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ANALYSIS OF WATER USE AND TREATMENT SYSTEMS IN CAR WASHES: A CASE STUDY IN SAMARKAND

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Abstract. According the National Statistics Committee of the Republic of Uzbekistan, in Samarkand 133 registered carwash facilities in 2023 (National Statistics Committee, 2023). More than 90% rely on groundwater supplies, while fewer than 50% discharge to the municipal sewer, the remainder dispose of effluent to cesspits following only rudimentary mechanical pre-treatment (bar screens and settling pits). In a water scarce region with a growing vehicle fleet, this configuration intensifies pressure on aquifers. Basin level indicators from the Global Environmental Flow Information System suggest that, in parts of the Zarafshan/Samarkand area, annual groundwater withdrawals reach approximately 2–5 billion m³, consistent with concerns about over abstraction and environmental impacts (GRAC, 2025) (IWMI, 2018). This study characterizes water use and wastewater management at three representative carwash types in Samarkand, combining metered water balances with semi-structured interviews, passenger car services predominate and are therefore emphasized. The analysis covers washing methods and sequencing, stage-specific water demands, treatment trains in current use, discharge pathways, applicable tariff structures, and discharge/reuse quality requirements. Practices are benchmarked against international experience. Comparative results of water demand showed that local car washes in Samarkand use 30–55% less water compared to international practices. Car washes in Samarkand demonstrated heavy reliance on groundwater, limited sewer connectivity, and reliance on mechanical pre-treatment, which increases the risk of environmental pollution. Practical recommendations are provided to reduce water consumption, improve wastewater discharge quality in line with regulations, or enable reuse through the application of new hybrid treatment systems.

Keywords: car wash; groundwater; water reuse; wastewater treatment.

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Annotatsiya. O‘zbekiston Respublikasi Davlat statistika qo‘mitasi ma’lumotlariga ko‘ra, Samarqand shahrida 2023 yilda 133 ta avtomobil yuvish shoxobchasi ro‘yxatga olingan. Ularning 90 foizdan ortig‘i yer osti suvlari hisobiga ishlaydi, biroq 50 foizdan kamrog‘i shahar kanalizatsiyasiga ulangan, qolganlari esa oqava suvlarni faqat sodda mexanik tozalashdan (panjaralar va cho‘ktirgichlar) o‘tkazib, septiklarga tashlaydi. Avtomobillar soni ortib borayotgan suv tanqisligi kuzatilayatgan hududlarda bunday tizim suv ta’minoti tiimlariga va yer osti suv qatlamlariga bosimni kuchaytiradi. Global ekologik oqimlar axborot tizimilar ma’lumotlariga ko‘ra, Zarafshon/Samarqand hududida yillik yer osti suvlaridan foydalanish hajmi taxminan 2–5 milliard m³ ni tashkil etadi, bu esa ortiqcha yer osti suvlaridan foydalanish va ekologik oqibatlar haqidagi xavotirlarni tasdiqlaydi. Ushbu tadqiqotda hozirda Samarqanddagi uchta turdagi avtomobil yuvish usulida suvdan foydalanish va oqava suvlarni oqizish tizimlarini tahlil qilindi. Tahlil avtomobil yuvish shaxobchalarida ishlatiladigan suv miqdori va avtomoyka egalari va injenerlaridan olingan intervyular asosida olib borildi, asosiy e’tibor yengil avtomobillarga qaratildi, chunki asosan shunaqa tirdagi avtomobillarga xizmat korsatiladi. Tadqiqotda yuvish usullari va ketma-ketligi, bosqichma-bosqich suv sarfi, amaldagi tozalash uskunalari, oqava suvlarning chiqarilish yo‘llari, amaldagi tariflar va qayta foydalanish uchun sifat talablariga e’tibor qaratildi. Amaliyot xalqaro tajribalar bilan solishtirildi. Suv sarfi bo‘yicha taqqoslash natijalari shuni ko‘rsatdiki, Samarqanddagi mahalliy avtoyuvish shoxobchalari xalqaro tajriba bilan solishtirganda 30–55 foiz kam suv sarflaydi. Samarqanddagi avtomobil yuvish shoxobchalari yer osti suvlariga kuchli tayanishi, kanalizatsiya tizimiga qisman ulanish va asosan mexanik tozalashdan foydalanishi bilan ajralib turadi, bu esa atrof-muhitni ifloslanish xavfini oshiradi. Maqolada suv sarfini kamaytirishga qaratilgan amaliy tavsiyalar, oqava suvlarning sifatini oqizishda me’yorlarga moslashtirish va yangi gibrid tozalash tizimlarini joriy etish orqali ularni qayta ishlatish imkoniyatlari o’rganilgan.

Kalit so‘zlar: avtomobil yuvish; yer osti suvlari; suvni qayta ishlatish; oqava suvlarni tozalash.

Аннотация. По данным Государственного комитета Республики Узбекистан по статистике, в Самарканде в 2023 году зарегистрировано 133 автомоечных объекта. Более 90% из них используют подземные воды, при этом менее 50% имеют подключение к городской канализации; остальные сбрасывают сточные воды в выгребные ямы после лишь элементарной механической предварительной очистки (решётки и отстойники). В условиях дефицита воды и роста числа автомобилей такая конфигурация усиливает нагрузку на водоносные горизонты. По данным показателей на бассейновом уровне из

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Глобальной информационной системы экологических стоков, в некоторых районах Зарафшан/Самарканд ежегодный забор подземных вод достигает примерно 2–5 млрд м³, что подтверждает обеспокоенность чрезмерным водоотбором и экологическими последствиями. В данном исследовании охарактеризовано водопользование и управление сточными водами на трёх репрезентативных типах автомоек в Самарканде, с использованием измеренного водного баланса и полуструктурированных интервьюс, основное внимание уделено обслуживанию легковых автомобилей как преобладающему виду деятельности. Анализ охватывает методы и последовательность мойки, поэтапное водопотребление, используемые схемы очистки, пути сброса, применяемые тарифы, а также требования к качеству сброса и повторного использования воды. Практика сопоставлена с международным опытом. Сравнительные результаты потребности воды показали, что локальные автомойки в Самарканде расходуют на 30–55% меньше воды по сравнению с международной практикой. Автомойки в Самарканде характеризуются сильной зависимостью от подземных вод, ограниченным подключением к канализационной сети и применением преимущественно механической предварительной очистки, что повышает риски загрязнения окружающей среды. Разработаны практические рекомендации по снижению водопотребления, улучшению качества сброса сточных вод в соответствии с нормативами или их повторному использованию за счёт внедрения новых гибридных систем очистки.

Ключевые слова: автомойочные станции; подземные воды; повторное использование воды; очистка сточных вод.

1. Introduction

Uzbekistan lies in the arid heart of Central Asia and depends heavily on rivers shared with neighboring states for its water supply. Only about a fifth of the country's water resources are generated within its borders, and projections by the Ministry of Water Resources indicate that, by 2030, the national water shortage could reach 15 billion m³ (World Bank, 2009) (Water Global Practice). Climate change is reducing transboundary flows, yet demand continues to rise with population growth. Inefficient irrigation systems lose about 14 billion m³ of water each year due to leaky earthen canals (World Bank, 2009). Consequently, Uzbekistan has entered an "emergency" phase of water management, prioritising canal concreting, pump modernisation and water-saving technologies.

Under these stresses, groundwater has become a critical buffer. Yet a recent systematic review of groundwater governance in Uzbekistan reports that aquifer reserves declined by 40 % between 1965 and 2002. Official decrees further

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acknowledge that about 35 % of groundwater reserves have been lost in the past three to four decades, with unsustainable withdrawal in districts of Navoi, Samarkand and Jizzakh provinces causing major declines. Monitoring and regulation remain weak; roughly 59 % of groundwater use is unregulated, and there is risk of losing most national reserves within the next ten years. Pollution from agricultural drainage and chemicals has also degraded groundwater quality. These figures highlight the precarious status of subterranean sources around Samarkand and the urgent need to reduce withdrawals (Yusupov, 2019).

At the same time, Uzbekistan's vehicle fleet has expanded rapidly. Data from the National Statistics Committee show that as of 1 April 2025 there were 4.522 million motor vehicles registered to individuals, of which 93 % were passenger cars; registrations grew by 79,800 vehicles in the first quarter of 2025. Growth has been steady: the number of private vehicles rose from about 3.27 million in 2022 to 4.02 million by 1 January 2024 (National Statistics Committee, 2023). Carwash businesses have proliferated to serve this expanding fleet. According to the national statistics agency, 1,467 legal entities provided washing, polishing and related services in 2022; the largest concentrations were in Tashkent city (208 enterprises), Tashkent region (150) and Samarkand region (133 enterprises) (National Statistics Committee, 2023). These figures imply a dense network of wash facilities in Samarkand and suggest high cumulative water demands.

A conventional automatic car wash typically consumes 150 litres of freshwater per vehicle a volume that dwarfs domestic per-capita use in many parts of Uzbekistan. The Ministry of Water Resources notes that many car washes rely on groundwater and often discharge untreated effluent to cesspits or sewers, exacerbating aquifer depletion and pollution. Modern wash-bay recycling systems can reduce water use by 60–90 % per cycle (Cabinet of Ministers, 2010), yet uptake remains limited. Given that most carwash operators in Samarkand currently utilise simple mechanical treatment (grit traps and settling tanks) before disposal, there is substantial opportunity to implement advanced wastewater treatment technologies. Integrating hybrid or other reuse methods would not only reduce groundwater withdrawals but also limit pollutant loads to municipal sewers and the environment.

This case study therefore situates car wash operations within the broader context of water scarcity and groundwater using stress in Uzbekistan. By quantifying water use, evaluating current treatment practices at selected facilities in Samarkand, and comparing them against international standards, the study aims to assess the potential for wastewater reuse and provide evidence-based recommendations to improve water efficiency.

2. Literature review

ISSN 3030-3907

It is useful to structure the review around four threads: (1) how much water car washes use, (2) what is typically found in their effluents, (3) which treatment technologies have been applied, and (4) what performance has been achieved.

Over the last decade, multiple studies confirm that specific water consumption per vehicle spans a wide range from 60–70 L at optimized, high-efficiency sites to 150–600 L at typical facilities without recycling (Afzal, 2024). One synthesis reports an average around 200 L per car, with large urban wash stations reaching about 10 m^3/day (and more in high-throughput tunnels) (Kazembeigi, 2023). Because most facilities historically discharged spent wash water to sewers or cesspits, several jurisdictions introduced strict rules, for example, in the Netherlands and Brazil car washes are required to recycle ≥70% of water used, which has pushed the sector toward closed loop systems (Afzal, 2024). Nevertheless, operators in many cities still consider recycling capital intensive and default to fresh groundwater abstraction with full disposal after use.

CWW (carwash wastewater) is dominated by detergents, oil/grease, and suspended solids. Reviews show COD frequently >400 mg/L, with turbidity up to 1,000 NTU after rudimentary settling (Tomczak W. W., 2023). Broader compilations report COD from 59 to 8,350 mg/L, suspended solids up to 5,460 mg/L, and oils and grease occasionally >4,800 mg/L, reflecting large inter-site variability (Tomczak W. W.-D., 2024). At comparatively "milder" sites, reported ranges were COD 335–555, BOD_5 178–232, anionic surfactants 148–192, and total solids 830–3,340 mg/L, illustrating how detergent packages, service mix, and housekeeping shape influent strength (Afzal, 2024).

Traditional treatment on site is usually limited to bar screens and settling pits, which capture coarse solids but leave dissolved organics, surfactants, and emulsified oil largely untreated. Consequently, research has focused on coagulation/flocculation, electrocoagulation (EC), membranes, and nature-based solutions. A widely cited review notes that flotation–flocculation can remove up to 85% SS and 90% turbidity, with COD reductions of 70–80%, when coupled with complementary steps, overall removal can reach 96%. Electrocoagulation typically achieves 90% turbidity and 80% COD removal, integrating adsorption or electro-oxidation elevates organics removal to 78–97% and anionic surfactant removal to 81–99% (Kuan, 2022). On real effluent from a "Mobil Car Wash" case, optimal conditions were pH 7–8, aluminum electrodes, and NaCl addition, the specific energy ranged 2.32–15.1 kWh/kg COD removed depending on current density and conductivity (El-Ashtoukhy, 2015).

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Membrane processes have gained prominence in recent years. A 2023 synthesis reports ultrafiltration (UF, 10 kDa) achieving near complete turbidity and oil/grease removal and cutting COD from 314 to 64–85 mg/L (≈80% reduction) when preceded by adequate solids oil control and followed by routine chemical cleaning (Tomczak W. W.-D., 2024). Comparative trials with PES UF (10 vs 100 kDa) found both delivered 99% turbidity removal, while the larger-pore membrane fouled more quickly, underscoring the need for cleaning protocols and upstream management of foaming agents and waxes (Tomczak W. W., 2023). Broader reviews covering NF/RO and hybrid trains report COD reductions of 77–95% and turbidity >90% across configurations, albeit with chronic fouling as the principal operational constraint affecting OPEX (Kazembeigi, 2023).

Nature-based and low-cost solutions have also been piloted. In Spain, vertical flow and horizontal flow constructed wetlands and infiltration–percolation beds, after robust mechanical pre-treatment, achieved turbidity <5 NTU and COD <20 mg/L, with recycling up to 60% for non-potable uses under appropriate hydraulic loading and disinfection (Antonina T., 2025). A recent field study in Pakistan integrated floating and subsurface wetlands with sand filtration, reporting compliance-grade effluents, multi-cycle reuse, and a payback <1 year, while promising, such systems remain site-specific and require careful validation for climate, oil/grease, and sludge management (Afzal, 2024).

Finally, regulatory benchmarks for discharge/reuse converge in many jurisdictions on SS <20–40 mg/L, turbidity <5 NTU, oils/grease <5 mg/L, and COD ≲50 mg/L, with microbiological control for onsite reuse loops (Kuan, 2022). Given that raw CWW typically exceeds these thresholds, the literature consistently frames car wash facilities as strong candidates for treatment and water reuse, emphasizing that hybrid trains mechanical pre-treatment → coagulation/EC → UF → optional carbon/AOP or nature-based polishing → disinfection can deliver compliant effluents at acceptable costs where throughput justifies investment.

3. Study area and case sites .

Samarkand lies in the middle Zarafshan basin and overlies the transboundary Zeravshan alluvial aquifer (IGRAC “Transboundary Aquifers of the World,” code AS44), which is shared with Tajikistan

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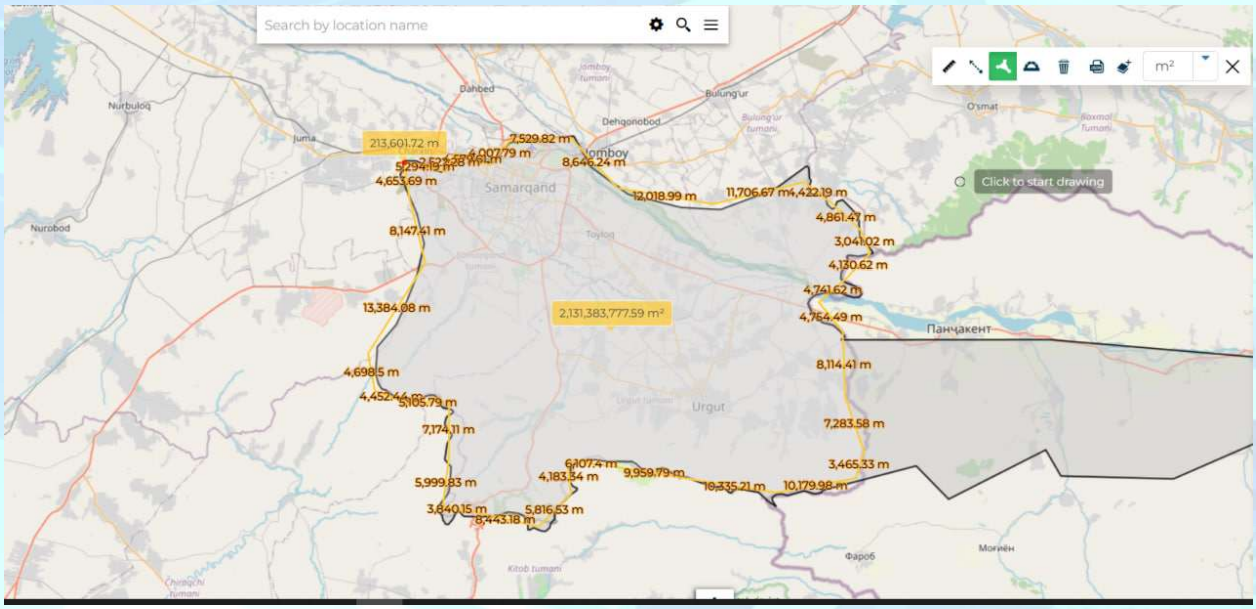


Figure 3.1. Zeravshan Aquifer (IGRAC, "Transboundary Aquifers of the World," AS44) overlaid on Samarkand municipal boundary

The basin's environmental-flow setting and sustainable groundwater abstraction envelopes indicate spatially heterogeneous headroom for pumping

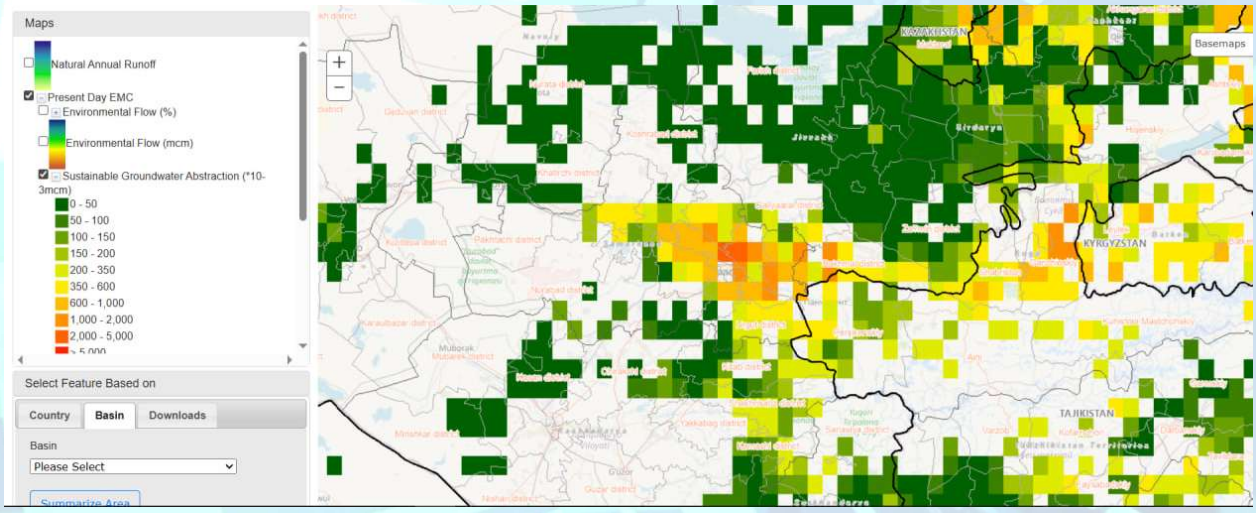


Figure 3.2. GEFIS (IWMI) tiles for the Zarafshan basin: (a) Sustainable Groundwater Abstraction; (b) Environmental Flows (%).

In practice, the city's carwash businesses predominantly rely on private boreholes and shallow alluvium, while municipal supply remains a mix of wellfields and river-connected groundwater galleries.

Regional hydrologic context. Uzbekistan's renewable water endowment is limited in per-capita terms (1,504 m³/person/yr), with total renewable resources averaging 48.9 km³/yr. Roughly 84% of renewable availability is surface water and 16% is groundwaterб flows are highly transboundary about 80% of surface water originates outside the country. These characteristics combine with marked continental seasonality (typical July means near 32 °C, winter means −1 to −6 °C)

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to heighten drought exposure across central and southeastern regions (Water Global Practice) (World Bank, 2009).

Regulatory setting relevant to carwash wastewater. Industrial/commercial wastewater discharged to municipal sewers is regulated by the Cabinet of Ministers' "Rules for Acceptance of Industrial Wastewater…," which require each discharger to meet a communal-ecological norm (KEN) a site-specific permit standard valid for five years and to pre-treat locally so that effluent at the connection does not disrupt sewer or WWTP operation (Cabinet of Ministers, 2010). Oversight is shared between the Uzsuvtaminot and territorial environmental authorities.

Operationally, the rules mandate (1) a two-party contract with the Uzsuvtaminot, (2) continuous internal control of volumes/quality, (3) sampling at the outlet of on-site pre-treatment and in a control manhole immediately upstream of the city connection, (4) full access for inspections and sampling, and (5) monthly reporting of volumes and pollutant loads; accredited Uzsuvtaminot laboratories perform routine monitoring.

Acceptance limits (KEN) most pertinent to carwash effluent values refer to concentrations at the control manhole unless a stricter site KEN applies: pH 6.5–8.5; suspended solids 500 mg/L; COD 500 mg/L; BOD_5 11.3–22.6 mg/L (BOD_{20} 15–30 mg/L); animal/vegetable fats and oils 5 mg/L; anionic surfactants 20 mg/L; petroleum products 1 mg/L (Cabinet of Ministers, 2010).

Case sites. The three surveyed carwash typologies in Samarkand (conventional hand-wash with two settling chambers; semi-automatic bays with pressurized jets; tunnel/roll-over units) operate 10–14 h/day and provide exterior wash, underbody rinse, and interior detailing. Sites with sewer connections use coarse screening and two-stage sedimentation before discharge, off-grid sites use screens plus grease/sand traps followed by soak pits. For sewer-connected sites, the acceptance limits above define design targets for on-site pre-treatment, for pit-discharging sites, these thresholds do not ensure environmental protection of the receiving subsurface and should be treated as minimums, with additional polishing required to protect the Zeravshan aquifer.

Implications for this study.

1. The combination of low per-capita availability, high transboundary dependence, and strong seasonality makes groundwater-efficient designs in Samarkand especially consequential.
2. Many car-washes seeking to avoid sewer-discharge tariffs and the CAPEX/OPEX of meeting effluent standards will continue to rely on self-supplied wells and non-sewered disposal unless compact recycle systems become standard.

ISSN 3030-3907

3. Where sewers exist, compliance hinges on meeting KEN values at the control manhole and on routine reporting/monitoring; this directly informs sampling plans and the sizing of pre-treatment units in our methods.

4. Data Analysis

This section examines the performance of three representative carwash typologies in Samarkand, manual (M1), self-service (M2) and automatic conveyor washes (M3), based on interviews and on-site observations. It then contrasts these findings with published international data to assess water-use efficiency, operational throughput, and wastewater management.

4.1. Local water-use patterns

The three sampled sites revealed distinct patterns in customer volumes and water consumption (Table 1). Self-service bays (M2) dominate the market (65–70 % of stations), followed by manual hand-wash stations (25–30 %) and automatic tunnels (2–5 %). Groundwater is the principal supply source interviewees indicated that more than 90 % of water is drawn from private wells, with only 40 % of stations connected to municipal sewers. After washing, effluent settles in basic sediment traps and either flows into the sewer (≈40 % of sites) or is discharged to soak-away pits, sludge is collected by vacuum trucks and hauled to disposal sites. Operators pay a discharge fee of about 5,600 UZS/m³ for sewer connections and a groundwater abstraction tax of 15,000 UZS/m³ for borehole use. Regulatory oversight is provided by Uzsuvtaminot and environmental authorities.

Table-1.

Summary of local carwash operation metrics and comparison with global ranges.

Method	Prevalence in Samarkand	Water per car (local)	World typical water use	Vehicles per day (local)	Daily water consumption (local)
Manual (M1)	25–30 % of stations	72–84 L	158 L for a salon car; manual wash 188 L; semi-automated 139 L; motorbike/SUV/bus 70–236 L (Monney, 2020).	20–30 vehicles	1.44–2.52 m³/day

ISSN 3030-3907

Self-service (M2)	65–70 % of stations	37–46 L	~120–200 L in global surveys for hand-held or in-bay systems	45–55 vehicles	1.67–2.53 m³/day
Automatic (M3)	2–5 % of stations	400 L	~200–600 L (automated and conveyor systems); buses may exceed 370 L (Monney, 2020).	8–12 vehicles	3.20–4.80 m³/day

The interviews indicate that self-service facilities process roughly 45–55 vehicles per day, each requiring 37–46 L of water (pre-wash, foaming and rinse). Manual stations handle 20–30 cars per day with 72–84 L per wash, while automatic tunnels process 8–12 vehicles per day but consume ≈400 L per car. Using mid-range values, daily water uses at M1, M2 and M3 stations is estimated at 1.5–2.5 m³, 1.7–2.5 m³, and 3.2–4.8 m³, respectively. Operators noted that water consumption increases by 30–40 % in winter due to heavier dirt loads. These figures are plausible when compared with a Ghanaian study that monitored seven stations: it reported that semi-automated bays used 139 ± 64 L per saloon car and manual bays used 188 ± 69 L, while our self-service and manual stations use significantly less water. The automatic tunnel in Samarkand consumes 400 L per car, which lies within the global range of 200–600 L for automated tunnels (Monney, 2020).

4.2. Process sequencing and water-supply arrangements

All three sites follow a similar process sequence: water is pumped from wells or channels into a clean-water tank; in roughly 5 % of stations this water passes through a coarse filter before entering a pump unit; vehicles undergo pre-wetting, foaming with detergent and high-pressure rinsing; wastewater then flows through a grit trap and small settling pit. The study noted almost no adoption of advanced reclaim systems, only occasional reuse of final rinse water for pre-wetting. In contrast, international good practices show that semi-automated spray-wand systems can save ≈55 % water compared to manual washing, and fully automated tunnels in Brazil recover 80 % of water used per vehicle (Monney, 2020; Sarmadi, 2020). On a daily basis, Ghanaian carwash stations monitored by Monney et al. consumed 2.4–15.5 m³/day depending on traffic (Monney, 2020) significantly higher than the observed consumption in Samarkand—suggesting that local washing practices may already be relatively conservative, though still far above the

ISSN 3030-3907

minimal volumes reported for high-efficiency tunnels (8–70 L per vehicle in US and European contexts).

4.3. Seasonal effects and throughput

Operators consistently reported that winter operations require 30–40 % more water due to mud and road salts. Average throughput correlates negatively with water use per vehicle; the Ghana study found that stations washing fewer cars used more water per car, whereas those with high demand used water more efficiently (Monney, 2020). The self-service model in Samarkand fits this pattern: high turnover per bay coincides with the lowest per-car water use. These observations suggest that optimizing operational efficiency (e.g., adopting timed spray wands, promoting single-bucket methods) could further reduce consumption.

4.4. Wastewater management and compliance

None of the surveyed stations employed chemical, biological, or membrane treatment. Owners stated that effluent is allowed to settle and then discharged to the sewer or soak-away pits, they claimed that standard parameters (pH, total suspended solids, COD, oils, and surfactants) met municipal acceptance limits set by the Communal-Ecological Norm (KEN). The regulations specify pH 6.5–8.5, suspended solids ≤ 500 mg/L, COD ≤ 500 mg/L, BOD_5 11.3–22.6 mg/L, oil/grease ≤ 5 mg/L, anionic surfactants ≤ 20 mg/L and petroleum products ≤ 1 mg/L (Cabinet of Ministers, 2010). However, literature indicates that raw carwash effluent often exceeds these limits; mean COD values for manual washes can be 188 mg/L and oil/grease levels can reach several hundred mg/L (Monney, 2020). Consequently, the assumption that simple sedimentation is adequate may be optimistic. Internationally, a variety of technologies, coagulation/flocculation, electrocoagulation, membrane filtration and constructed wetlands can reduce turbidity and COD by 70–95 % (Espinoza-Montero, 2023). For Samarkand, implementing compact recycle units or nature-based polishing could both reduce groundwater abstraction and improve effluent quality.

4.5. Economic considerations and operator perceptions

The interviews highlighted that owners perceive water recycling systems as costly and technically complex. Yet examples from Brazil and Ghana show that conventional carwash stations can save more than twice the water used in manual washes, and recycling can cut water bills by around 32 % (Monney, 2020). With groundwater taxes at 15,000 UZS/m^3 and potential penalties for exceeding KEN limits, the payback period for compact treatment units may be shorter than assumed, especially as water scarcity intensifies.

This analysis underscores that although Samarkand's carwash industry currently uses less water per car than some international counterparts, it still relies

ISSN 3030-3907

almost entirely on groundwater, lacks systematic reuse, and discharges largely untreated wastewater. Aligning with global best practices through optimized spray-wand techniques, mandatory recycling targets and adoption of compact treatment units could significantly reduce water withdrawals and pollutant loads.

Conclusion. In a semi-arid, groundwater-dependent city like Samarkand, carwash facilities can deliver large, measurable water savings with relatively small, well-targeted upgrades. Our case data show self-service bays currently use 37–46 L/vehicle (1.7–2.5 m³/day for 45–55 cars), manual sites 72–84 L/vehicle (1.4–2.5 m³/day for 20–30 cars), and automatic tunnels about 400 L/vehicle (3.2–4.8 m³/day for 8–12 cars). Against international experience, these numbers are mixed: self-service in Samarkand is already below typical global surveys (120–200 L/vehicle), manual is below the 188 ± 69 L reported for similar stations, while the tunnel sits mid-range of 200–600 L/vehicle. The literature further shows that semi-automated spray-wand systems often cut water use by 50–55% relative to manual practice, automated tunnels with recirculation routinely reach ≥ 70–80% internal reuse, and hybrid treatment trains remove turbidity and oils almost completely while pushing COD down by 70–90%, nature-based polishing after mechanical pre-treatment has achieved turbidity < 5 NTU and COD < 20 mg/L, enabling 60% internal recycling. Translating these benchmarks to Samarkand yields clear, numeric targets and payoffs. For a typical self-service site washing 50 cars/day at a global baseline of 150 L/vehicle (7.5 m³/day fresh), installing ≥ 70% recirculation alone drops fresh input to 2.25 m³/day, a saving of 5.25 m³/day, pairing recirculation with process efficiency to 60 L/vehicle drives fresh demand to 0.9 m³/day, a saving of 6.6 m³/day. With the current groundwater abstraction tax of 15 000 UZS/m³, those two steps alone translate into about 2.36–2.97 million UZS/month in avoided abstraction (30-day month). If connected to sewer, cutting bleed-off by the same 5.25–6.6 m³/day also avoids roughly 0.88–1.11 million UZS/month at 5 600 UZS/m³. Winter increases in demand (+30–40%) will raise absolute volumes, but the percentage savings from recirculation and better sequencing hold. Based on these numbers and on the city's regulatory context, the recommended end-state is explicit: near-term ≤ 90 L/vehicle fresh water for passenger cars, medium-term ≤ 60 L/vehicle, ≥ 70–80% internal reuse, and verified compliance at the control manhole with municipal acceptance (KEN) limits for pH, suspended solids, COD, oil/grease, and anionic surfactants.

Operational roadmap (stage-specific water quality with a configurable EC-centred loop). Instead of treating all process water to a single, highest specification, allocate fit-for-purpose water qualities by wash stage and design the reuse train to meet each grade with minimal energy and chemicals. A practical three-grade ladder

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is: Class C (pre-rinse/under-body, floor wash-down) with clarity good enough to protect pumps and no visible oil (turbidity ≤ 15–20 NTU; oils/grease ≤ 5 mg/L); Class B (foam make-up and main high-pressure wash) with low turbidity and suppressed surfactants/oils (turbidity ≤ 5–10 NTU; anionic surfactants kept low; no odor/film); and Class A (final rinse) with near-clear, low-surfactant water (turbidity ≤ 2–5 NTU; oils ≤ 1 mg/L). A combined treatment system can be configured so that electrocoagulation (EC) is the core step for breaking emulsions and aggregating fines, followed by solid–liquid separation (lamella settling or DAF), ultrafiltration (UF) as the physical barrier, and optional polishing activated carbon or mild advanced oxidation where very low surfactant/odor thresholds are needed for Class A.

Crucially, this loop is tunable to the site's dirt load, throughput and target class. In EC, operators can adjust current density and hydraulic retention time (with the well-documented sweet spot around pH 7–8 and a small NaCl dose to stabilize conductivity), trading a few minutes of residence for deeper removal when winter mud increases organics. UF flux and backwash interval can be optimized to keep permeability stable, periodic clean-in-place protects membranes from seasonal fouling. With buffer tanks assigned to Class C/B/A and PLC-based valves, the plant routes clarified (EC) water to Class C, UF permeate to Class B, and carbon-polished UF permeate to Class A, while a small continuous bleed-off (to sewer where available) maintains salt balance. Many car-washes seeking to avoid sewer-discharge tariffs and the CAPEX/OPEX of meeting effluent standards will continue to rely on self-supplied wells and non-sewered disposal unless compact recycle systems become standard, this staged-quality, EC-centred configuration makes that transition practical by matching treatment effort to end-use quality and maximizing internal reuse with documented removals. In sum, combining (1) process efficiency to ≤ 60–90 L/vehicle, (2) ≥ 70–80% recirculation using EC→UF with targeted polishing and class-based allocation, and (3) routine monitoring not only aligns Samarkand's carwash sector with world practice but also delivers 5–7 m^3/day savings per busy site, six-figure UZS monthly cost reductions, and a credible path to KEN-compliant discharge while easing pressure on groundwater resourses.

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