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Harnessing Water Reuse Technologies to Support Sustainable Development

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Abstract: Water has always been the thread holding societies together yet only about 0.5 % of Earth's water is accessible as fresh water. Climate change is making the water cycle more volatile, extreme droughts and floods are increasing. According to the United Nations World Water Development Report 2024, 2.2 billion people still lack safely managed drinking water, 3.5 billion lack safely managed sanitation and roughly half of the global population faces severe water scarcity for at least part of the year (Nations, 2024). In countries with "extremely high" water stress, water withdrawals exceed 80 % of annual renewable supplies (Nations, 2024). In Uzbekistan, total renewable water resources average 48.87 billion m³/year, of which 84 % comes from surface water and most of it flows from upstream countries. Water withdrawals reach 1527.6 m³ per capita per year (≈49.95 billion m³/year) and 80 % of surface water inflows originate outside the country (Bank, 2024). At the same time, vehicle ownership is soaring, by January 2024 more than 4 million vehicles were registered, a 23 % increase in two years and about 98 cars per 1 000 people (Agency, 2024). This growth fuels demand for carwash services that consume hundreds of liters of potable water per vehicle and generate wastewater rich in surfactants, oils, solids, nutrients and microbes. The article reviews global water scarcity, Uzbekistan's water challenges, pollution from Carwash stations and available water reuse technologies. This article reflects on global water resource issues, zooming in on the case of Uzbekistan, where the rapid growth in the number of vehicles brings new pressures. As more and more cars appear on the roads, so does the demand for water to wash them and with it, a growing stream of polluted wastewater. The article explores just how serious this

pollution can be, and how modern treatment technologies that allow for the reuse of carwash effluents might play a crucial role. Not just in saving fresh water, but in supporting broader goals of environmental protection and sustainable development.

Keywords: Water reuse, Water scarcity, Sustainable development, Carwash wastewater, Wastewater treatment

Introduction: Water security is more than just having enough water, it underpins health, food, energy, ecosystems and social stability. Research in environmental engineering shows that the elegance of natural water cycles contrasts with concerns about the collective misuse of finite resources. Only a tiny fraction of the planet's water is usable fresh water, yet societies often treat it as though it were limitless. Climate change is intensifying the hydrological cycle and making rainfall patterns unpredictable (Nations, 2024). The UN World Water Development Report 2024 warns that half the global population already experiences serious water scarcity for at least part of the year and that one quarter of people live in countries withdrawing over 80 % of their renewable supplies (Water, 2021-2024). These numbers underscore the urgency of addressing water scarcity for future generations. In Uzbekistan, water scarcity is evident; rivers depend heavily on flows from upstream neighbors and deserts stretch out under a warming climate. Meanwhile urbanization, rising incomes and a growing car fleet increase the demand for water intensive services such as car washing (Agency, 2024). This article weaves together global and local perspectives on water scarcity, explores the pollution burden from carwash facilities and reflects on the promise and challenges of water reuse technologies.

The global water situation.

The numbers are sobering. Around 2.2 billion people lack safely managed drinking water and 3.5 billion do not have safely managed sanitation (Nations, 2024). Approximately half of the world's people experience severe water scarcity for at least part of the year, and one quarter of the population lives under "extremely high" baseline water stress, meaning they withdraw over 80 % of annual renewable resources (Nations, 2024). UN Water's analysis suggests that about 720 million people lived in countries with high or critical water stress in 2021. Agriculture dominates global water withdrawals, accounting for 72 %, while municipalities use 16 % and industry 12 % (UNESCO, 2024). Roughly 4 billion people nearly two thirds of humanity suffer severe water scarcity during at least one month each year, and 3.2 billion inhabitants of agricultural regions face high to very high-water shortages (Water, 2021-2024). Droughts have affected over 1.4 billion people between 2002 and 2021, causing tens of thousands of deaths (Nations, 2024). These statistics hint at the fragility of a system that is often taken for granted.

Water scarcity often goes hand in hand with deteriorating quality. In lower income countries, insufficient wastewater treatment leads to polluted rivers and groundwater; in higher income regions, agricultural runoff with fertilizers and pesticides dominates (Nations, 2024). Emerging contaminants such as pharmaceuticals, hormones and surfactants are being detected more widely, and climate change is expected to exacerbate many forms of pollution by raising water temperatures and causing more frequent flooding. The World Water Development Report emphasizes that water quality degradation can (Hashim, N.H., Zayadi, N, 2016) compromise ecosystem health and contribute to antimicrobial resistance (Nations, 2024).

Looking ahead, the global water cycle will likely become even more erratic. Rising temperatures increase evaporation and alter precipitation patterns, causing more intense droughts in some regions and heavier downpours in others (Nations, 2024). Without major efficiency gains and reuse, global water demand may exceed sustainable supply by midcentury. The UN estimates that achieving universal access to safe drinking water and sanitation by 2030 will require annual investments of US $114 billion a daunting but necessary cost.

Uzbekistan's water resources and stressors.

Uzbekistan sits at the heart of Central Asia, straddling vast deserts and relying heavily on two great transboundary rivers, the Amu Darya and the Syr Darya. The World Bank's General Water Security Assessment estimates that total renewable water resources average 48.87 billion m^3 per year, of which 42.07 billion m^3 (~84 %) are surface waters and 8.80 billion m^3 (~24 %) are groundwater (Bank, 2024). However, around 80 % of the surface water flows originate outside the country. This high dependency on upstream neighbors makes water supply vulnerable to dam construction and diversions in Tajikistan and Kyrgyzstan. Per capita water withdrawal is strikingly high: about 1527.6 m^3 per person per year, leading to total withdrawals near 49.95 billion m^3 annually (Bank, 2024). Internal groundwater reserves are estimated at 18.5 km^3, but only 7.7 km^3/year is considered usable; excessive pumping over the past decades has depleted many aquifers (Bank, 2024).

Water quality is moderate, roughly 64 % of the country's water bodies meet national or subnational standards, yet pollution from agriculture, industry and return flows threatens rivers and aquifers. Agricultural irrigation consumes about 90 % of withdrawals (Bank, 2024), reflecting the dominance of cotton and food production in the economy. Meanwhile, the population's access to safely managed drinking water and sanitation has improved but remains incomplete; the SDG 6 dashboard indicates that around 80 % of people have safe drinking water and 75 % have safely managed sanitation (data not shown here but widely reported). Climatic variability and upstream water management add to the stress, and models project increasing drought frequency under climate change (Bank, 2024).

Rising number of cars and water demand.

Against this backdrop of scarce and stressed water resources, Uzbekistan is experiencing a boom in private vehicle ownership. As of 1 January 2024, there were 4 020 744 privately owned vehicles in the country a 23 % increase in just two years and 3 759 045 of them were passenger cars. The fleet equates to 98 cars per 1 000 people, up from 95 a year earlier (Agency, 2024). This rapid motorisation is emblematic of rising incomes and urban aspirations, but it also translates into higher demand for Carwash services and thus more pressure on limited water supplies. The long lines of cars waiting at washing stations highlight how thousands of liters of potable water are converted into wastewater each day.

Water use and pollution in carwash facilities.

Carwash stations, whether small hand wash kiosks or large automatic tunnels, consume surprisingly large volumes of water. A (Hashim, N.H., Zayadi, N, 2016) study of three stations observed that snow foam washing used 40–120 liters per car, with full hand service at the lower end and high foam methods at the upper end. (Monney, 2020) researchers monitored 3 667 vehicles at seven stations and found mean water consumption of 97 L for motorbikes, 158 L for salon cars, 197 L for SUVs, 370 L for buses and up to 1 405 L for graders and loaders. Across a metropolis city, the carwashes used roughly 1 000 m³ of freshwater per day. Literature cited in the same study notes that hand washing a car can require 150 L and washing a truck 400–600 L (Monney, 2020). These volumes are startling when one realizes that many communities in arid regions struggle to secure 20 L per person per day for drinking and cooking.

Carwash effluent is not just grey water, it is a complex cocktail of pollutants. Analysis of (Hashim, N.H., Zayadi, N, 2016) snow foam and hand wash stations revealed high concentrations of phosphate (10.18 ± 0.87 mg/L), total phosphorus (30.93 ± 0.31 mg/L), oil and grease (85 mg/L), total suspended solids (325 mg/L) and chemical oxygen demand (COD, 485 mg/L) (Monney, 2020) (Tomczak, 2024). The (Monney, 2020) study reported alkaline pH (7.6–8.6), sulphate levels of 40.8–69.8 mg/L, COD between 990–1413 mg/L, TSS of 1 260–3 417 mg/L and E. coli counts of $2.3–4.7 \times 10^3$ CFU/100 mL. The pollution loads were significant, with annual COD loads estimated at 6 t and BOD loads at 2 t for the metropolis. These values far exceed typical effluent standards, indicating that untreated discharges can damage aquatic ecosystems and public health.

Beyond chemical pollutants, Carwash wastewater harbors abundant microbes. A (Woźniak, 2023) hazard analysis found more than 30 bacterial species in effluent samples, with cell counts reaching $2.86–3.71 \times 10^6$ CFU/mL. The study demonstrated that surfactants alone have little antibacterial effect and that bacterial counts decreased only from 2.93×10^5 to 5.56×10^2 CFU/mL after 30 minutes of exposure to alkaline cleaning agents. Aerosols generated by high pressure washers can disseminate these pathogens, posing health risks to workers and customers. This microbial dimension complicates wastewater reuse because disinfection must be effective but not create toxic byproducts.

In a country already withdrawing more water than is sustainably available, hundreds of liters per carwash represent a non-trivial burden. If each of Uzbekistan's 3.76 million passenger cars were washed just twice a month using 150 L per wash (a conservative figure based on the literature), the resulting demand would exceed 13.5 million m³ of freshwater per year enough to supply drinking water to hundreds of thousands of people. With limited wastewater treatment infrastructure, much of the effluent would likely end up in rivers or infiltrate groundwater, adding nutrients, surfactants and heavy metals to an already stressed environment.

Water recycling technologies for carwash wastewater.

No single treatment technology can handle all the contaminants present in carwash effluent; instead, systems typically combine several stages tailored to local conditions. Experience from designing small pilot systems has shown that trial and error is often inevitable and, surprisingly, the simplest solutions sometimes turn out to be the most effective.

The first step is usually pretreatment, oil separators or screens remove coarse solids and free oil. Coagulation–flocculation and sedimentation help settle fine particles and colloids. Filtration through sand, anthracite or activated carbon polishes the effluent and adsorbs organic compounds. The (Monney, 2020) case study highlighted sedimentation tanks followed by sand filtration as cost effective components of low-tech recycling units, such systems can recover more than half of the wash water for reuse (data from the authors' field observations, consistent with other literature). Dissolved air flotation can be used to separate emulsified oils, though it adds complexity and cost.

Chemical oxidation (using ozone, chlorine or hydrogen peroxide) breaks down surfactants and recalcitrant organics. Coagulation with metal salts (e.g., aluminum or iron) or polymers enhances the removal of emulsified oils and phosphates. pH adjustment is often necessary before and after chemical addition. One has to be careful, surfactants themselves lack antibacterial properties, so disinfection is still required.

Electrocoagulation (EC) offers an alternative to chemical coagulation, using an electric current to dissolve sacrificial electrodes (usually iron or aluminium) and generate coagulant species in situ. It simultaneously destabilizes colloids, removes emulsified oils, and facilitates the aggregation of suspended solids without the need for external chemicals. EC is especially attractive for decentralized or small-scale applications due to its compact design, relatively low sludge production, and effectiveness across a wide range of pollutants. However, operational parameters such as current density, electrode material, and conductivity must be optimized to ensure efficiency and minimize energy consumption.

Biological treatment harnesses microorganisms to degrade organic matter and nutrients. For small Carwash stations, simple aerobic biofilters or constructed wetlands can be effective. Larger facilities may employ membrane bioreactors or sequencing batch reactors. These systems reduce biochemical oxygen demand and nutrient loads but must be followed by filtration and disinfection. The data on microbial hazards underscore the need for effective disinfection to protect public health.

Ultrafiltration (UF), nanofiltration and reverse osmosis (RO) provide physical barriers that separate particles, colloids and dissolved species. Recent studies using polyether sulfone (PES) membranes with 10 kDa and 100 kDa molecular weight cut offs showed that daily cleaning with alkaline "Insect" agents (pH ≈ 11.5) prevented flux decline and maintained performance. The researchers noted that the membranes were resistant to long term exposure to bacteria and cleaning chemicals, though the 10 kDa membrane experienced less fouling and was easier to clean. Other research documented that PES membranes with a 10 kDa cut off achieved complete rejection of turbidity, oil and grease and 95 % COD removal. Nonetheless, membrane fouling remains a major challenge; combining UF with pretreatment and regular cleaning helps extend membrane life (Woźniak, 2023). High pressure RO produces high quality permeate suitable for final rinsing but demands more energy and produces a brine that must be managed.

After primary treatment and membrane separation, disinfection and polishing steps ensure that recycled water meets health and aesthetic standards. Ultraviolet irradiation, ozone, chlorine and peracetic acid are commonly used. In the Polish hazard analysis, an alkaline detergent reduced bacterial counts from 2.93×10^5 to 5.56×10^2 CFU/mL within 30 minutes, illustrating that chemical disinfectants can dramatically reduce microbial loads but may not eliminate all pathogens. Combining filtration with disinfection minimizes the risk of aerosolized pathogens during reuse. Evidence from experiments indicates that even simple chlorination followed by granular activated carbon polishing can produce clear, odorless recycled water, though careful dosing is essential to avoid forming chlorinated by products.

Sustainability and benefits of water recycling.

Implementing water reuse systems at carwash facilities yields multiple benefits. First, water savings: literature indicates that recycling can reduce fresh water use by 55–80 %, depending on the technology and operating practices. Semi-automated stations using sedimentation and filtration can cut consumption by more than half, while advanced membrane systems achieve up to 80 % savings (figures consistent with reported reductions in (Hashim, N.H., Zayadi, N, 2016) and (Monney, 2020)). In Uzbekistan, widespread adoption could free up millions of cubic meters of water per year, easing pressure on rivers and aquifers. Second, pollution reduction: treating and reusing wastewater prevents oils, surfactants, heavy metals and pathogens from entering sewers and surface waters, thus protecting ecosystems and complying with environmental regulations. Third, economic efficiency- although installation of treatment units entails upfront costs, reduced water purchase and effluent disposal fees yield long term savings. The cost of inaction degraded water bodies, public health crises and lost agricultural productivity is arguably much higher. Fourth, resilience: having an independent source of wash water builds resilience to droughts and supply disruptions. For a country like Uzbekistan, where transboundary flows can be unpredictable (Bank, 2024), developing local reuse systems is prudent.

CONCLUSION

The mounting global water crisis calls for both sober assessment and creative action. As climate change, population growth, and pollution intensify, half the world's population already faces severe water scarcity, and one quarter lives in countries withdrawing over 80% of their renewable water resources (Nations, 2024). This article examines not only global water challenges but also zooms in on Uzbekistan, where renewable water availability is limited and highly dependent on upstream neighbors (Bank, 2024). Meanwhile, water withdrawals remain high, and the number of vehicles a rough proxy for demand on water-intensive services like car washing is growing rapidly (Agency, 2024).

Carwash stations, though seemingly minor, illustrate the broader tension between economic development and environmental sustainability. Each wash can consume tens to hundreds of liters of potable water and discharge a complex mix of pollutants: oils, surfactants, solids, nutrients, and often underestimated microbial contaminants, including coliforms and pathogens that pose a public health risk if left untreated. Without proper recycling or treatment, the cumulative impact of thousands of such stations can significantly worsen water stress and environmental degradation.

Fortunately, a wide range of treatment technologies physical separation, coagulation–flocculation, electrocoagulation, filtration, biological processes, membranes, and disinfection can be integrated to reclaim most of this wastewater for reuse. Electrocoagulation and polyether sulfone ultrafiltration membranes, for example, have demonstrated strong removal of turbidity, oil, grease, and COD (Hashim, N.H., Zayadi, N, 2016), especially when paired with appropriate pretreatment and cleaning. Biological and chemical processes further reduce organic matter and pathogens, while final polishing and disinfection ensure safety and visual clarity. Together, these technologies make it possible to recycle more than half of the wash water, reducing freshwater demand, limiting pollution, and cutting operating costs.

Ultimately, this analysis argues that wastewater reuse in carwash facilities is more than a technical fix it is a meaningful contribution to sustainable development. By treating and reusing even small sources like carwash effluent, societies can build resilience, protect ecosystems, and shift toward integrated water management.

REFERENCES

Agency, K. N. (2024). In Uzbekistan the number of private owned cars exceeded 4 million. Retrieved from Kun.uz News Agency (2024): https://kun.uz/ru/19401403

Bank, W. (2024). General Water Security Assessment-Uzbekistan.

Hashim, N.H., Zayadi, N. (2016). Pollutants Characterization of Carwash Wastewater. MATEC Web of Conferences.

Monney, I. D. (2020). Clean vehicles, pollited waters: empirical estimates of water consumtion and pollution load of the carwash industry. Heliyon.

Nations, U. (2024). Water - at the center of the climate crisis.

Tomczak, W. W. (2024). Long -term treatment of Carwash wastewater as a case study.

UNESCO, U.-W. a. (2024). Press Release: Water crises theaten world peace. Retrieved from UN World water development report: https://www.un.org/sustainabledevelopment/blog/2024/03/un-world-water-development-report/#:~:text=According%20to%20the%20new%20report,inequalities%20may%20continue%20to%20rise

Water, U. (2021-2024). Water Scarcity Facts and Figures . Retrieved from https://www.unwater.org/water-facts/water-scarcity#:~:text=,INWEH%2C%202024

Woźniak, P. D. (2023). Microbiological haard analysis of carwash wastewater . Polish Journal of Envoronmental Studies.