Research Article

Evaluation of Microbial and Chemical Contamination in Drinking Water and the Role of Household Purification Systems in Improving Water Quality

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Abstract | The study aimed to evaluate the level of microbial and chemical contamination in drinking water in Thi Qar Governorate, Nasiriyah City Iraq, and to investigate the role and efficiency of household water purification systems in improving water quality and reducing contaminants under local conditions. A completely randomized design (CRD) was applied, including six treatments: bottled water (T1), tap water (T2), a new system without a UV unit (T3), an old system without a UV unit (T4), a new system equipped with a UV unit (T5), and an old system equipped with a UV unit (T6).Water samples were collected weekly for four weeks and analyzed for microbiological, physicochemical, algal, and heavy metal parameters. The results showed significant differences among treatments ($P \leq 0.05$). Tap water recorded the highest levels of microbial contamination (Total Coliforms, E. coli, Pseudomonas aeruginosa, and total plate count (TPC)), as well as the highest algal density and heavy metal concentrations (Pb, Cd, Cu, and Zn). In contrast, bottled water exhibited the lowest values across all parameters, indicating high quality. Household purification systems significantly improved water quality compared with tap water. New systems demonstrated higher efficiency than old ones, highlighting the effect of system age on purification performance. Systems equipped with UV units achieved superior performance in reducing microbial load and algal density. In addition, these systems significantly improved physicochemical properties, reducing EC (680 to 280–350 µS/cm), TDS (450 to 170–210 mg/L), and turbidity (2.5 to 0.8–1.5 NTU). Heavy metals were also reduced, including Pb (15 to 2–8 µg/L), Cd (2.5 to 0.3–1.2 µg/L), Cu (25 to 6–18 µg/L), and Zn (50 to 18–35 µg/L). Overall, the findings confirm that household water purification systems, particularly modern systems integrated with UV technology, are effective in enhancing drinking water quality and reducing potential health risks associated with contaminated water.

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Introduction

Water is one of the most essential natural resources required for sustaining life and supporting environmental and agricultural systems. The quality of drinking water is closely linked to human health and environmental sustainability. However, rapid population growth, urban expansion, and industrial activities have significantly increased the risk of water pollution, leading to the deterioration of water quality in many regions worldwide. Drinking water contamination may occur due to various physical, chemical, and biological pollutants originating from natural processes or anthropogenic activities. Therefore, the assessment of drinking water quality commonly relies on a range of physicochemical and biological indicators that reflect its suitability for human consumption. Among these indicators, microbial parameters such as coliform bacteria and Escherichia coli are widely used as biological indicators of fecal contamination, while chemical parameters, including dissolved substances and heavy metals, are considered important indicators of chemical pollution that may pose serious environmental and health risks when present at elevated levels (Zhang *et al*., 2023; Jurczynski *et al*., 2024).

Microbial and chemical contamination of drinking water remains a major environmental and public health challenge in many parts of the world, particularly in regions where water treatment infrastructure is limited or inefficient. The presence of pathogenic microorganisms, algae, and toxic chemical compounds in drinking water may lead to the spread of waterborne diseases, including gastrointestinal infections and other microbial illnesses, in addition to long-term health effects associated with chronic exposure to heavy metals. Consequently, the evaluation of drinking water quality typically involves the analysis of multiple microbiological and physicochemical parameters, including total bacterial counts, coliform bacteria, pH, electrical conductivity, total dissolved solids, turbidity, and concentrations of selected heavy metals such as lead, cadmium, copper, and zinc. Such integrated assessment approaches have become widely adopted in environmental and agricultural studies to determine pollution levels and assess potential risks associated with contaminated water resources (Aghalari *et al*., 2020; Rao *et al*., 2024).

Several previous studies have investigated the effectiveness of household water purification systems in improving drinking water quality and reducing microbial and chemical contamination. Zhang *et al*. (2019) reported that household filtration systems can significantly reduce microbial contamination in drinking water; however, their efficiency may vary depending on filter type, operational conditions, and maintenance practices. Similarly, Lin *et al*. (2020) demonstrated that household water purifiers may substantially improve water quality, although poorly maintained systems may also serve as potential sites for microbial growth. In another study, Rodrigues *et al*. (2021) indicated that integrating filtration technologies with ultraviolet (UV) disinfection can significantly reduce coliform bacteria and E. coli levels in treated water. More recently, Ammar *et al*. (2024) reported that multi-stage household filtration systems can effectively improve both chemical and microbiological characteristics of domestic drinking water. Furthermore, a recent review by Kirpichenkova *et al*. (2024) confirmed that household water treatment technologies, particularly those combining filtration and ultraviolet disinfection, represent effective approaches for improving drinking water safety when properly maintained.

Despite considerable advances in water treatment technologies, many regions continue to experience challenges related to drinking water quality due to microbial and chemical contamination. Therefore, field-based studies assessing local water quality and evaluating the performance of household purification systems remain essential for improving water safety and public health protection. Such investigations provide valuable scientific data that can support the development of effective water management strategies and promote the sustainable use of water resources. Accordingly, the present study aims to evaluate drinking water quality and the levels of microbial and chemical contamination using selected environmental indicators, as well as to assess the role of household water purification systems in improving water quality and reducing potential health risks associated with contaminated drinking water.

Materials and Methods

Experimental design and analytical methods for samples

This study was conducted in Thi Qar Governorate, Nasiriyah City, Iraq, with laboratory analyses performed in the Microbiology Laboratory at the

College of Pharmacy, University of Thi-Qar. The study aimed to evaluate the efficiency of integrated household water purification systems in improving drinking water quality, focusing on the effects of system age and the presence of an ultraviolet (UV) disinfection unit. Household water purification systems manufactured by Hyundai were used, differing in terms of duration of use and the presence or absence of a UV disinfection unit.

The experiment was designed as a Completely Randomized Design (CRD) with six treatments (T1–T6) and three replicates per treatment. Each replicate represented an independent household water purification system Water samples were collected weekly for one month (four consecutive weeks) on days 7, 14, 21, and 28. One sample was taken from each replicate each week to monitor temporal changes in water quality.

- T1: Positive Control (Reference Range): Commercial bottled water from Salsal Company, representing drinking water processed according to standard quality specifications.
- T2: Baseline (Tap Water): Tap water collected from different locations within Thi Qar Governorate, representing typical local drinking water conditions.
- T3: New System without UV Unit: A newly installed household water purification system without an ultraviolet disinfection unit.
- T4: Old System without UV Unit:A household water purification system used for three months without an ultraviolet disinfection unit.
- T5: New System with UV Unit: A newly installed household water purification system equipped with an ultraviolet disinfection unit.
- T6: Old System with UV Unit: A household water purification system used for three months and equipped with an ultraviolet disinfection unit.

Water samples were collected directly from the outlets of the purification systems using sterile glass containers to prevent external contamination. Samples were transported to the laboratory and analyzed following standard laboratory procedures. Analyses included the evaluation of microbiological characteristics of water, and physicochemical parameters in addition to the assessment of algae and selected heavy metals using standard laboratory techniques and instruments. This experimental framework was designed to assess the actual performance of new and aged household water purification systems, with and without UV disinfection units, and to compare their efficiency with both high-quality bottled water and locally supplied tap water.

The experimental treatments included bottled water, tap water, and household purification systems differing in age and the presence of a UV unit, as illustrated in Figure 1 and Figure 2.

Microbiological analysis

Microbiological analyses of water samples were conducted to determine the presence and levels of indicator bacteria associated with drinking water contamination. The analyses focused on Total Coliforms, Escherichia coli, Pseudomonas aeruginosa, and the Total Plate Count (TPC), following standard microbiological procedures described by Da Silva *et al.* (2017) and Al-Salhi *et al.*, (2022). Water samples were

Figure 1: *Home water purification system filters (used and new)*

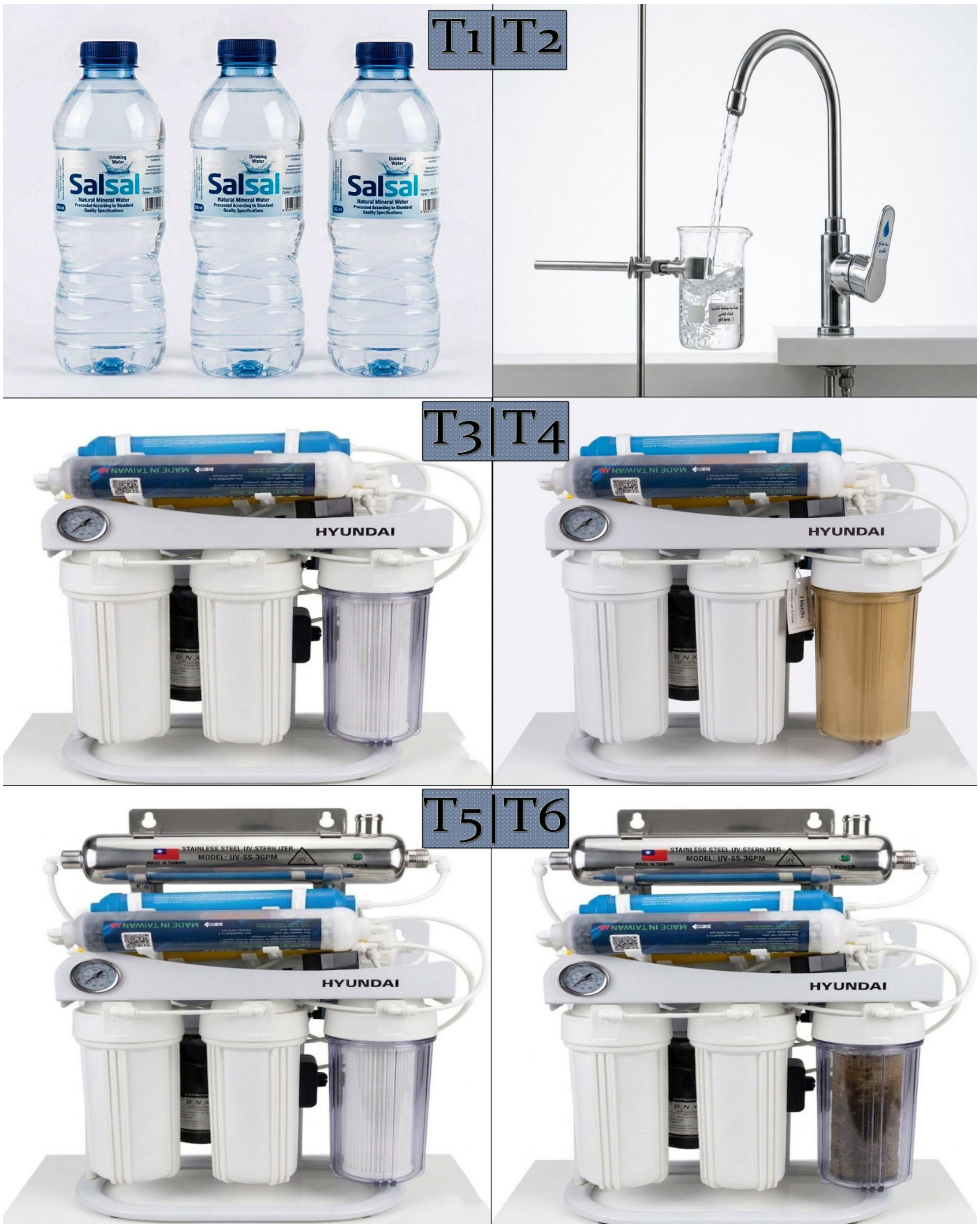

Figure 2: *Experimental treatments of household water purification systems*

collected in sterile glass containers directly from the outlet of each purification system and transported to the laboratory under controlled conditions to prevent external contamination. For the detection of Total Coliforms and E. coli, water samples were subjected to membrane filtration using sterile membrane filters with a pore size of 0.45 µm. The membranes were then placed on selective agar media and incubated at appropriate temperatures for 24–48 hours. Colonies showing characteristic morphology were counted and expressed as colony-forming units per 100 mL (CFU/100 mL). Pseudomonas aeruginosa was detected using Pseudomonas selective agar, followed by incubation at 37°C for 24–48 hours. Suspected colonies were confirmed using standard biochemical identification tests.

The Total Plate Count (TPC) was determined using the spread plate method on Plate Count Agar to estimate the total number of heterotrophic bacteria present in the water samples. Plates were incubated at 35–37°C for 24–48 hours, and results were reported as CFU/mL. All analyses were performed in triplicate to ensure the accuracy and reproducibility of the results.

Physicochemical analysis of water

Physicochemical analyses of water samples were conducted to evaluate the effect of household water purification systems on drinking water quality. These analyses included the measurement of pH, electrical conductivity (EC), total dissolved solids (TDS), and turbidity using standard laboratory instruments and according to the standard procedures used in drinking water analysis.

The pH value was measured using a digital pH meter after calibration with standard buffer solutions. Electrical conductivity and total dissolved solids were measured using a multiparameter meter, while turbidity was determined using a turbidity meter.

Algal enumeration

Algal density in water samples was determined using direct microscopic examination following sample concentration by the sedimentation method. Water samples were collected in sterile glass containers and allowed to stand for 24 hours at room temperature to permit algal cells to settle at the bottom of the container. After sedimentation, a small portion of the concentrated sample was carefully collected using a sterile pipette. A drop of the concentrated sample was placed on a clean glass slide and covered with a cover slip. The prepared slide was examined under a compound light microscope at appropriate magnifications, and algal cells were counted in several randomly selected microscopic fields. The average number of algal cells was then calculated and expressed as the number of algal cells per milliliter of water (Cells/mL). All analyses were performed in replicates to ensure the accuracy and reliability of the results (Wehr *et al*., 2015; APHA, 2017).

Heavy metals analysis

After sample collection, water samples were preserved in pre-cleaned, acid-washed glass containers by acidification. Concentrations of lead (Pb), cadmium (Cd), copper (Cu), and zinc (Zn) were determined using atomic absorption spectrophotometry (AAS) following standard protocols for drinking water analysis (Ghaderpoori *et al*., 2018; Ravanipour *et al*., 2021). Proper sample handling and preservation are essential to ensure the reliability and accuracy of spectrophotometric measurements, as variations in sample collection and processing conditions may influence biochemical and chemical analytical results (Al-Salhi, 2025).

Statistical analysis

Data were expressed as Mean ± Standard Error (Mean ± SE). The experiment was arranged in a Completely Randomized Design (CRD), and significant differences among treatments were determined using Duncan's Multiple Range Test at $P \leq 0.05$. All statistical analyses were performed using SPSS software version 25 (Snedecor and Cochran, 1994).

Table 1: *Effect of household water purification systems on total coliform counts (Log_{10} CFU/100 mL, Mean ± SE)*

Treatment	Week 1	Week 2	Week 3	Week 4	Overall mean
T1 Bottled water	0.00 ± 0.00 d	0.00 ± 0.00 d	0.00 ± 0.00 d	0.00 ± 0.00 d	0.00 ± 0.00 d
T2 Tap water	1.82 ± 0.04 a	1.86 ± 0.05 a	1.91 ± 0.04 a	1.96 ± 0.05 a	1.89 ± 0.04 a
T3 New system without UV	0.95 ± 0.03 c	0.90 ± 0.03 c	1.00 ± 0.04 c	1.04 ± 0.04 c	0.97 ± 0.03 c
T4 Old system without UV	1.36 ± 0.04 b	1.41 ± 0.03 b	1.46 ± 0.04 b	1.49 ± 0.05 b	1.43 ± 0.04 b
T5 New system with UV	0.00 ± 0.00 d	0.00 ± 0.00 d	0.30 ± 0.02 d	0.31 ± 0.02 d	0.15 ± 0.01 d
T6 Old system with UV	0.85 ± 0.03 c	0.90 ± 0.03 c	0.95 ± 0.04 c	1.00 ± 0.03 c	0.93 ± 0.03 c
Sig.	*	*	*	*	*

Values represent Mean ± Standard Error (SE) of three replicates. Means followed by different letters within the same column differ significantly at $P \leq 0.05$ according to the Least Significant Difference (LSD) test. Microbial counts were log-transformed using Log10 (CFU + 1) prior to statistical analysis.

Results and Discussion

Effect of household water purification systems on total Coliform counts during the experimental period

The data presented in Table 1 indicate significant differences among the studied treatments in Total Coliform counts throughout all experimental weeks as well as in the overall mean at a significance level of ($P \leq 0.05$). Tap water (T2) recorded the highest bacterial counts during all weeks, with an overall mean of 1.89 Log_{10} CFU/100 mL, whereas bottled water (T1) showed no detectable bacterial growth throughout the study period.

Household purification systems exhibited a significant reduction in bacterial counts compared with tap water ($P \leq 0.05$). The new system without a UV unit (T3) recorded an overall mean of 0.97 Log_{10} CFU/100 mL, while the old system without a UV unit (T4) showed higher values with an overall mean of 1.43 Log_{10} CFU/100 mL. Furthermore, the presence of a UV disinfection unit resulted in a significant decrease in bacterial counts ($P \leq 0.05$). The new system equipped with a UV unit (T5) showed very low values with an overall mean of 0.15 Log_{10} CFU/100 mL, whereas the old system with a UV unit (T6) recorded an overall mean of 0.93 Log_{10} CFU/100 mL.

Table 2: *Effect of household water purification systems on Escherichia coli counts (Log10 CFU/100 mL, Mean ± SE)*

Treatment	Week 1	Week 2	Week 3	Week 4	Overall mean
T1 Bottled water	0.00 ± 0.00 c	0.00 ± 0.00 c	0.00 ± 0.00 c	0.00 ± 0.00 c	0.00 ± 0.00 c
T2 Tap water	0.95 ± 0.04 a	1.04 ± 0.05 a	1.11 ± 0.04 a	1.18 ± 0.05 a	1.07 ± 0.04 a
T3 New system without UV	0.30 ± 0.02 b	0.30 ± 0.03 b	0.48 ± 0.03 b	0.48 ± 0.03 b	0.39 ± 0.03 b
T4 Old system without UV	0.60 ± 0.03 b	0.69 ± 0.04 b	0.71 ± 0.03 b	0.78 ± 0.04 b	0.70 ± 0.03 b
T5 New system with UV	0.00 ± 0.00 c	0.00 ± 0.00 c	0.00 ± 0.00 c	0.00 ± 0.00 c	0.00 ± 0.00 c
T6 Old system with UV	0.30 ± 0.02 b	0.44 ± 0.03 b	0.48 ± 0.03 b	0.52 ± 0.03 b	0.44 ± 0.03 b
Sig.	*	*	*	*	*

Values represent Mean ± Standard Error (SE) of three replicates. Means followed by different letters within the same column differ significantly at P ≤ 0.05 according to the Least Significant Difference (LSD) test. Microbial counts were log-transformed using Log10 (CFU + 1) prior to statistical analysis.

Overall, the results demonstrate that household water purification systems significantly reduced Total Coliform counts compared with tap water, with superior performance observed in newly installed systems equipped with a UV disinfection unit, and all treatment differences were significant at ($P \leq 0.05$).

Effect of household water purification systems on escherichia coli counts during the experimental period

The results presented in Table 2 reveal significant differences among the studied treatments in Escherichia coli counts throughout all sampling weeks and in the overall mean at ($P \leq 0.05$). Tap water (T2) consistently exhibited the highest bacterial counts during the study period, with an overall mean of 1.07 Log_{10} CFU/100 mL.

In contrast, no detectable E. coli colonies were observed in bottled water (T1) or in the newly installed purification system equipped with a UV unit (T5), where bacterial counts remained 0.00 Log_{10} CFU/100 mL across all sampling weeks, indicating a significant reduction compared with the other treatments ($P \leq 0.05$). Purification systems without UV disinfection units showed lower bacterial levels than tap water but still differed significantly among treatments ($P \leq 0.05$). The new system without UV (T3) recorded an overall mean of 0.39 Log_{10} CFU/100 mL, whereas the old system without UV (T4) exhibited relatively higher values with an overall mean of 0.70 Log10 CFU/100 mL. Similarly, the old system equipped with a UV unit (T6) demonstrated a noticeable reduction in E. coli counts compared with tap water, with an overall mean of 0.44 Log_{10} CFU/100 mL. Overall, the findings indicate that household water purification systems effectively reduced E. coli contamination to varying degrees depending on system age and the presence of a UV disinfection unit, with all treatment differences being significant at ($P \leq 0.05$).

Table 3: *Effect of household water purification systems on pseudomonas aeruginosa counts(Log_{10} CFU/100 mL, Mean ± SE)*

Treatment	Week 1	Week 2	Week 3	Week 4	Over-all mean
T1 Bottled water	0.00 ± 0.00 d	0.00 ± 0.00 d	0.00 ± 0.00 d	0.00 ± 0.00 d	0.00 ± 0.00 d
T2 Tap water	1.26 ± 0.04 a	1.30 ± 0.05 a	1.38 ± 0.04 a	1.41 ± 0.05 a	1.34 ± 0.04 a
T3 New system without UV	0.48 ± 0.03 c	0.54 ± 0.03 c	0.54 ± 0.03 c	0.60 ± 0.03 c	0.54 ± 0.03 c
T4 Old system without UV	0.95 ± 0.03 b	1.04 ± 0.04 b	1.11 ± 0.04 b	1.15 ± 0.04 b	1.06 ± 0.03 b
T5 New system with UV	0.00 ± 0.00 d	0.00 ± 0.00 d	0.00 ± 0.02 d	0.18 ± 0.02 d	0.05 ± 0.01 d
T6 Old system with UV	0.48 ± 0.03 c	0.54 ± 0.03 c	0.60 ± 0.03 c	0.60 ± 0.03 c	0.55 ± 0.03 c
Sig.	*	*	*	*	*

Values represent Mean ± Standard Error (SE) of three replicates. Means followed by different letters within the same column differ significantly at P ≤ 0.05 according to the Least Significant Difference (LSD) test. Microbial counts were log-transformed using Log10 (CFU + 1) prior to statistical analysis.

Effect of household water purification systems on Pseudomonas aeruginosa counts during the study period

The data shown in Table 3 demonstrate significant differences among the treatments in Pseudomonas aeruginosa counts across all sampling weeks and in the overall mean at ($P \leq 0.05$). Tap water (T2) exhibited the highest bacterial counts compared with the other treatments, with an overall mean of 1.34 Log_{10} CFU/100 mL, showing a gradual increase throughout the experimental period.

In contrast, no detectable growth of Pseudomonas aeruginosa was observed in bottled water (T1) during the entire study period, indicating a significant reduction compared with the other treatments ($P \leq 0.05$). Similarly, the newly installed purification system equipped with a UV unit (T5) showed very low bacterial levels, with an overall mean of 0.05 Log_{10} CFU/100 mL.

Purification systems lacking a UV unit also demonstrated a significant reduction in bacterial counts compared with tap water ($P \leq 0.05$). The new system without UV (T3) recorded an overall mean of 0.54 Log_{10} CFU/100 mL, whereas the old system without UV (T4) showed relatively higher values with an overall mean of 1.06 Log_{10} CFU/100 mL. Likewise, the old system equipped with a UV unit (T6) reduced bacterial counts compared with tap water, with an overall mean of 0.55 Log_{10} CFU/100 mL. Overall, the results indicate that household water purification systems contributed to reducing Pseudomonas aeruginosa contamination to varying extents depending on system age and the presence of a UV disinfection unit, with all treatment differences being significant at ($P \leq 0.05$).

Table 4: *Effect of household water purification systems on Total Plate Count (TPC) (Log_{10} CFU/100 mL, Mean ± SE)*

Treatment	Week 1	Week 2	Week 3	Week 4	Overall Mean
T1 Bottled water	0.48 ± 0.02 d	0.48 ± 0.03 d	0.54 ± 0.01 d	0.55 ± 0.02 d	0.51 ± 0.02 d
T2 Tap water	2.51 ± 0.05 a	2.56 ± 0.05 a	2.58 ± 0.05 a	2.61 ± 0.05 a	2.56 ± 0.05 a
T3 New system without UV	1.54 ± 0.04 c	1.60 ± 0.03 c	1.62 ± 0.04 c	1.65 ± 0.02 c	1.60 ± 0.04 c
T4 Old system without UV	2.01 ± 0.04 b	2.05 ± 0.05 b	2.08 ± 0.05 b	2.11 ± 0.05 b	2.06 ± 0.04 b
T5 New system with UV	1.02 ± 0.03 d	1.04 ± 0.02 d	1.05 ± 0.04 d	1.07 ± 0.03 d	1.05 ± 0.03 d
T6 Old system with UV	1.52 ± 0.04 c	1.55 ± 0.03 c	1.58 ± 0.05 c	1.60 ± 0.04 c	1.56 ± 0.04 c
Sig.	*	*	*	*	*

Values represent Mean ± Standard Error (SE) of three replicates. Means followed by different letters within the same column differ significantly at $P \leq 0.05$ according to the Least Significant Difference (LSD) test. Microbial counts were log-transformed using Log10 (CFU + 1) prior to statistical analysis.

Effect of household water purification systems on total Plate Count (TPC) during the study period

Table 4 shows significant differences among the studied treatments in Total Plate Count (TPC) throughout all sampling weeks and in the overall mean at ($P \leq 0.05$). Tap water (T2) consistently recorded the highest bacterial counts compared with the other treatments, with an overall mean of 2.56 Log_{10} CFU/100 mL, showing a slight increase during the experimental period.

Conversely, bottled water (T1) exhibited the lowest bacterial counts with an overall mean of 0.51 Log_{10} CFU/100 mL, indicating a significant reduction compared with the remaining treatments ($P \leq 0.05$). A noticeable reduction in TPC was also observed in the newly installed purification system equipped with a UV unit (T5), which recorded an overall mean of 1.05 Log_{10} CFU/100 mL. Purification systems lacking a UV unit showed relatively higher bacterial levels. The new system without UV (T3) recorded an overall mean of 1.60 Log_{10} CFU/100 mL, whereas the old system without UV (T4) exhibited higher counts with an overall mean of 2.06 Log_{10} CFU/100 mL. Similarly, the old system equipped with a UV unit (T6) reduced bacterial counts compared with tap water, with an overall mean of 1.56 Log_{10} CFU/100 mL. Overall, the findings indicate that household water purification systems contributed to lowering the total bacterial load in drinking water to varying degrees depending on system age and the presence of a UV disinfection unit, with all treatment differences being significant at ($P \leq 0.05$).

The significant reduction in pathogenic bacterial counts in drinking water, as shown in Tables (1–4), can be explained by the ability of household water purification systems to remove microorganisms through a combination of physical and chemical processes. Multi-stage filtration systems function by trapping fine particles and microbial cells within the different filter layers, such as activated carbon filters or semi-permeable membranes, thereby reducing the microbial load in treated water compared with untreated water. In addition, adsorption and physical retention mechanisms within filter media contribute to the removal of a considerable proportion of bacteria and suspended materials that may otherwise provide a suitable environment for microbial growth (Brown *et al*., 2021; Rao *et al*., 2024).

The greater improvement observed in systems equipped with ultraviolet (UV) disinfection units can be attributed to the direct antimicrobial action of UV radiation. Ultraviolet light damages the deoxyribonucleic acid (DNA) of bacterial cells through the formation of thymine dimers, which interfere with DNA replication and ultimately inhibit the ability of microorganisms to reproduce and survive in water. For this reason, UV disinfection is considered one of the most effective methods for reducing microbial contamination in household water treatment systems (Hijnen *et al*., 2006; Kirpichenkova *et al*., 2024).

The variation in system efficiency depending on system age may also be explained by the gradual accumulation of suspended particles and organic matter within the filter media over time. Such accumulation can reduce filtration efficiency and promote the formation of biofilms within the system components. These biofilms may provide favorable conditions for microbial growth, thereby decreasing the effectiveness of microbial removal in older systems compared with newer ones. Several studies have indicated that failure to replace filters regularly can lead to a decline in the performance of household water purification systems over time (Lin *et al*., 2020)

The present findings are consistent with those reported by Zhang *et al.* (2019), who demonstrated that household filtration systems can significantly reduce microbial contamination in drinking water through the removal of bacteria and suspended solids during the filtration process. Similarly, Rodrigues *et al.* (2021) reported that combining filtration technologies with ultraviolet disinfection results in a substantial reduction in coliform bacteria and Escherichia coli in treated water. In addition, Ammar *et al.* (2024) found that multi-stage household filtration systems significantly improve the microbial quality of drinking water and reduce bacterial contamination levels.

Recent studies have also emphasized the potential of environmentally sustainable antimicrobial agents derived from organic waste in reducing microbial contamination in environmental systems. For example, Al-Salhi *et al.* (2025) reported the production of antibacterial compounds derived from poultry manure and Ziziphus spina-christi leaves, which demonstrated significant inhibitory activity against pathogenic microorganisms. Similarly, Naser *et al.* (2025) developed a natural multi-purpose cleaner and disinfectant produced from restaurant organic waste that showed promising efficiency in reducing microbial loads. These findings highlight the growing importance of utilizing natural and sustainable resources as complementary approaches for controlling microbial contamination in water and environmental systems.

Overall, the results presented in Tables (1–4) indicate that household water purification systems particularly those combining multi-stage filtration with ultraviolet disinfection represent an effective approach for improving the microbial quality of drinking water and reducing bacterial contamination levels. However, maintaining the efficiency of these systems depends largely on regular maintenance and periodic filter replacement to ensure their continued effectiveness in removing microbial contaminants.

Effect of household water purification systems on physico-chemical characteristics of drinking water

The results presented in Table 5 indicate significant differences among the studied treatments in the physicochemical characteristics of drinking water, including pH, electrical conductivity (EC), total dissolved solids (TDS), and turbidity, at ($P \leq 0.05$).

Tap water (T2) exhibited the highest values of EC, TDS, and turbidity, reaching 680 µS/cm, 450 mg/L, and 2.5 NTU, respectively, reflecting higher concentrations of dissolved salts and suspended particles compared with the other treatments. In contrast, bottled water (T1) showed the lowest values for these parameters, recording 250 µS/cm for EC, 160 mg/L for TDS, and 0.5 NTU for turbidity, with a pH value of 7.2.

The results further demonstrate that household water purification systems significantly improved these physicochemical parameters compared with tap water ($P \leq 0.05$). The new system without a UV unit (T3) recorded values of 300 µS/cm for EC, 180 mg/L for TDS, and 1.0 NTU for turbidity, whereas the old system without a UV unit (T4) exhibited relatively higher values of 350 µS/cm, 210 mg/L, and 1.5 NTU, respectively. Purification systems equipped with a UV unit also showed noticeable improvement in water quality parameters. The newly installed system with UV (T5) recorded 280 µS/cm for EC, 170 mg/L for TDS, and 0.8 NTU for turbidity, while the old system with UV (T6) recorded 320 µS/cm, 200 mg/L, and 1.2 NTU, respectively. Overall, the findings indicate that household water purification systems contributed to improving the physicochemical quality of drinking water compared with tap water, while pH values remained close to neutrality across all treatments, with significant differences observed among treatments at ($P \leq 0.05$).

Table 5: *Physicochemical characteristics of drinking water from household purification Systems (Mean ± SE)*

Treatment	pH	EC (µS/cm)	TDS (mg/L)	Turbidity (NTU)
T1 Bottled water	7.2 ± 0.02 c	250 ± 5.41 d	160 ± 4.22 d	0.5 ± 0.03 d
T2 Tap water	7.8 ± 0.03 a	680 ± 10.00 a	450 ± 8.12 a	2.5 ± 0.10 a
T3 New system w/o UV	7.3 ± 0.02 bc	300 ± 6.10 c	180 ± 5.10 c	1.0 ± 0.05 c
T4 Old system w/o UV	7.4 ± 0.03 b	350 ± 7.50 b	210 ± 6.24 b	1.5 ± 0.07 b
T5 New system w/ UV	7.2 ± 0.02 c	280 ± 6.09 cd	170 ± 5.31 cd	0.8 ± 0.04 cd
T6 Old system w/ UV	7.3 ± 0.03 bc	320 ± 7.01 bc	200 ± 6.60 bc	1.2 ± 0.06 bc
Sig.	*	*	*	*

Values represent Mean ± Standard Error (SE) of three replicates. pH, EC, TDS, and Turbidity were measured according to standard procedures.

The improvement observed in the physical and chemical characteristics of drinking water, as presented in Table 5, can be explained by the ability of household water purification systems to remove various suspended and dissolved contaminants through a combination of physical and chemical processes occurring within different filtration units. Multi-stage filtration systems remove suspended particles and organic and inorganic substances through mechanical filtration and adsorption processes, particularly when filtration media such as activated carbon or fine membranes are used. These materials contribute significantly to improving the physical properties of water and reducing turbidity and total dissolved solids compared with untreated water (Shannon *et al*., 2008; Tang *et al*., 2019).

This improvement may also be attributed to the ability of certain household purification systems to reduce the concentration of dissolved ions and minerals through membrane filtration or ion exchange technologies. These processes function by selectively removing dissolved salts and chemical contaminants that may negatively affect drinking water quality. Several studies have reported that membrane filtration technologies used in household water treatment systems can effectively reduce a wide range of chemical contaminants and improve the physicochemical properties of drinking water (Pendergast and Hoek, 2011; Elimelech and Phillip, 2011).

Furthermore, the variation in system efficiency may be related to the type of filtration media used and the number of treatment stages within the purification system. Multi-stage filtration systems are generally more effective in contaminant removal compared with single-stage systems because each treatment stage targets specific types of contaminants. Consequently, the sequential treatment process enhances the overall quality of drinking water (Peter-Varbanets *et al*., 2009).

The present findings are consistent with several previous studies that have demonstrated the effectiveness of point-of-use water treatment systems in improving drinking water quality by reducing turbidity, total dissolved solids, and certain chemical contaminants. For instance, Lantagne and Clasen (2012) reported that household water treatment technologies can significantly improve the physical and chemical characteristics of drinking water and reduce health risks associated with untreated water consumption. Similarly, Sinha *et al*. (2023) indicated that modern household filtration systems are capable of reducing various chemical contaminants and improving the quality of drinking water in domestic environments.

Overall, the results presented in Table 5 indicate that household water purification systems can play a significant role in improving the physicochemical quality of drinking water. However, the efficiency of these systems largely depends on the type of treatment technology employed, the number of filtration stages, and regular maintenance practices, including periodic filter replacement, to ensure sustained effectiveness in removing different types of contaminants.

This may be related to improved environmental monitoring and early detection of pollutants that affect public health (Al-Salhi *et al*., 2026).

Effect of household water purification systems on algal density during the experimental period

The results presented in Table 6 revealed significant differences among the studied treatments in algal density throughout all sampling weeks as well as in the overall mean at ($P \le 0.05$).

Table 6: *Algal density in drinking water from household purification systems (Log_{10} CFU/100 mL, Mean ± SE)*

Treatment	Week 1	Week 2	Week 3	Week 4	Overall mean
T1 Bottled water	0.00 ± 0.00 d	0.00 ± 0.00 d	0.00 ± 0.00 d	0.00 ± 0.00 d	0.00 ± 0.00 d
T2 Tap water	220 ± 10.00a	230 ± 12.00a	240 ± 10.01a	250 ± 12.44a	235 ± 10.15 a
T3 New system w/o UV	50 ± 4.22 c	55 ± 3.20 c	60.0 ± 4.11 c	65 ± 4.34 c	57 ± 3.22 c
T4 Old system w/o UV	120 ± 6.12 b	130 ± 7.24 b	140 ± 6.14 b	150 ± 7.23 b	135 ± 6.13 b
T5 New system with UV	10 ± 1.45 d	12 ± 1.27 d	10 ± 1.19 d	12 ± 1.33 d	11 ± 1.16 d
T6 Old system with UV	40 ± 3.14 c	45 ± 3.64 c	50 ± 3.54 c	55 ± 3.12 c	48 ± 3.24 c
Sig.	*	*	*	*	*

Values represent Mean ± Standard Error (SE) of three replicates.
Means followed by different letters within the same column differ significantly at $P \le 0.05$ (LSD test).
Algal density measured after sedimentation and direct microscopic counting.

Tap water (T2) exhibited the highest algal density compared with the other treatments, with an overall mean of 235 cells/mL, showing a gradual increase over the experimental period. This may be attributed to the higher availability of nutrients and favorable conditions for algal growth in untreated water.

In contrast, no algal cells were detected in bottled water (T1) throughout the study period, indicating its high quality and absence of algal contamination. Household water purification systems significantly reduced algal density compared with tap water ($P \le 0.05$). The new system without a UV unit (T3) recorded an overall mean of 57 cells/mL, whereas the old system without a UV unit (T4) showed higher values with an overall mean of 135 cells/mL, suggesting a decline in system efficiency over time. Furthermore, the presence of a UV disinfection unit resulted in a marked reduction in algal density. The newly installed system equipped with a UV unit (T5) recorded the lowest values, with an overall mean of 11 cells/mL, while the old system with a UV unit (T6) showed an overall mean of 48 cells/mL. Although still lower than non-UV systems, the higher values observed in the old system indicate a reduction in disinfection efficiency with system age. Overall, the findings demonstrate that household water purification systems effectively reduced algal density, with superior performance observed in newly installed systems equipped with UV disinfection units. All treatment differences were significant at ($P \le 0.05$).

The results presented in Table 6 indicate noticeable changes in the chemical characteristics of drinking water after treatment using household purification systems. These changes can be attributed to the ability of household filtration technologies to modify the chemical composition of water through several treatment mechanisms, including adsorption, membrane filtration, and ion exchange processes.

One of the main factors contributing to this improvement is the presence of activated carbon and other filtration media within household purification systems. Activated carbon has a high adsorption capacity due to its large surface area and porous structure, enabling it to remove dissolved organic compounds, chlorine residues, and certain inorganic contaminants from drinking water. This process contributes to improving the chemical stability of treated water and reducing undesirable chemical components (Mohan and Pittman, 2007; Bhatnagar and Sillanpää, 2017).

In addition, membrane-based filtration systems such as reverse osmosis or ultrafiltration can effectively reduce the concentration of dissolved salts and ions present in water. These technologies operate by allowing water molecules to pass through semi-permeable membranes while retaining larger dissolved particles and ionic species, thereby improving the chemical quality of drinking water and reducing parameters such as total dissolved solids and electrical conductivity (Greenlee *et al*., 2009; Subramani and Jacangelo, 2015). The variation observed among the purification systems may also be related to differences in system design, treatment stages, and operational conditions. Multi-stage purification systems generally demonstrate higher efficiency in improving water chemistry because each treatment stage targets specific contaminants, resulting in more comprehensive removal of undesirable substances from drinking water (Peter-Varbanets *et al*., 2009).

These findings are consistent with several studies that have demonstrated the effectiveness of household water treatment systems in improving the chemical quality of drinking water. For example, Bhatnagar and Sillanpää (2017) reported that adsorption-based filtration systems significantly reduce organic and inorganic contaminants in water.

Similarly, Subramani and Jacangelo (2015) highlighted the important role of membrane technologies in improving drinking water quality by reducing dissolved chemical substances. Overall, the results presented in Table 6 suggest that household water purification systems can significantly contribute to improving the chemical quality of drinking water. However, the effectiveness of these systems depends largely on the type of filtration technology used, the quality of the filtration media, and proper maintenance practices, including regular filter replacement to maintain optimal system performance.

Effect of household water purification systems on heavy metal concentrations in drinking water

The results presented in Table 7 indicate significant differences among the studied treatments in the concentrations of heavy metals (Pb, Cd, Cu, and Zn) at ($P \leq 0.05$).Tap water (T2) recorded the highest concentrations of all analyzed heavy metals, reaching 15, 2.5, 25, and 50 µg/L for Pb, Cd, Cu, and Zn, respectively, reflecting elevated levels of metal contamination in local water sources.

In contrast, bottled water (T1) exhibited the lowest concentrations, with values of 1.0, 0.2, 5, and 15 µg/L, respectively, indicating compliance with standard drinking water quality specifications. Household water purification systems significantly reduced heavy metal concentrations compared with tap water ($P \leq 0.05$). The new system without a UV unit (T3) recorded concentrations of 5, 0.8, 12, and 25 µg/L, whereas the old system without a UV unit (T4) showed higher values of 8, 1.2, 18, and 35 µg/L, suggesting a decline in removal efficiency with system age. Furthermore, systems equipped with a UV disinfection unit demonstrated additional improvement in reducing heavy metal concentrations. The newly installed system with UV (T5) recorded very low values of 2, 0.3, 6, and 18 µg/L, while the old system with UV (T6) showed values of 4, 0.5, 10, and 22 µg/L. Although still lower than non-UV systems, the increase in values in the old system indicates reduced efficiency over time. Overall, the findings demonstrate that household water purification systems effectively reduce heavy metal concentrations in drinking water, with superior performance observed in newly installed systems, particularly those equipped with UV disinfection units. All treatment differences were significant at ($P \leq 0.05$).

Table 7: *Concentrations of heavy metals in drinking water from household purification systems (µg/L, Mean ± SE)*

Treatment	Pb (µg/L)	Cd (µg/L)	Cu (µg/L)	Zn (µg/L)
T1 Bottled water	1.0 ± 0.05 d	0.2 ± 0.01 d	5.0 ± 0.2 c	15 ± 0.5 c
T2 Tap water	15 ± 0.5 a	2.5 ± 0.1 a	25 ± 1.1 a	50 ± 2.2 a
T3 New system w/o UV	5 ± 0.2 c	0.8 ± 0.05 c	12 ± 0.5 b	25 ± 1.2 b
T4 Old system w/o UV	8 ± 0.3 b	1.2 ± 0.05 b	18 ± 0.8 a	35 ± 1.0 b
T5 New system with UV	2 ± 0.1 d	0.3 ± 0.01 d	6 ± 0.2 c	18 ± 0.5 c
T6 Old system with UV	4 ± 0.2 c	0.5 ± 0.02 c	10 ± 0.3 b	22 ± 0.6 b
Sig.	*	*	*	*

Values represent Mean ± Standard Error (SE) of three replicates. Means followed by different letters within the same column differ significantly at P ≤ 0.05 (LSD test).
Heavy metals measured using Atomic Absorption Spectrophotometry (AAS).Acidification used.

The results presented in Table 7 indicate a noticeable improvement in certain chemical characteristics of drinking water after treatment using household purification systems. This improvement can be explained by the ability of various treatment technologies used in these systems to remove or reduce the concentration of several dissolved chemical contaminants in water. Most household water purification systems rely on a combination of physical and chemical processes, including adsorption, membrane filtration, and ion exchange, which collectively contribute to improving water quality by reducing the concentration of salts, minerals, and undesirable chemical substances (Tchobanoglous *et al*., 2014).

Adsorption using activated carbon is one of the most widely applied techniques in household water purification systems due to its high efficiency in removing dissolved organic compounds, chlorine residues, and certain chemical contaminants that may affect the taste, odor, and overall quality of drinking water. This efficiency is mainly attributed to the large surface area and porous structure of activated carbon, which allows it to adsorb a wide range of chemical compounds from water (Snyder *et al*., 2007).

The improvement in water chemistry may also be attributed to the use of membrane filtration technologies such as reverse osmosis, which is considered one of the most effective techniques for removing dissolved salts, heavy metals, and various chemical pollutants from drinking water. Semi-permeable membranes in these systems allow water molecules to pass through while retaining most dissolved ions and contaminants, thereby improving the chemical quality of treated water compared with untreated water (Ghaffour *et al*., 2013).

The variation observed among different purification systems may also be related to several factors, including the type of treatment technology used, the number of filtration stages within the system, and the characteristics of the raw water entering the treatment unit. Multi-stage purification systems are generally more efficient in removing chemical contaminants than single-stage systems because each stage is designed to target specific types of pollutants (Shannon *et al*., 2008).

These findings are consistent with previous studies demonstrating that point-of-use water treatment systems can effectively improve the chemical and physical characteristics of drinking water while reducing health risks associated with untreated water consumption. For instance, Lantagne and Clasen (2012) reported that household water treatment technologies can significantly improve drinking water quality in domestic environments. Similarly, Momba *et al*. (2015) showed that household treatment systems contribute to improving drinking water quality by reducing the concentration of several chemical contaminants.

Overall, the results presented in Table 7 suggest that household water purification systems can play an important role in improving the chemical characteristics of drinking water. However, the effectiveness of these systems largely depends on the type of treatment technology employed, the quality of filtration materials, and proper maintenance practices, including regular replacement of filters to ensure optimal performance in removing chemical contaminants.

Conclusions and Recommendations

In conclusion, this study demonstrates that household water purification systems are effective in improving drinking water quality by reducing microbial contamination, lowering algal density, decreasing heavy metal concentrations, and enhancing physicochemical properties. The efficiency of these systems was influenced by their age, with newly installed systems showing superior performance compared to older ones. Systems equipped with ultraviolet (UV) disinfection units achieved the highest treatment efficiency. Therefore, the use of modern household water purification systems, particularly those integrated with UV technology, is recommended to ensure safer and higher-quality drinking water.

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Novelty Statement

This study provides valuable insights into the current state of water quality and highlights the extent of pollution in locally available water sources. It also examines the effectiveness of domestic water purification systems in improving water quality and reducing pollutants. These findings provide valuable scientific insights for enhancing water quality management and promoting environmental and agricultural sustainability.

Author's Contribution

Hawraa A.Mohammed: Study design, supervision, and manuscript writing.
Noor al-huda M. Ali: Experimental work and data collection.
Khansaa A. Hussein: Methodology and statistical analysis.
Asawer H. Sharif: Scientific review and final editing.

Generative AI and AI-assisted technology statement

The authors declare that no generative AI and AI assisted technology was used in the creation of this manuscript.

Conflict of interest

The authors have declared no conflict of interest.

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