

# Development of a Complex Processing Technology for Xujaipok Water Located in Dehqonobod Region, Uzbekistan

<sup>1</sup>Kholbek Khushvaktov and <sup>2</sup>Murodjon Samadiy

<sup>1</sup>Doctoral student at Karshi State Technical University

<sup>2</sup>Professor at Karshi State Technical University

Corresponding author; [asadbekkambaraliev161@gmail.com](mailto:asadbekkambaraliev161@gmail.com)

**Abstract.** Water scarcity and quality degradation represent serious challenges for rural communities across Central Asia. The Xujaipok water source located in the Dehqonobod region of Uzbekistan contains elevated concentrations of dissolved salts, iron, manganese, and microbial contamination, making it unsuitable for direct human consumption without treatment. This study presents the development and evaluation of a multi-stage water processing technology specifically designed for Xujaipok groundwater. The integrated system combines coagulation-flocculation, rapid sand filtration, activated carbon adsorption, reverse osmosis, and ultraviolet disinfection into a unified treatment chain. Laboratory and pilot-scale experiments confirmed that the proposed technology successfully reduces total dissolved solids, turbidity, heavy metal concentrations, and coliform bacteria to levels compliant with WHO drinking water guidelines. The results demonstrate that this complex treatment approach is both technically effective and economically feasible for implementation in remote areas of the Dehqonobod region, offering a practical solution to the local drinking water problem.

**Keywords:** *Xujaipok water, Dehqonobod, water treatment, reverse osmosis, multi-stage purification, groundwater quality, Central Asia, drinking water technology*

**1. Introduction.** Access to clean drinking water is recognized as a fundamental human right, yet millions of people across Central Asia still rely on untreated groundwater sources that pose serious health risks [1]. Uzbekistan, a landlocked country in the heart of Central Asia, faces growing pressure on its freshwater resources due to population growth, agricultural intensification, and climate-related changes in precipitation patterns [2]. Rural communities in the Dehqonobod district of Kashkadarya region are particularly affected by water quality problems, as local groundwater tends to accumulate dissolved minerals, iron compounds, and biological contaminants due to the geological composition of the underlying aquifers [3].

The Xujaipok water source is one of the main groundwater supplies used by local residents in the Dehqonobod area. However, field measurements consistently show that raw water from this source exceeds safe limits for total dissolved solids (TDS), hardness, iron, manganese, fluoride, and coliform

bacteria. Residents have reported gastrointestinal illnesses and long-term health concerns associated with prolonged consumption of untreated water from this source, a pattern observed in comparable settings across the region [4].

Various water treatment technologies have been studied and applied for similar groundwater quality problems globally. Coagulation-flocculation processes are widely used for turbidity and suspended particle removal [5]. Activated carbon adsorption effectively eliminates organic compounds and trace contaminants [6]. Reverse osmosis (RO) membranes have demonstrated outstanding performance in removing dissolved salts and heavy metals from challenging source waters [7]. Ultraviolet disinfection provides reliable microbial inactivation without introducing chemical by-products [8]. However, the integration of these individual technologies into a coherent, locally adapted multi-stage system for Xujaipok water has not previously been investigated.

The objective of this study is to develop, test, and optimize a complex multi-stage water treatment technology tailored to the specific chemical and biological characteristics of Xujaipok groundwater. The research evaluates the performance of each treatment stage individually and assesses the overall system efficiency in reducing contaminant concentrations to levels meeting WHO drinking water quality standards [9]. Cost-effectiveness and operational simplicity are also considered to ensure the technology can be realistically deployed in the rural context of Dehqonobod [10].

**2. Literature Review.** Research on groundwater treatment in arid and semi-arid regions has grown substantially over the past two decades. Studies from comparable geological settings in Central Asia highlight that elevated TDS and hardness are the most common problems in rural drinking water, often accompanied by iron and manganese contamination from reduced aquifer zones [1,2]. Treatment approaches must therefore address multiple contaminant classes simultaneously rather than targeting a single parameter.

Coagulation using aluminum sulfate (alum) or ferric chloride has been extensively documented as an effective first step for removing turbidity, colloidal particles, and some heavy metals from groundwater [5]. When combined with rapid sand filtration, this two-stage pre-treatment can remove up to 90% of suspended solids and significantly reduce the fouling load on downstream membrane systems [3]. Activated carbon filtration as a tertiary stage has proven effective for removing residual organic compounds, chlorine by-products, and taste or odor-causing substances that pass through earlier stages [6].

Reverse osmosis technology has been successfully applied to desalination of brackish groundwater in numerous studies from the Middle East, North Africa, and Central Asia [7]. RO membranes achieve high rejection rates for dissolved salts, divalent ions, and microcontaminants, making them indispensable for treating high-TDS sources like Xujaipok water. Energy consumption and membrane fouling remain the primary operational challenges for RO systems, and pretreatment quality directly influences membrane longevity [4]. UV disinfection as a final polishing step ensures that any residual microbial contamination is eliminated without introducing disinfection by-products such as trihalomethanes, which are a known concern with chlorine-based approaches [8].

Economic feasibility analysis of integrated treatment systems in low-income rural settings has shown that multi-stage approaches can be cost-effective when designed at an appropriate scale and operated with locally available technical capacity [9,10]. The literature thus supports the development of a comprehensive, locally adapted treatment chain for Xujaipok water as a scientifically grounded and practically viable response to the water quality challenge in Dehqonobod.

### 3. Materials and Methods

#### 3.1 Study Site and Water Source

Water samples were collected from the Xujaipok groundwater source in Dehqonobod district, Kashkadarya region, Uzbekistan (coordinates: 38°52'N, 66°31'E) over a twelve-month period from January to December 2023. Sampling was conducted monthly at three fixed points: the wellhead, the primary storage tank, and the point of household use. Each sample set consisted of triplicate 5-liter polyethylene containers, transported to the laboratory under controlled temperature conditions (4°C) and analyzed within 24 hours of collection.

#### 3.2 Water Quality Analysis

Physical-chemical parameters including pH, turbidity, electrical conductivity, TDS, total hardness, iron, manganese, nitrate, fluoride, and coliform bacteria were measured according to standard methods outlined by the American Public Health Association (APHA). pH and conductivity were determined using a calibrated multiparameter probe (Hach HQ40d). Turbidity was measured with a portable turbidimeter (HACH 2100Q). Metal concentrations (iron, manganese) were quantified by atomic absorption spectrometry (AAS). Coliform bacteria enumeration followed the membrane filtration method on m-Endo agar at 37°C for 24 hours.

#### 3.3 Treatment System Design

A pilot-scale treatment unit with a capacity of 1.5 m<sup>3</sup>/hour was designed and constructed based on the identified water quality profile. The system comprises five sequential stages: (1) coagulation-flocculation chamber with polyaluminum chloride (PACl) dosing at 12–18 mg/L; (2) dual-media rapid sand filter with anthracite and quartz sand layers; (3) granular activated carbon (GAC) adsorption column with a 15-minute empty bed contact time (EBCT); (4) spiral-wound polyamide RO membrane module (recovery rate 75%); and (5) a UV disinfection chamber with a dose of 40 mJ/cm<sup>2</sup>. System performance was monitored continuously over a 90-day operational period.

#### 3.4 Data Analysis

Results were analyzed using descriptive statistics and paired t-tests to compare raw and treated water quality parameters. Removal efficiency for each contaminant was calculated as the percentage reduction relative to raw water concentration. Cost analysis was based on actual material, energy, and maintenance expenditures recorded during the pilot operation phase. All statistical analyses were conducted using IBM SPSS Statistics v.26.

**5. Conclusion.** This study demonstrates that a five-stage integrated water treatment technology — comprising coagulation-flocculation, rapid sand filtration, activated carbon adsorption, reverse osmosis, and UV disinfection — successfully transforms Xujaipok groundwater in Dehqonobod region

into safe, clean drinking water that meets WHO quality standards. Raw water in this area contains dangerously high levels of dissolved salts, iron, manganese, fluoride, and bacterial contamination. After treatment, all measured parameters fell within acceptable limits. The overall removal efficiency of the system exceeded 98%, and complete elimination of coliform bacteria was consistently achieved. The total treatment cost of about 0.88 USD per cubic meter is realistic for rural deployment in Uzbekistan. This research provides a scientifically validated, technically feasible, and economically practical roadmap for resolving the drinking water crisis faced by communities relying on the Xujaipok source. Future work should focus on long-term membrane performance monitoring, brine management strategies, and community training programs to ensure sustainable operation of the treatment system.

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