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Driving Towards Sustainability: Assessment of Water Use and Wastewater Characteristics in Ghana's Carwash Industry

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ABSTRACT

In Africa, the carwash industry remains largely unregulated, using large volumes of potable water and releasing polluted wastewater into the environment. However, as freshwater resources dwindle worldwide, the need to conserve water has become very paramount. Implementing water conservation measures for the carwash industry requires comprehensive empirical data on water usage patterns and wastewater characteristics. To this end, this study assessed the water volumes used by the carwash industry and the nature of the wastewater generated at two locations in Ghana. Four proxy carwash stations were purposively selected and monitored over three weeks to determine water used to wash different vehicles, water consumed and wastewater generated. Composite wastewater samples were collected from two carwash stations to characterize the wastewater generated. ANOVA was used to test for statistical variation in wastewater characteristics using IBM SPSS version 26. Between 30 to 50 vehicles are washed daily at the carwash stations. Water volumes used to wash the vehicles varied widely – between 116 and 1127 litres, depending on the size. Vehicles washed manually used more water than those washed with spray guns. Each car wash station used up to 16,000 litres of fresh water and generated about 13,000 litres of wastewater. All the wastewater quality parameters except pH showed a statistically significant variation ($p<0.05$) between the two sample locations. On average, BOD (120-160mg/L) and COD (314-382mg/L) in the carwash wastewater exceeded their respective limits for effluent discharge. The mean BOD:COD ratio was 0.4, indicating difficulty in biological treatment. BOD and COD loads in the wastewater were about 2.55kg/day and 6.1kg/day, respectively. To minimize water consumption and wastewater generation at the carwash stations, spray guns for washing vehicles should be mandatory. Innovative approaches to recycling wastewater should also be further studied.

Keywords: Wastewater, Carwash, Pollutants, Vehicles, Conservation, Recycling

INTRODUCTION

A carwash station, also referred to as a washing bay, is a non-domestic facility used to clean vehicles of all types (Phungula, 2016; Hashim & Zayadi, 2017). This is where the dirt and grime accumulated on vehicles are gotten rid of. The method used for washing the vehicles influences the quantity of water used (Sarmadi *et al.*, 2020). Moreover, this is affected by the size of the vehicle washed (Monney *et al.*, 2020), and the number of washing steps involved in the washing process. Cars usually use about 150L of water per wash, while trucks and buses use 400-600L (Tammiazo *et al.*, 2015). The resulting wastewater from the carwash facilities, usually loaded with dirt, oils and grease, heavy metals, and detergents, mostly ends up in water courses (Bhatti *et al*., 2011). The consequences include the destruction of aquatic ecosystems.

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In Ghana, discharging polluted wastewater from carwash stations is a common practice. The carwash industry is generally unregulated, and personnel in the carwash business seem not to understand the impact of their practices on local water quality degradation (Aikins & Boakye, 2015). Moreover, local authorities seem aloof to the glaring impact on water supply systems and the environment. Meanwhile, earlier studies have revealed the significant challenges that the carwash industry poses to the water supply and the environment. An earlier study in the Kumasi Metropolis of Ghana reported that the carwash industry used about 1,000m^3 of fresh water daily, representing water that could otherwise be used by 9,000 people daily (Monney *et al.*, 2020). As freshwater dwindles globally, this poses a huge challenge to water security, especially in urban centres. Water demand is expected to increase due to the rapidly growing population. In the absence of water conservation measures, this could affect the availability of drinking water for the populace.

For local authorities in Ghana to institute water conservation measures in the carwash industry, empirical data is required to inform decisions. However, available data on water consumption by the carwash industry in Ghana is limited to only two out of sixteen regions in the country. This warrants further empirical data to provide sufficient data and inform decision-makers to develop and implement standardized water conservation measures for the carwash industry nationwide. Therefore, this study adds to the existing knowledge on how much water the carwash industry consumes and the quality of wastewater produced. The study is conducted at selected carwash stations in two towns (Techiman and Nkoranza) in the Bono East Region. Primarily, the study focuses on estimating the water consumed by the carwash industry and the characteristics of wastewater generated. Such information is vital for adopting water conservation measures and designing appropriate wastewater recycling systems to ensure sustainable water use in the carwash industry.

METHODOLOGY

Study Area

The study was conducted at two locations in Ghana, namely, Techiman and Nkoranza. Techiman serves as the capital city of both the Techiman Municipal and the Bono East Region of Ghana. It is a hub for commercial activities and hosts West Africa's largest traditional market. This attracts traders from the West African sub-region who engage in various trades. Nkoranza is located just about 30km South East of Techiman and serves as the capital of the Nkoranza South District, also in the Bono East Region. Due to its proximity to Techiman, it is also home to brisk business activities.

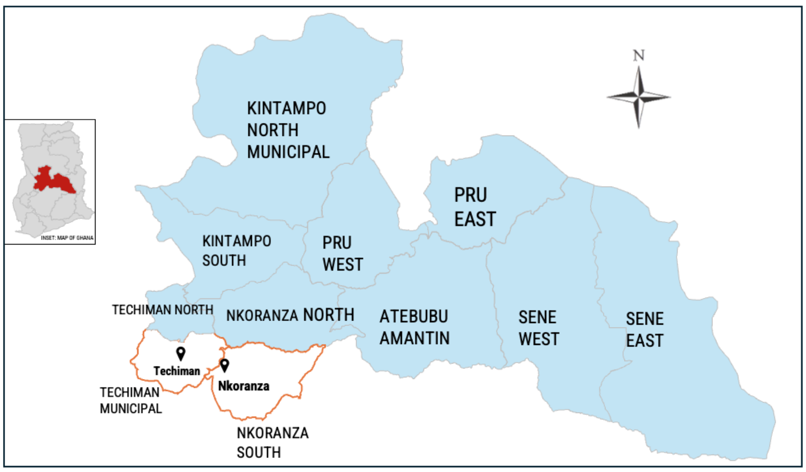


Figure 1: Map of the study area

Selection of Carwash Stations

Reconnaissance surveys were conducted at the two study locations to assess the number of carwash stations, the mode of vehicle washing, the source of water, nature of washing surface, wastewater disposal practices and other relevant characteristics. Based on the initial survey, twenty-two car wash stations were identified, comprising fifteen carwash stations from Techiman and seven from Nkoranza. Two proxy carwash stations were purposively selected from each study location; one used the manual washing method, and the other used the spray gun method.

Monitoring Types and Number of Vehicles Washed

Over a three-week period, including weekends, trained field assistants monitored the type of vehicle washed at each of these car wash stations. The vehicles were grouped into six categories according to that used by Monney *et al.* (2020) and counted using tally sheets. This was to determine the number of different vehicles washed daily at the carwash stations.

Estimation of Water Quantities Used for Washing Vehicles and Wastewater Generated

The approach to determining the quantities of water used for washing vehicles and estimation of wastewater generated followed that described by Monney *et al.* (2020). For each of the four carwash stations, water quantities used for each type of vehicle observed throughout the day were computed. The average amount of water used for each category was determined from this. As the total number of vehicles in each category washed per day were observed, the average amount of water used to wash each vehicle type were multiplied with the total number of vehicles washed and summed up to obtain the total amount of water used by the carwash station daily.

To estimate the volume of wastewater generated in a day by a carwash station, the formula below, per Monney *et al.* (2020) was used:

$$qd = R \times Wd + \sum_{i=l}^{n} pi \times vi$$

where;
qd = daily volumetric flow rate of wastewater of a washing bay
R= estimated return flow of the washing bay (0.8 for paved washing surface; 0.5 for unpaved washing surface)
i = category of vehicle
W_d = median number of cars washed per day (due to high variation in daily vehicles washed).
p_i = proportion of vehicles in the ith category (%)
v_i = volume of water used to wash vehicle in the ith category (L).

Similarly, the pollution loads of the wastewater samples were determined according to Monney *et al*. (2020).

Sampling and Laboratory Analysis of Wastewater

Two carwash stations were purposively selected to collect wastewater samples from vehicles being washed. Wastewater samples were collected on three occasions (once per week) from the selected stations. Composite samples were collected from each washing bay in the morning which was the rush hours - from 9am to 11am. Samples were collected from vehicles being washed and stored in pre-washed 100L plastic containers before being collected into smaller sterilized sampling bottles with 250mL capacity. On the field, measurements of pH, Electrical Conductivity and TDS were done. Samples for heavy metal analysis were acidified using concentrated Nitric acid before being transported. Laboratory analysis were conducted at the Kwame Nkrumah University of Science and Technology, Department of Civil Engineering Laboratory, Kumasi. The wastewater samples were collected from the outfalls of the car wash stations before joining the public drains.

Water quality parameters and the methods used to analyse them are shown in Table 1. All laboratory procedures followed standard protocols described in Standard Methods for the Examination of Water and Wastewater.

Table 1: Water quality parameters and methods of analysis

Parameters	Method/Equipment
pH	EUTECH PC300
EC (µS/cm)	EUTECH PC300
TDS (mg/L)	EUTECH PC300
TSS (mg/L)	Gravimetric method
Turbidity (NTU)	HANNA HI93414 Turbidimeter
COD (mg/L)	HACH 21259 Vial Digestion Solution for COD;HACH DR3900 Spectrophotometer
BOD (mg/L)	Winkler Method
Nitrates (mg/L)	Nitraver 5 Nitrite Reagent Powder Pillows;HACHDR3900 Spectrophotometer
Nitrites (mg/L)	NitriVer 3 Nitrite Reagent Powder Pillows;HACHDR3900 Spectrophotometer
Sulphate (mg/L)	Sulfaver 4 Sulphate Reagent Powder Pillows;HACHDR3900 Spectrophotometer
Phosphate (mg/L)	Phosver 3 Phosphate Reagent Powder Pillows;HACHDR3900 Spectrophotometer
Lead	Atomic Absorption Spectrophotometer
Iron	Atomic Absorption Spectrophotometer

Statistical Analysis

Data entry was done using MS Excel and analysis done using IBM SPSS Statistics 26. Descriptive statistics, including means and standard deviations, were determined. Single factor Analysis of Variance (ANOVA) was used to determine whether the difference in variation of the wastewater characteristics was statistically significant at a 5% significance level. P values less than 0.05 were considered to be statistically significant.

RESULTS

On average, carwash stations using spray guns washed 50 vehicles daily, whereas those using manual washing washed 30 vehicles daily (Figure 2). Almost all (91%, n=20) of these stations obtained water from mechanized boreholes. Overall, 3348 vehicles were washed at the two car washing bays during the three-week monitoring period. Saloon cars were the commonest vehicles washed representing more than one-third (36%) of all vehicle types.

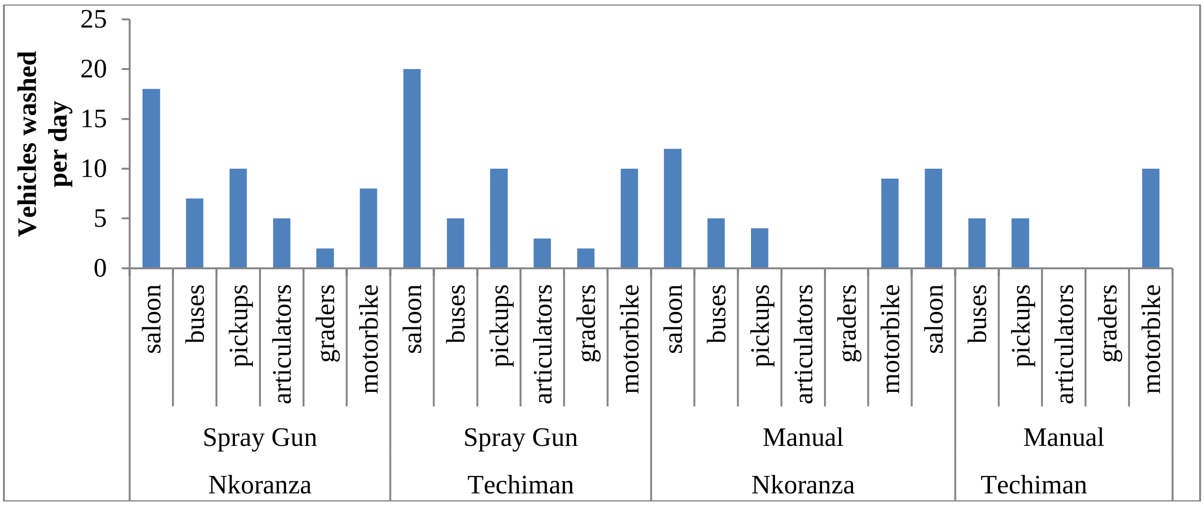
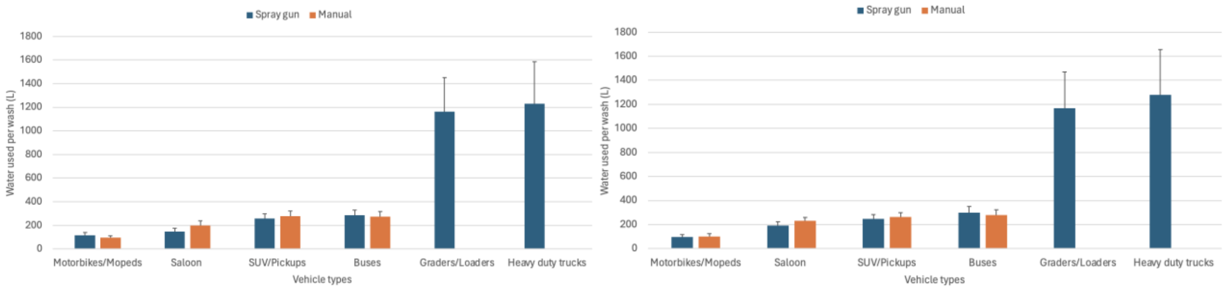


Figure 2: Number of vehicles washed at carwash stations daily

Figure 3 shows the volume of water used to wash the different types of vehicles at both study locations. Generally, the volume of water used per wash increased with the vehicle size. Motorbikes consumed the least volume of water, using up to 116±25L per wash. Conversely, Graders/Loaders and Heavy duty trucks show significantly higher water usage than other vehicle categories. The vehicle categories used between 1164 and 1277L per wash. This is expected, given their larger size and surface area. Washing vehicles using manual methods uses relatively more water than a spray gun. Graders and Heavy duty trucks were washed using only spray guns but not manually. Comparatively, similar water volumes were used to wash different vehicles at both study locations.



a) Nkoranza **b) Techiman**

Figure 3: Volume of water used to wash each type of vehicle

Volume of Wastewater Generated from Carwash Operations

Table 2 shows the volume of wastewater generated daily from the different vehicles at the two study locations. Overall, carwash stations employing spray guns to wash vehicles generated about 3 times more wastewater (up to about 13,400 litres) than those that manually washed vehicles (up to about 4,600 litres). This is because stations with spray guns washed about twice more vehicles than those employing the manual washing method. Moreover, while those using spray guns wash every type of vehicle, the stations that wash vehicles manually do not wash Graders and Heavy duty trucks, which use relatively higher quantities of water to wash.

Table 2: Volume of wastewater generated daily for the different vehicles in the two locations

Location of washing bays	Method of washing	Type of vehicle	Volume of water used for washing daily (L)	Runoff coefficient (Paved =0.8/Not paved = 0.5)	Average volume of wastewater generated (L)
Nkoranza	**Spray Gun**	Saloon	2685±425	0.8	2148
		Buses	2002±397		1604
		Pickups	2600±415		2080
		Heavy articulators	6150±858		4921
		Graders/loaders	2328±413		1863
		Motorbike/moped	928±158		742
		Total	**16697**		**13358**
Techiman	**Spray Gun**	Saloon	3820±589	0.8	3052
		Buses	1505±325		1203
		Pickups	2470±405		1973
		Heavy articulators	3831±590		3066
		Graders/loaders	2338±415		1870
		Motorbike/moped	970±170		777
		Total	**14927**		**11942**
Nkoranza	**Manual washing**	Saloon	2400±400	0.8	1920
		Buses	1375±252		1100
		Pickups	1108±155		886
		Heavy articulators	-		-
		Graders/loaders	-		-
		Motorbike/moped	855±145		684
		Total	**5738**		**4590**
Techiman	**Manual washing**	Saloon	2300±350	0.8	1840
		Buses	1400±250		1120
		Pickups	1325±222		1060
		Heavy articulators	-		-
		Graders/loaders	-		-
		Motorbike/moped	1000±250		800
		Total	**5025**		**4020**

Wastewater Characterization

Table 3 presents the results of the characteristics of carwash wastewater generated from carwash stations at Techiman and Nkoranza compared with their respective EPA effluent guideline values and P-values. The carwash wastewater generally had close to neutral pH (7.35-7.55). Notably, levels of COD, BOD, TSS and Turbidity were above the EPA limits for the discharge of effluents into water bodies. Besides pH that did not significantly vary between the two study locations ($p > 0.05$), all other parameters showed a statistically significant variation ($p < 0.05$).

Table 3: Characteristics of wastewater generated from the washing bays

Parameter	Nkoranza	Techiman	EPA	P-value
pH	7.55±0.87	7.35±1.32	6-9	0.720
EC (µS/cm)	111.8±20.66	997.9±198.12	1500	0.000
Turbidity (NTU)	1190±355.39	1680±417.97	75	0.000

TDS (mg/L)	125.5±25	148.60±27.54	1000	0.000
Suspended Solids (mg/L)	857±143	2624±1047.20	50	0.000
SO_4^{2-} (mg/ L)	68±20.30	66±15.00	-	0.000
PO_4^{3-}(mg/L)	0.37±0.16	0.41±0.11	-	0.002
BOD_5 (mg/ L)	120±13.23	160±17.32	50	0.000
COD (mg/ L)	314±33.29	382±17.10	250	0.000
Nitrate (mg/ L)	1.86±0.31	2.20±0.53	-	0.034
Nitrite (mg/ L)	1.40±0.1	2.4±0.40	-	0.027
Lead (mg/ L)	0.2524±0.08	0.4345±0.23	-	0.003
Iron (mg/ L)	2.046±0.55	2.382±0.11	-	0.042

Pollution Load Associated with Wastewater Generation

Table 4 shows the pollution loads of the wastewater from the study locations. Overall, wastewater from the carwash station in Techiman showed higher pollution loads than Nkoranza. Both Nkoranza and Techiman exhibited relatively similar TDS pollution loads. However, Techiman showed a significantly higher TSS pollution load than Nkoranza, indicating higher levels of suspended particles in the wastewater. Nkoranza has a slightly higher sulphate pollution load than Techiman, although the difference is not substantial. Both locations show minimal phosphate pollution load, suggesting relatively low levels of phosphorus contamination in the wastewater samples. BOD5 pollution loads were comparable at both locations, indicating similar levels of organic pollutants that require oxygen for decomposition. Conversely, Techiman exhibited a slightly higher COD pollution load than Nkoranza, suggesting higher levels of organic and inorganic pollutants that require oxygen for chemical oxidation. Both nitrate and nitrite pollution loads are relatively low in both locations, indicating minimal nitrogen contamination in the wastewater samples. Similarly, both locations show minimal pollution loads for lead and iron, suggesting low levels of heavy metal contamination in the wastewater samples.

Table 4: Pollution loads associated with wastewater generation

Parameter	Nkoranza (kg/day)	Techiman (kg/day)	Pollutions load (kg/year)
TDS	2.25	2.37	821.98-865.78
TSS	15.38	41.88	5,614.43-15,287.66
SO_4^{2-}	1.22	1.05	445.30-384.35
PO_4^{3-}	0.01	0.01	2.56-2.56
BOD_5	2.15	2.55	786.21-932.21
COD	5.64	6.10	2,056.78-2,225.77
Nitrate	0.03	0.04	12.41-12.78
Nitrite	0.03	0.04	9.13-14.24
Lead	0.00	0.01	1.46-2.92
Iron	0.04	0.04	13.14-13.87

DISCUSSION

Similar to Moazzem *et al.* (2018), who reported that most washing bay facilities offer two major services (automatic and manual car wash bays), this study found out that the car washing industries in Ghana offer two services; manual and spray guns. However, manual washing tends to use more water than a spray gun, resulting in inefficient water use. According to Panizza and Cerisola (2010), promoting spray gun washing methods could save water. Therefore, carwash operators should be educated on the benefits of this method and encouraged to transition towards this more water-efficient practice. Larger vehicles also consume more water than smaller ones due to larger surface areas, corroborating the findings of Tamiazzo *et al.* (2015). Local authorities such as the Environmental Protection Agency could consider mandating spray guns for washing larger vehicles. This method uses high-pressure and low-volume water and could significantly reduce water wastage. The water used per wash for the different vehicle categories mirrored earlier findings in Kumasi by Monney *et al.* (2020) and in Cape Coast by Quayson and Awere (2018). Decision makers could, therefore leverage this to develop standardized water conservation strategies that can be implemented at multiple locations in Ghana.

None of the carwash stations identified treated their wastewater but released it into public drains, eventually emptying into the Pra River. Meanwhile, most of the water used is obtained from groundwater, depicting a cycle of pumping potable water to waste. This confirms earlier observations by Monney *et al.* (2020), indicating that the carwash industry turns freshwater from groundwater reserves into polluted wastewater, eventually ending up in urban waterways. Particularly for the carwash stations depending on the urban water utility, this could affect urban water supply as they would compete with users who need the water for vital domestic purposes.

Overall, up to 13,000 litres of wastewater are released per car wash station daily. This is lower than values reported in the Kumasi Metropolis (Monney *et al.*, 2020) due to the relatively lower number of vehicles washed in the study locations. However, it is similar to Boluarte *et al.* (2016), who reported that commercial carwash stations can generate up to 10,000 L of car wash wastewater daily.

The carwash wastewater from the various locations had a nearly neutral to alkaline pH, reflecting the detergents used for washing the vehicles. The pH was within the recommended limit by the EPA. Electrical conductivity, TDS, TSS, and Turbidity for Nkoranza were very low compared to Techiman. Mucha and Kułakowski (2016) stated that turbidity depends on the particulate matter in wastewater. High levels of TSS in wastewater translate into high turbidity. The turbidity values reported in this study were similar to those reported by Monney *et al.* (2020) but higher than the ones reported by Aikins and Boakye (2015). The high levels of sulphate reported in this study indicated high usage of detergents at the station, translating into an alkaline pH. Sulphate is a common detergent additive and contributes to foaming when released on water pathways (Dubey, 2012; Stringfellow *et al.*, 2014). Nitrates and Nitrites were lower in the wastewater. BOD and COD are important indicators of wastewater pollution. In the carwash wastewater samples, both BOD and COD exceeded the required limits for discharge into watercourses. High BOD levels indicate a large amount of organic material in the water, such as sewage or other biodegradable waste. When wastewater with high BOD is discharged into a stream, microorganisms such as bacteria and algae rapidly consume the organic matter, decreasing dissolved oxygen levels in the water (Reynolds, 2002). Low dissolved oxygen levels can harm aquatic life, as many species of fish and other organisms require oxygen to survive (Servais, *et al.*, 1999). COD measures the total amount of oxygen needed for both biochemical and chemical processes. High COD levels in wastewater indicate the presence of complex organic compounds and/or inorganic chemicals that can harm aquatic ecosystems (Mohan *et al.*, 2005; Zaghloul, 2019). The BOD:COD ratio for the carwash wastewater in the study is about 0.4. According to literature (Lee & Nikraz, 2015; Samudro & Mangkoedihardjo, 2010), the lowest ratio of BOD:COD for water to be easily biodegradable is 0.4, and the best value is greater than 0.5. Generally, the characteristics of the carwash wastewater in this study suggest that a wastewater recycling system is required. Therefore, further studies need to develop and test a recycling system at the carwash stations should be undertaken.

Except for pH, there was a statistical difference in the rest of the water quality parameters between the two stations sampled. This indicates that any treatment technology developed to recycle wastewater should be tailored to cater for a wide variation in characteristics. Further studies are, however, required in other washing stations to confirm the significant difference in wastewater quality. The pollution load of the wastewater is useful in designing effective treatment processes to remove organic pollutants and protect the environment (Karia *et al.*, 2024). Specifically, the BOD load informs engineers about the amount of organic matter that needs to be removed from the wastewater. This is useful for sizing treatment components such as sedimentation tanks, aeration basins, and biological reactors to ensure adequate capacity to handle the incoming pollutant load. Considering the number of vehicles washed at the study locations, this would require adopting technologies with low capital investment and use low-cost inputs such as low-cost coagulants shown in existing studies (Monney *et al.*, 2019; Agyen *et al.*, 2021). This will make it affordable for the carwash operators.

CONCLUSION AND RECOMMENDATIONS

The study highlights the pressing need for water-efficient practices and improved wastewater management in the carwash industry in Ghana. Manual washing of vehicles and the release of untreated carwash wastewater into the environment contribute to water wastage and potential environmental challenges. Mandating spray guns for washing vehicles is crucial to reducing water consumption in the carwash industry. This would directly minimise the wastewater generated. Pollution levels (BOD and COD) in the carwash wastewater generated are concerning, exceeding the recommended effluent discharge limits. Therefore, innovative solutions for carwash wastewater recycling at carwash stations should be promoted to address this. Carwash operators should be encouraged and, where necessary, supported through subsidy schemes to install wastewater recycling systems. This can provide a two-pronged benefit to carwash station operators – increasing profit margins and protecting the environment.

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