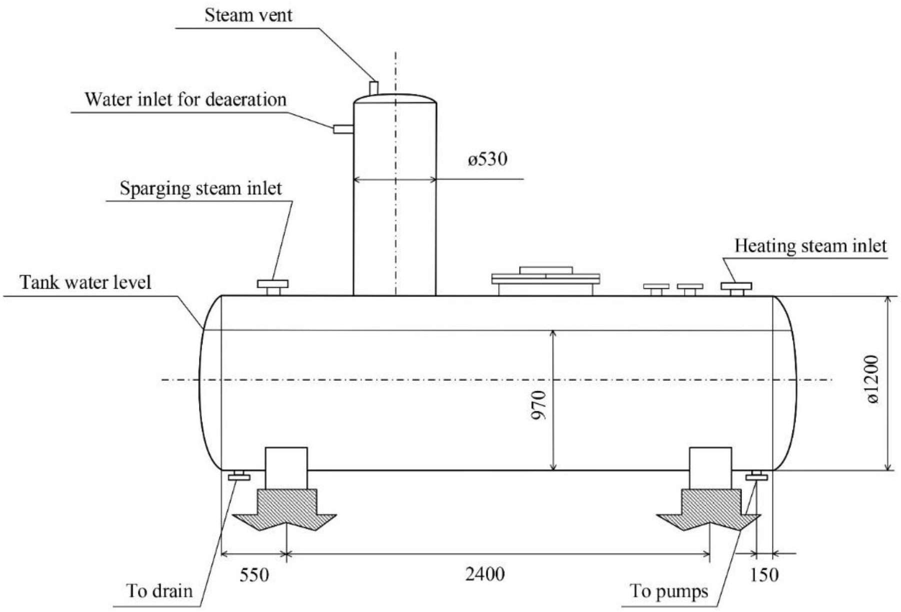

Figure 4. Diagram of the deaerator

The atmospheric deaerator ensures effective removal of dissolved gases from the softened water through direct contact with bubbling steam and subsequent heating [18–20].

The design includes a column with steam and water inlets, as well as a horizontal tank supplied with heating steam. The length of the tank body between the supports is 2400 mm, the distance from the left end to the axis of the drain nozzle (“To drain”) is 550 mm, and the distance from the right end to the axis of the nozzle supplying water to the pumps (“To pumps”) is 150 mm. This principle allows for a high degree of degassing without the use of vacuum. The steam-air mixture is discharged through a steam vent, preventing gas accumulation. The unit is equipped with drainage and pressure nozzles that ensure stable operation under varying hydraulic loads. Table 3 presents the water quality parameters at the inlet and outlet of the deaerator.

Table 3. Water quality parameters at the inlet and outlet of the deaerator

Water Quality Parameters	At the inlet of the deaerator	At the outlet of the deaerator
Dissolved oxygen, mg/L	6÷10	≤ 0.05
Free CO_2, mg/L	5÷10	–

Table 3 demonstrates a significant reduction in the concentration of dissolved oxygen after the water passes through the deaerator. This result complies with regulatory requirements and confirms the high efficiency of degassing achieved through the thermal effect of steam and intensive gas exchange. A decrease or complete removal of free CO_2 is also observed, which further reduces the corrosive activity of the water and enhances the reliability of feedwater pipelines and equipment.

CONCLUSION

The results of the study demonstrated the high efficiency of the operating water treatment system at TPP-1 in the city of Semey, which is based on a three-stage purification scheme including mechanical filtration, ion exchange, and thermal deaeration.

At the first stage – mechanical filtration with an anthracite media – up to 96–98% of suspended solids are removed. Water turbidity is reduced from the initial 45–65 NTU to 0.6 NTU, and the content of mechanical impurities decreases from 130–210 mg/L to less than 5 mg/L. These values are within the acceptable range for water treatment schemes of thermal power plants and ensure the effective operation of the subsequent purification stages.

At the second stage, water softening using first- and second-stage sodium cation exchange filters results in the near-complete removal of hardness. Total hardness is reduced from 12 mg-eq/L to 0.05 mg-eq/L; calcium concentration decreases from 40–100 mg/L to ≤ 1 mg/L, and magnesium from 10–30 mg/L to ≤ 0.5 mg/L. These values fully comply with regulatory standards for boiler feedwater and effectively prevent scale formation in the water-steam circuit.

The final stage – thermal degassing in an atmospheric deaerator – ensures a reduction of dissolved oxygen concentration from 6–10 mg/L to ≤ 0.05 mg/L. Free CO_2 is also effectively removed, with its concentration decreasing from 5–10 mg/L to nearly zero, significantly reducing the corrosive activity of the water.

A comprehensive assessment of the effectiveness of all three stages confirmed that the water treatment system at TPP-1 consistently achieves the required parameters for turbidity, hardness, and dissolved gas content. According to [17] the limit values for these parameters are: total hardness ≤ 0.1 mg-eq/L, dissolved oxygen ≤ 0.05 mg/L, and free CO_2 is not allowed. The obtained results fully comply with these standards, which contributes to reliable and economical operation of boiler equipment, reduces the frequency of repairs, and extends inter-repair periods.

The data obtained may be used to optimize water-chemical regimes at similar thermal power facilities, as well as in the training of thermal power engineering students, helping to develop solid competencies in the operation of water treatment systems.

REFERENCES

1. Chichirova N., Filimonova A., Vlasov S., Babikov O. Biological pollution of technological equipment and the chemically desalting water treatment plant at a TPP (review) // Thermal Engineering. – 2023. – Vol. 70, No. 9. – P. 665–672. https://doi.org/10.1134/S0040601523090021
2. Romanova L.N. The current status of water treatment systems // International Research Journal. – 2023. – No. 2 (128). https://doi.org/10.23670/IRJ.2023.128.49
3. Su Z., Ma H., Ding X. Research on key technologies for optimization of water systems and efficient utilization of regenerated water in thermal power plants // Academic Journal of Science and Technology. – 2024. – Vol. 9. – P. 111–116. https://doi.org/10.54097/rva23p06
4. Stănciulescu D., Zaharia C. Process water treatment in a thermal power plant: characteristics and its sediment/sludge disposal // Environmental Engineering and Management Journal. – 2020. – Vol. 19, No. 2. – P. 255–267. https://doi.org/10.30638/eemj.2020.024
5. Galligan J. Advanced water treatment solutions for thermopower plants // Fluence Technical Review. – 2025. – URL: https://www.fluencecorp.com/advanced-water-treatment-solutions-for-thermopower-plants/ (accessed: 25.06.2025).
6. Fajri A. A., Rahmatullah T. A., Septano G. D., Nasaruddin. Analysis of Hardness Level in Enim River for Demineralization Water Process in Thermal Power Plant Tanjung Enim // Jurnal Informasi dan Teknologi. – 2025, – P. 67–75. https://doi.org/10.60083/jidt.vi0.632
7. Zaharia C., Stanciulescu D. Process water treatment in a thermal power plant: characteristics and sediment/sludge disposal // Environmental Engineering and Management Journal. – 2020. – Vol. 19, No. 2. – P. 255–267. https://doi.org/10.30638/eemj.2020.024

8. Tsubakizaki S., Wada T., Tokumoto T., Ichihara T., Kido H., Takahashi S. Water Quality Control Technology for Thermal Power Plants (Current Situation and Future Prospects) // Mitsubishi Heavy Industries Technical Review. – 2013. – Vol. 50, No. 3. – URL: https://www.mhi.co.jp/technology/review/pdf/e503/e503022.pdf
9. ST RK ISO 7027–2007. Water quality. Determination of turbidity. – Astana: Committee for Technical Regulation and Metrology, 2007. – 11 p.
10. ST RK 3865–2023. Industrial waters of thermal power plants. Determination of suspended solids by gravimetric method. – Astana: Committee for Technical Regulation and Metrology, 2023. – 9 p.
11. GOST 31954–2012. Drinking water. Methods for determination of hardness (ISO 6059:1984, NEQ; ISO 7980:1986, NEQ). – Moscow: Standartinform, 2018. – 20 p.
12. ST RK 2518–2014. Water quality. Methods for determination of dissolved oxygen. – Astana: Committee for Technical Regulation and Metrology, 2014. – 14 p.
13. GOST 23268.5–78. Water. Methods for determination of dissolved carbon dioxide. – Moscow: Standards Publishing, 1978. – 7 p.
14. Zhao Y., Wang R., Liu X., Ma H. Study on the performance of mechanical filtration for removal of suspended solids in industrial water treatment // Journal of Water Process Engineering. – 2022. – Vol. 45. – Art. 102483. https://doi.org/10.1016/j.jwpe.2021.102483
15. Brocx R., Kusic H., Spanjers H. Performance of strong acid cation-exchange filters in multi-stage water-treatment systems: removal of hardness and suspended solids // Journal of Water Process Engineering. – 2021. – Vol. 40. – Art. 102123. https://doi.org/10.1016/j.jwpe.2021.102123
16. Powell H., Smith J. Role of strong acid cation exchange in multi-stage water treatment at thermal power plants // Water Science & Technology. – 2022. – Vol. 86, No. 3. – P. 587–597. https://doi.org/10.2166/wst.2022.123
17. ST RK 2248–2012. Quality standards for feedwater and steam. – Astana: Committee for Technical Regulation and Metrology, 2012. – 28 p.
18. Chen C., Johnson P. Deaerators in industrial steam systems // U.S. Department of Energy. Improving Steam System Performance. – 2025. – (online publication). – URL: https://www.energy.gov/eere/amo/articles/deaerators-industrial-steam-systems (accessed: 10.07.2025).
19. Leduhovsky G.V. An analysis of carbonic acid removal in an atmospheric deaerator // Thermal Engineering. – 2020. – Vol. 67. – P. 320–323. https://doi.org/10.1134/S004060152005002X (accessed: 13.07.2025).
20. Sharapov V.I. The vapor of thermal deaerators as a factor of their energy efficiency // Power Technology and Engineering. – 2020. – Vol. 54. – P. 96–100. https://doi.org/10.1007/s10749-020-01174-2

СЕМЕЙ ҚАЛАСЫНДАҒЫ ЖЭО-1 СУ ДАЙЫНДАУ КЕШЕНІНДЕГІ СУ ТАЗАРТУ САПАСЫН БАҒАЛАУ

А. Р. Хажидинова[1], А. С. Хажидинов[2], С. Л. Елистратов[3]

[1] «Шәкәрім Университеті» КЕАҚ, Семей, Қазақстан
[2] Ядролық медицина және онкология орталығы, Семей, Қазақстан
[3] Новосибирск мемлекеттік техникалық университеті, Новосибирск, Ресей

** Байланыс үшін E-mail: khazhidinova1991@mail.ru*

Жылу энергетикалық қондырғылардың сенімді әрі тиімді жұмысы сапалы су дайындаусыз мүмкін емес. Бұл, әсіресе, лайлылығы жоғары, ілінген бөлшектер мен еріген газдар көп табиғи су көздерін пайдаланатын нысандар үшін өзекті. Осы мақалада Семей қаласындағы ЖЭО-1-де қолданылатын үш сатылы су дайындау жүйесі қарастырылады. Зерттеудің мақсаты – суды тазартудың әр кезеңінің (механикалық сүзу, натрий-катиониттік жұмсарту және жылулық дегазация) тиімділігін бағалау. Зерттеу барысында тазарту сатыларының алдындағы және кейінгі су сапасы аспаптық әдіспен бағаланды, жабдықтарға визуалды тексеру жүргізілді, сондай-ақ пайдалану құжаттары талданды. Алынған нәтижелер тазартудың жоғары деңгейін көрсетті: антрацитті сүзгіштер лайлылықты 95%-дан астам төмендетеді, натрий-катионит сүзгілері қаттылықты 12 мг-экв/л-ден 0,05 мг-экв/л-ге дейін азайтады, ал деаэратор еріген оттек концентрациясын $\leq$ 0,05 мг/л-ге дейін төмендетеді. Технологиялық параметрлерді (сүзгі жүктемесі, регенерация режимі, шаю қарқындылығы) сақтау тазартудың тиімділігіне және жабдықтың ұзақ қызмет етуіне тікелей әсер ететіні көрсетілді. Зерттеу нәтижелері тазартылған судың бу қазандарының коректік суына қойылатын нормативтік талаптарға сай келетінін көрсетті. Өлшеу нәтижелері негізінде су дайындау сызбасының әрбір тораптарының жұмысының тиімділігіне сандық бағалау жүргізілді. Бұл деректер ұқсас жылу энергетикалық нысандардағы су дайындау жүйелерін жобалау мен жаңғыртуда пайдаланылуы мүмкін және энергетикалық жабдықтар мен су-химиялық режимдерді пайдалануда инженерлік құзыреттіліктерді қалыптастыруда практикалық мәнге ие.

Түйін сөздер: *су дайындау, механикалық сүзгі, антрацит, натрий-катионитті сүзгі, деаэратор, су сапасы.*

ASSESSMENT OF WATER TREATMENT QUALITY AT THE WATER TREATMENT COMPLEX OF TPP-1 IN THE CITY OF SEMEY

ОЦЕНКА КАЧЕСТВА ОЧИСТКИ ВОДЫ В ВОДОПОДГОТОВИТЕЛЬНОМ КОМПЛЕКСЕ ТЭЦ-1 ГОРОДА СЕМЕЙ

А. Р. Хажидинова[1], А. С. Хажидинов[2], С. Л. Елистратов[3]

[1] НАО «Университет Шакарима», Семей, Казахстан
[2] Центр ядерной медицины и онкологии, Семей, Казахстан
[3] Новосибирский государственный технический университет, Новосибирск, Россия

* *E-mail для контактов: khazhidinova1991@mail.ru*

Обеспечение надёжной и эффективной работы теплоэнергетических установок невозможно без организации качественной водоподготовки. Особенно это актуально для объектов, использующих в качестве источника воды природные водоёмы, характеризующиеся высокой мутностью, содержанием взвешенных частиц и растворённых газов. В настоящей работе рассматривается трёхступенчатая система водоподготовки, эксплуатируемая на теплоэлектроцентрали ТЭЦ-1 города Семей. Целью исследования явилась оценка эффективности работы каждого этапа водоочистки: механической фильтрации, натрий-катионитного умягчения и термической дегазации. В ходе исследования была проведена инструментальная оценка качества воды до и после каждой стадии очистки, а также визуальный осмотр оборудования и анализ эксплуатационной документации. Полученные данные свидетельствуют о высоком уровне очистки: механические фильтры с антрацитовой загрузкой позволяют снизить мутность воды более чем на 95%, натрий-катионитные фильтры уменьшают жёсткость с 12 мг-экв/л до 0,05 мг-экв/л, а деаэратор обеспечивает снижение концентрации растворённого кислорода до уровня ≤ 0,05 мг/л. Показано, что соблюдение технологических параметров, таких как уровень загрузки, режим регенерации, интенсивность промывки, напрямую влияет на эффективность очистки и долговечность оборудования. Результаты работы подтверждают соответствие показателей очищенной воды нормативным требованиям, предъявляемым к питательной воде паровых котлов, и могут быть использованы при проектировании и модернизации систем водоподготовки на аналогичных теплоэнергетических объектах. На основании результатов измерений производилась количественная оценка эффективности работы каждого узла водоподготовительной схемы. Также полученные данные представляют практическую ценность для формирования устойчивых инженерных компетенций в области эксплуатации энергетического оборудования и водно-химических режимов.

Ключевые слова: *водоподготовка, механический фильтр, антрацит, натрий-катионитный фильтр, деаэратор, качество воды.*