Evaluation of car wash effluent quality through various pollution indices

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Abstract

This study was conducted to assess the quality of water before and after a car washing, based on the levels of heavy metals present. The six heavy metals chosen for this research included chromium, nickel, zinc, copper, iron, and lead. The average concentration values found in the pre-wash used for washing cars were (0.024, 0.004, 0.023, 0.011, 0.231, and 0.003) ppm, respectively. Additionally, the concentrations identified in the post-wash produced from car washing were recorded as (0.044, 0.050, 0.121, 0.070, 0.442, and 0.077) ppm, according to the results obtained. In this research, three indices were utilized to measure the quality of water that was contaminated by heavy metals: the heavy metal pollution index, the metal evaluation index, and the contamination index. The outcomes indicated that, although the chromium, nickel, iron, and lead concentrations in nearly all the post-wash sampling sites were outside the permissible range, the concentrations of metals in pre-wash were within the permitted limits set by the world health organization. According to the means, the heavy metal pollution index, metal evaluation index, and contamination index values in pre-wash were 30.06, 1.78, and -4.24, while the values in post-wash were 524.97, 12.59, and 6.59. The values of these three indices for pre-wash and metal evaluation index values for post-wash collected from five car wash centers in Kalar City were significantly below the danger threshold. However, except for heavy metal pollution index and contamination index in post-wash being higher than the danger threshold, which interpreting them unfit and contaminated .

Keywords: Heavy metals, Water quality, Contamination.

Introduction

Heavy metal contamination of the natural situation is a universal issue since these metals are stable and lethal to living things when they reach a certain level [10]. One of the most significant accepted resources required for the being of life is water. Modern expansion and population development have improved the demand for water resources universally. Therefore, the welfare of all society is hard to the maintainable exploration of water resources [7]. Unfortunately, water bodies have been the main receivers of pollutants exclusively in developing nations. Water quality is under hazard because of mechanization and development, with car wash wastewater being an important pollution source [15]. Wastewater is described as water that has been contaminated by a variety of uses [36.[

Many contaminated materials, including heavy metals, are typically present in the wastewater generated during the car wash process [37]. Heavy metals, which are obviously happening metals with an essential mass more than 5 g cm-3 and an atomic number greater than 20 [3], are one of the main pollutants released by cars. The brake linings constitute the major source of heavy metals in car wastewater, besides the dust and sand that are washed off, as well as minimal amounts of surfactants that are rarely corrupted in the environment. The most serious issue arises when car wash wastewater is discharged into the water system, posing a health risk to humans and other living things [21]. A significant environmental concern is the contamination of water by metals [27.[

The most common heavy metals found in wastewater produced by service centers are (Zn) zinc, (Ni) nickel, (Pb) lead, (Fe) iron, (Cr) chromium, and (Cu) copper. By washing away road dirt and various portions of the car that have stuck to the cars' outsides, heavy metals can catch their way into the wastewater stream of a car wash. Not only can heavy metals like iron, copper, chromium, and zinc be released into the car wash wastewater from various parts of the vehicle and dust attached to the car [22], but lead and nickel can also be removed from brake components [19]. In order to assess water quality pollution with regard to metal contamination, a variety of pollution indices have been developed and put into use [23]. These indices help evaluate the current level of contamination in wastewater and associate all the water contamination limits into a certain easy method [30]. The main goal of this study is to measure the levels of heavy metals in several car wash facilities in Kalar City both before and after the car washing process.

Material and Methods

Study area explanation

This study was attended in Kalar City, which is situated in the Kurdistan region of Iraq and acts as the central hub for the Garmian administration. The city's geographical coordinates are situated among latitudes 34° 38' and 34° 35' north and longitudes 45° 15' and 45° 21' east Figure (1), and it is between 300 and 355 meters above sea level. The area encompasses 32 km² and is situated southeast of Kirkuk 150 km, south of Sulaymaniyah 140 km, north of Baghdad 180 km, and near the Iranian border 35 km [33]. Kalar City has experienced significant population growth over the last twenty years. This demographic rise is attributed to natural economic progress and the exclusive political conditions in Iraq. The population of Kalar City center is around 177346 persons [17]. The climate in the study zone is described as continental semiarid, with famous possible evaporation [18]. Summers are really hot, with temperatures going from 39 to 48 ºC, whereas winters are wet and cold, with temperatures between 13 and 22 ºC. The average yearly rainfall in the region is noted at 300 mm.

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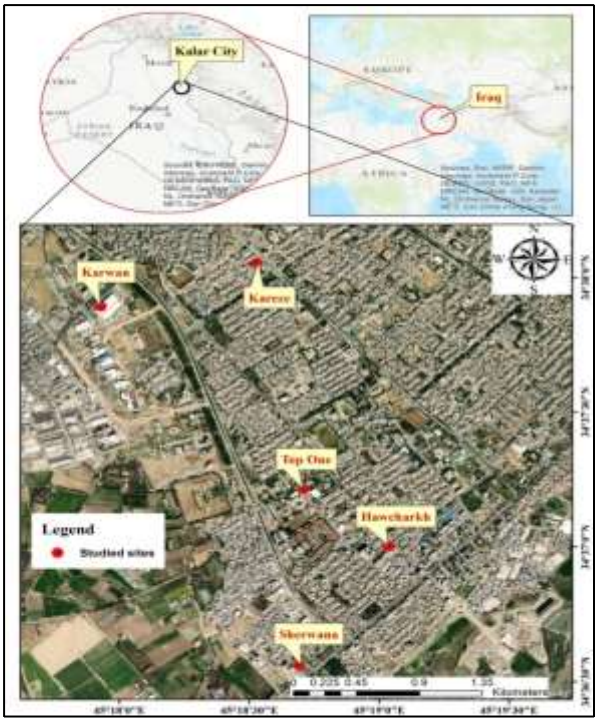

Figure 1. Location of the studied sites.

Water sampling and analysis

Based on the initial survey, a total of eleven distinct categories of fixed-type permanent car wash stations were detected. Five car washing stations have been deliberately chosen for sampling sites in Kalar City due to access to researchers and the willingness of owners and managers to participate, as well as budgetary constraints for sampling costs and sampling analysis costs. Water samples before and after a car washing were collected and kept in plastic containers. Then, the samples were saved in the refrigerator at 4 ºC to avoid biodegradation. The sampling process was conducted during the period September 2024. Water samples from well water (pre-wash) were used for washing the cars and car wash wastewater (post-wash) was sampled utilizing grab sampling methodology from 10 a.m. to 2 p.m. in agreement with the standard method for examination of water and wastewater [4]. The samples of water were first passed over a 0.45 µm filter in order to identify any dissolved metals. To decrease metal adsorption and precipitation on the container walls, the samples were later acidified using concentrated nitric acid. The goal of this process was to transform the sample into a format that could be aspirated by an instrument. The concentrations of Cr, Ni, Zn, Cu, Fe, and Pb were measured using inductively coupled plasma optical emission spectrometers (ICP-OES) (German). It derives from WinLab32 software, which improves the workflow and precision following the procedure as delineated by [5.[

Heavy metal pollution assessment techniques

One significant component of water quality assessment packages has been the assessment of heavy metal contamination. [8] Highlighted that metal pollution indices are an important device for valuing the quality of water and have been successfully used around the world. According to the research conducted by [27], metal effluence of water is a significant environmental issue. Three well-established techniques-the HPI, HEI, and Cd are employed in this study to define the pollution rank of water before and after a car wash. A complete assessment of the water's heavy metal quality is given by the (HPI) and (HEI) methods. Conversely, the (Cd) method calculates the level of contamination to rate the quality of water. Assessments of wastewater by using certain indices are a very beneficial tool to solve water quality connected problems [2.[

HPI-Heavy metal pollution index

The concept of the HPI was initially suggested by [26]. HPI is an operative technique for judging the whole water quality in relative to metals [9]. A contamination level above the critical pollution limit and potentially dangerous to human wellbeing and the surroundings is specified by an HPI value larger than 100. The HPI is intended using the following equation offered by [25:[

$$HPI=\sum_{i=1}^{n}(Qi*Wi)/\sum_{i=1}^{n}Wi$$

$$Qi=Vi/Si*100$$

Where Qi is the sub-index for the ith parameter, Wi is the unit weight of the ith parameter, n is the number of parameters, Vi is the observed value of the heavy metal for the ith parameter, and Si is the standard value for the ith parameter according to WHO guidelines [29]. An HPI > 100 shows severe metal pollution (serious pollution index), an HPI = 100 shows moderate metal pollution (the threshold for hazardous contamination), and an HPI < 100 (non-contaminated water) shows low heavy metal pollution.

HEI-Heavy metal evaluation index

The HEI is a mode for assessing water quality that concentrates on metals in water examples [12]. Based on [8], the HEI is divided into three sorts: low metals (HEI < 40), which shows a low level of metal contamination; moderate to heavy metals (40 < HEI < 80), which proposes a medium level of contamination; and high heavy metals (HEI > 80), which denotes an excessive level of metal contamination and presents a serious danger to both water quality and possibly human wellbeing. The HEI reflects the whole water quality according to heavy metal concentrations [11], and the index is computed with following equation [39:[

$$HEI=\sum_{i=1}^{n}(Hc/Hmac)$$

Where Hc represents the monitored value of the ith parameter and Hmac denotes the optimize allowable concentration of that parameter [35]. By contrasting measured concentrations with permissible limits, the HEI delivers a straightforward assessment in contrast to the HPI. Conversely, HPI presents an additional comprehensive analysis that considers the comparative poisonousness of each metal through fixed weighting factors. While HPI offers a more detailed evaluation of pollution by considering differences in metal toxicity, HEI simplifies the evaluation of adherence to regulations.

Cd-Contamination index

Another index used to assess water quality is the contamination index [20]. [32] Proposed the following formula, which is used to compute the Cd, which quantitatively assesses the total level of contamination based on the concentrations of different heavy metals.

$$Cd=\sum_{i=1}^{n}(Cf)$$

$$Cf=Ca/Cn-1$$

Where Cn is the extreme acceptable concentration of the ith element, Ca is the component's investigative value, and Cf is the pollution factor for the element. [1] Have classified water samples into three levels built on the measured Cd values: low pollution (Cd < 1), medium pollution (Cd = 1–3), and high pollution (Cd > 3). Cd should be less than 1.

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The specific goals of the evaluation and the regulatory environment will determine which of these indices to use.

Results and Discussion

The findings indicated that concentrations of heavy metals Cr, Ni, Zn, Cu, Fe, and Pb were identified in well water (pre-wash) used for car washing, as well as in the wastewater (post-wash) generated in this study. Table (1 and 2) displays the WHO-established water quality standards and summary statistics of the contaminant levels in the sample stages that were taken.

The mean concentrations of heavy metals in the (pre-wash) were 0.024 ppm for Cr, 0.004 ppm for Ni, 0.023 ppm for Zn as presented in (Table 1), 0.011 ppm for Cu, 0.231 ppm for Fe, and 0.003 ppm for Pb, as seen in (Table 2). According to [14], the meditations and fluctuations of metals in baseline sources are influenced by many features, including mineral structure, soil composition, underlying rocks and their geological characteristics, hydro-chemical properties, and human activity on the land surface. Whereas the mean heavy metals of (post-wash) concentrations were 0.044 ppm for Cr, 0.050 ppm for Ni, 0.121 ppm for Zn as exposed in (Table 1), 0.070 ppm for Cu, 0.442 ppm for Fe, and 0.077 ppm for Pb (Table 2). Depended on the highest mean concentration values, the sequence of metals in pre-wash was Fe > Cr > Zn > Cu > Ni > Pb, whereas in post-wash it was Fe > Zn > Pb > Cu > Ni > Cr. The statistical analysis shows that the significant difference at LSD0.01 for all metals between locations and between stages as presented in (Table 1 and 2). Cr concentrations rose at all site following washing, with (Karwan) exhibiting the highest value after washing 0.062 ppm. The rise in Cr is linked to detergents or cleaning agents that have chromium compounds in car components like plating, bumpers, and metal coatings, which leach into wastewater while being cleaned. After washing, there was a significant increase in Ni levels. The greatest concentrations were seen in (Karwan and Sherwana) 0.068 ppm. Ni is a common element in car parts, such as brake pads, battery components, and alloys. The wear and tear on these components might cause it to be released when washed. The site with the greatest post-wash value 0.146 ppm was (Kareze), although Zn levels increased significantly throughout. The majority of tires, motor oil, and galvanized car components include zinc. The increased Zn levels are most likely caused by particulate debris from tire wear and oil residue. The highest post-wash level was found at (Top One) 0.099 ppm. Copper is likely derived from brake pad dust, engine parts, and the corrosion of electrical or wiring components, all of which can collect on cars and be released during washing. Iron concentrations were higher at all locations, notably (Sherwana) 0.543 ppm. The majority of the iron is probably derived from soil particles dislodged during washing, rusting car parts, and steel components. Lead concentrations rose notably, with (Karwan) noting the peak at 0.090 ppm. Pb can come from battery remnants, aged paint, tire particles, and car exhaust residues on the surfaces that are removed during cleaning. The results clearly indicate that the car washing process significantly increases the concentration of heavy metals in water.

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Table 1. Displays the statistical parameters of (Cr, Ni, and Zn) found in the studied locations

Location		Cr (ppm)			Ni (ppm)			Zn (ppm)		
		Stage		Mean	Stage		Mean	Stage		Mean
		Pre-wash	Post-wash		Pre-wash	Post-wash		Pre-wash	Post-wash	
Top One		0.027	0.049	0.038	0.004	0.043	0.024	0.033	0.129	0.081
Hawcharkh		0.016	0.034	0.025	0.003	0.049	0.026	0.015	0.103	0.059
Kareze		0.012	0.021	0.016	0.005	0.054	0.029	0.021	0.146	0.083
Karwan		0.035	0.062	0.049	0.007	0.068	0.037	0.025	0.117	0.071
Sherwana		0.031	0.054	0.042	0.001	0.068	0.018	0.022	0.110	0.066
Mean		0.024	0.044	0.034	0.004	0.050	0.027	0.023	0.121	0.072
$LSD_{0.01}$	Stage	0.006			0.007			0.007		
	Location	0.009			0.011			0.012		
WHO		0.05			0.02			3		

Table 2. Displays the statistical parameters of (Cu, Fe, and Pb) found in the studied locations.

Location		Cu (ppm)			Fe (ppm)			Pb (ppm)		
		Stage		Mean	Stage		Mean	Stage		Mean
		Pre-wash	Post-wash		Pre-wash	Post-wash		Pre-wash	Post-wash	
Top One		0.006	0.099	0.053	0.226	0.439	0.332	0.003	0.086	0.045
Hawcharkh		0.009	0.061	0.035	0.218	0.404	0.311	0.001	0.055	0.028
Kareze		0.018	0.076	0.047	0.194	0.477	0.336	0.004	0.080	0.042
Karwan		0.009	0.063	0.036	0.180	0.350	0.265	0.005	0.090	0.047
Sherwana		0.013	0.053	0.033	0.337	0.543	0.440	0.002	0.072	0.037
Mean		0.011	0.070	0.041	0.231	0.442	0.337	0.003	0.077	0.040
$LSD_{0.01}$	Stage	0.005			0.031			0.010		
	Location	0.009			0.049			0.015		
WHO		2			0.3			0.01		

Figure (2) shows that, with the exception of iron at the (Sherwana) location, which has no limit; the concentrations of all metals examined in the pre-wash throughout the study period were below the typical limits established by the WHO at all other sites (Table 1 and 2.(

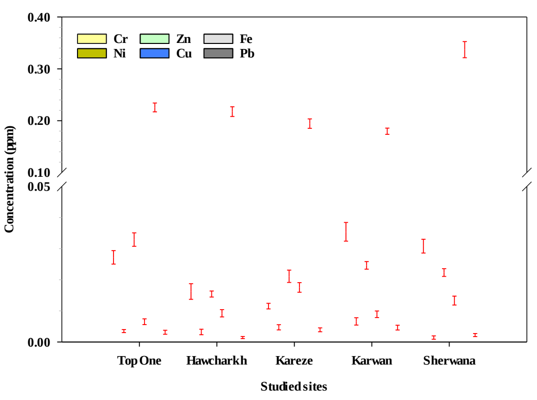

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Figure 2. Standard error of mean of metals in pre-wash (ppm .(

Compared to the pre-wash stage, the post-wash stage contained a higher quantity of studied metals due to car wash activities. As graphically presented in Figure (3), at all examined locations, nickel, iron, and lead concentrations were found to be above the WHO's agreed-upon limits, whereas at all studied sites had zinc and copper below the allowable limits. However, at both (Karwan and Sherwana) locations, chromium were found to be above the WHO guideline limit.

One possible description is that these heavy metals leak out of paints, varnishes, brakes, engines, tires, wheels, oil, and grease when cars are washed, contaminating the water. Copper in car wash wastewater may originate from industrial paints and pigments, as well as from motor cars, according to [24]. According to [34], the sources of lead in car wash effluent might be detergents, greases, lead paints, car batteries, or other chemicals.

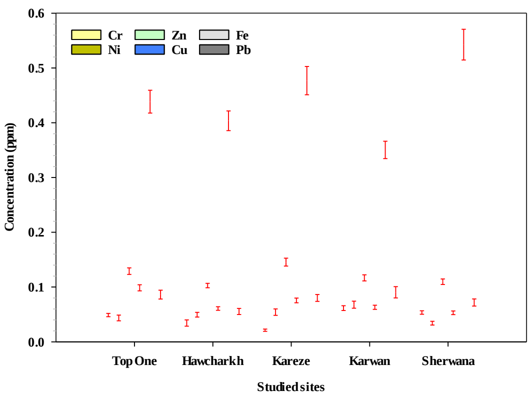

Figure 3. Standard error of mean of metals in post-wash (ppm.(

Additionally, the iron concentration in the post-wash samples was above the WHO acceptable limit (Table 2). Iron was commonly used in the production of car components like the engine block, brake drums and rotors, and intake manifold. As a result, iron was found in the post-wash samples due to the rinse of car machines at the many sampling sites. Chromium is a common metal surface coating, according to [3]. Thus, by cleaning chromium-coated car components like the wheels and bumper at different sample sites, chromium was found in the samples. One such harmful contaminant is chromium, particularly in its hexavalent form, because of its harmful impact on human health [38]. The sources of zinc in the post-wash from car washes may include galvanized parts, transport (brakes, wheels, and asphalt), paint and varnish production, surface treatments, metalworking, and lubricant oil and grease, as outlined by [16.[

Metal pollution indices

Today, researchers and various organizations are concentrating on evaluating water quality to decrease the effect of pollutants on health and the environment. The timeline of hydrological studies illustrates the advancement of several techniques to recognize the origin of contaminants and comprehensively assess water quality. In this study, three accepted indices were used to classify the quality of water. The HPI for the studied sites was calculated for water separately using the average concentration

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values of the certain metals Cr, Ni, Zn, Cu, Fe, and Pb. HPI is an actual technique to describe the water pollution. It denotes the combined effect of metals on the whole quality of water [31.[

The HPI of the pre-wash stage and post-wash stage in expressions of heavy metal levels for each sampling location is presented in Figures (4 and 5). The HPI of the pre-wash ranges from 17.74 to 45.17 with a mean value of 30.06 (Figure 4), while the values for post-wash range from 398.90 to 632.63 with a mean value of 524.97 (Figure 5). In post-wash stage, the HPI value showed that all sample sites were heavily polluted as the concentration of all exceeded the threshold value of the pollution index, which is 100 [28]. The degree of pollution is unacceptable over this threshold. This finding suggests that the six metals under study have a concerning influence on the quality of the water, consistent with the evaluation of the HPI index and similar outcomes reported by [13 .[

The HEI values for pre-wash varied from 1.36 to 2.11 with a mean of 1.78, but the post-wash values varied from 10.10 to 14.90 with a mean of 12.59 (Figures 4 and 5). The findings indicated that the average HEI values in pre-wash and post-wash stages were considerably below the danger threshold of 40, signifying a low degree of heavy metal contamination. According to the data, Cd ranged from -4.64 to -3.89 with a mean of -4.24 in pre-wash and from (4.10 to 8.90) with a mean of 6.59 in post-wash, respectively (Figures 4 and 5). According to the arrangement, the mean Cd values for all the pre-wash stage are below one and low contamination, while the Cd mean values for all post-wash stage are above the danger threshold three and highly polluted

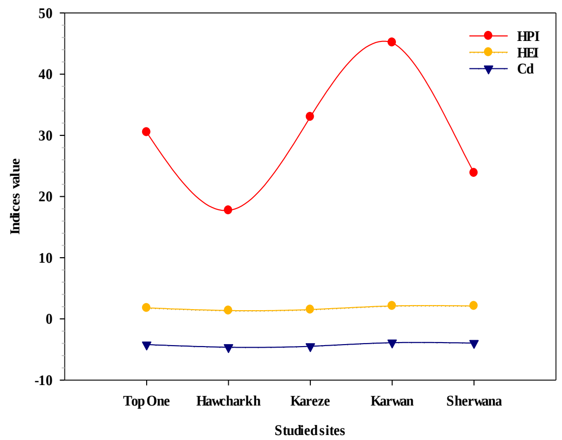

Figure 4. Heavy metal pollution indices (HPI, HEI and Cd) of the pre-wash

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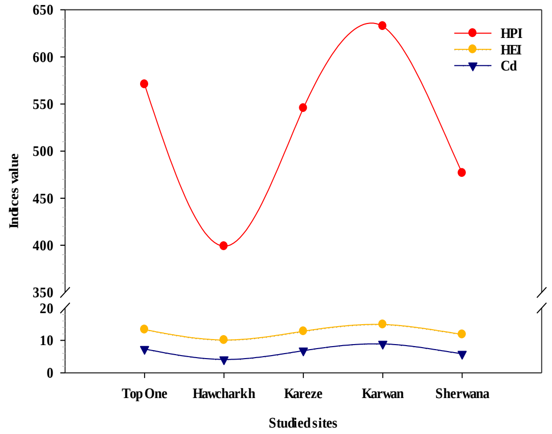

Figure 5. Heavy metal pollution indices (HPI, HEI and Cd) of the post-wash.

Trends for HPI, HEI, and Cd remained similar for nearly all the locations for both pre-wash and post-wash; however, these parameters were found to be higher at the (Karwan) studied location due to a high concentration of metals and lower at the (Hawcharkh) location due to a low metals concentration (Figure 4 and 5.(

Conclusion

To assess the quality of water before and after a car wash, 5 water samples were collected. The samples were analyzed for elements like Cr, Ni, Zn, Cu, Fe, and Pb, and the estimated values were compared to the WHO recommended limits. At almost every wastewater study location, levels of Cr, Ni, Fe, and Pb exceeded WHO-recognized limits. Water quality indices like HPI, HEI, and Cd have also been evaluated for each of the locations being studied to gain a better appreciation of the situation. Consequently, it was demonstrated that water quality indices were a very successful way to measure the general level of water pollution. The average values of the indices for the pre-wash samples were HPI = 30.06, HEI = 1.78, and Cd = -4.24, while the post-wash sample's average values were HPI = 524.97, HEI = 12.59, and Cd = 6.59. Differences in heavy metal levels used for various evaluation methods might explain the variations observed. However, except for HPI and Cd in post-wash being higher than the danger threshold, making them unfit and contaminated, the values of these three indices for per-wash and HEI values for post-wash collected from five car wash facilities in Kalar City were considerably lower than the danger threshold .

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