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Quantitative and Qualitative Study of Wastewater Generated by Carwashes with Work Permit in Karaj and the Efficiency of Coagulation and Clarification Process to Treat Wastewater of the Stations in 2016-2017

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Abstract

This is an experimental-cross-sectional study with applied nature. Ten carwashes were selected in cluster form at two sampling stages in March 2011 and July 2011. At the beginning of each sampling stage, samples were taken from every carwash and pH, COD, TDS, turbidity, electrical conductivity, oil and grease, and surfactant were measured. In the next stage, three carwashes with the highest, the lowest and the average COD concentrations were selected and they underwent re-sampling. The efficiency of the coagulation and clarification process was investigated through Jar test for treating the wastewater of these units using two coagulants of aluminum sulfate and iron sulfate. The results were analyzed by Excel; and statistical indices including mean value and standard deviation were calculated. The average value of water consumption for washing each car was estimated to be 97 liters in March 2016 and 100 liters in July 2017, respectively. On average, each carwash in Karaj generated 4557 liters wastewater per day in winter and 4900 liters per day in summer. The mean pH, TSS, TDS, EC, COD, oil and grease and surfactant and turbidity of wastewater generated from studied carwashes were obtained as 7.78±0.49,2948.7±25.3 mg/L,705±104.85mg/L, 1401.5±229microsiemes/cm, 989.89/ ±337.4mg/L, 157.87±47.42 mg/L, 14.71±5.92mg/L and 431± 286.6 NTU, respectively. In the coagulation and clarification process, the highest COD removal efficiency was obtained using aluminum sulfate coagulant with concentration of 450 mg /L, which its result with a homogeneous wastewater with initial COD was 1150 mg /L at pH equal to 8.5, equal to 82.03%. The highest removal efficiency of oil and grease for wastewater clarified with initial oil and grease was 248 mg /L at pH 7.31, using an iron sulfate coagulant with a concentration of 250 mg /L, 86.29%. The highest removal efficiency of turbidity in using iron sulfate coagulant with a concentration of 350 mg /L for homogeneous wastewater with an initial turbidity of 789 mg /L at pH equal to 9.5, equal to 99.64%. In using iron sulfate coagulant, the highest removal efficiency of surfactant in the concentration of iron sulfate at a concentration of 400 mg /L for homogeneous wastewater with initial surfactant was 26 mg /L at pH equal to 9.5, equal to 56.77%. The proposed method in this study is to treat the wastewater in an efficient way, but it does not reduce most of the pollutants to a standard level and requires another complementary method to meet the standards.

Keywords: Carwash Wastewater Treatment, Chemical Oxygen Demand, Total Suspended Solids, Oil And Grease, Surfactants

Introduction

In recent years, along with the increase in automobile production, a slight increase in the number of carwashes is observable in the cities of Iran and unfortunately, most of the carwashes lack the wastewater treatment system. The carwashes need a lot of water and they also generate a significant amount of wastewater that has a large variety of pollutants. Most of the time, the wastewater of carwashes are discharged into the municipal wastewater collection system without any treatment (Rodriguez Boluarte et al., 2016). Wastewater from commercial processes, especially carwashes, play a significant role in contaminating water resources and sometimes the concentration of BOD, COD and compounds existing in it reaches ten thousands of milligrams per liter. Discharge of this wastewater in the recipient natural environment has brought about irreparable effects (Vafadar and Tavakkoli, 2011). The staff of the carwashes with their

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inadequate knowledge about the harmful effects of effluents of contaminants in the mentioned units on the environment has made most of the carwashes, unknowingly, to discharge wastewater contaminated with wells and public streams (Vafadar and Tavakkoli, 2011).

Given the contaminants in the wastewater system of the carwashes, wastewater treatment from this industry can help greatly to maintain surface and underground water resources (Bazr Afshan et al., 2011). From the viewpoint of environmental protection and effective utilization of water resources, reusing water in the carwashes are among the most important items around the world. In most of the parts of the world water used in carwashes after treatment either are re-rotated or direct it to the basins of groundwater, river or seas (Boussu et al., 2007). In order for better management of the effluents of the carwashes and the program to refine and recycle it, the first step is to correctly estimate the amount of water consumed in carwashes (Hoseini, Rahimi and Yosefi, 2015). The effluent of carwashes contain contaminants such as fat, oil, grease, surfactants (detergents), phosphates, chemicals, heavy metals, dyes, turbidity, hydrocarbons, as well as clay which bio-ecologically removing these pollutants is important (El-Ashtoukhy, Amin and Fouad, 2015).

Carwashes with a work permit in Karaj, under the supervision of the union of carwashes in Karaj, located in Azadegan Square, are working. There are 58 carwashes in the cities. Given that wastewater collection network in the city has not been yet fully exploited, most of the effluent generated from carwash units enters the receiving surface water without any special treatment or drains into absorbent wells.

In Iran, several studies have been conducted for the purifying and recycling of carwash effluent, using DAF methods, electrical coagulation, and chemical coagulation using PAC along with electrical coagulation. Also, in the foreign countries, some studies have been conducted to refine and recycle the carwash effluent, using combined electrocoagulation and electro-oxidation, coagulants and co-coagulant, electrical coagulation, membrane processes, combined technique of chemical coagulation and MBR.

Considering the fact that most of these methods cost a lot and are not practical for carwashes across the city, the purification method used in this study was to use conventional coagulants (Rodriguez Boluarte et al., 2016; Bazr Afshan et al., 2011; El-Ashtoukhy, Amin and Fouad, 2015).

In a study conducted by Torabi et al. (2016) entitled “The Study of Anion Surfactant Removal Level and COD of the Carwash Wastewater with the Ozonation Process in a Reactor with Packed Bedding”, the results indicated that the efficiency of COD removal and anionic surfactant increases with increasing pH and contact time, so that at pH equaling 11, and after the reaction time equaling 90 minutes for an ozone dose of 1/1 mg / min, the removal efficiency, was obtained as 68.57% and 77.71%, respectively (Torabi et al., 2016). Also, in a survey by Vafadar et al. (2011), in the environmental organization of the carwashes in Sowme'eh Sara, the results from tests indicated highly contaminated effluents from carwashes. Also, the average pH was obtained as 6.02. Average COD, BOD5 and TDS were 580, 300 and 153 mg /L, respectively (Vafadar and Tavakkoli, 2011).

In an article by Gonder Beril et al. (2017), under the title of “Wastewater Treatment of Carwash by Electric Coagulation Using Iron and Aluminum Electrode”, optimal conditions were determined for iron and aluminum electrodes. Under optimal conditions for an iron electrode containing pH equaling 8, a flow of 3 mA/cm2 and retention time 91 minutes, the removal rate for COD, oil, and fat and chloride was 88%, 90% and 50%, respectively. Under optimal conditions for an aluminum electrode containing a pH equals to 6, a flow of 1 mA per cm2 and the retention time of 30 minutes, the removal rate for COD, oil, and fat and chloride was 88%, 68% and 33% (Beril Gonder et al., 2017). In a research by Rodriguez Boluarte (2016) entitled “Reuse of Carwash Wastewater Using Chemical Coagulation and MBR”, water consumption per automatic carwash was indicated to be 200 liters in Australia.

Materials and Methods

This is an experimental, cross-sectional, and applied research. The population studied in this study included carwashes with work permit in Karaj and sampling was done for 58 carwashes. Sampling method was in cluster form and non-random. Therefore, the central part of Karaj was divided into 5 regions of north, south, east, west and the center. The number of samples was estimated to be 10. According to Standard of 7960 Standard Institutes and Industrial Researches in Iran (Iran IoSaIRo, 2005) sampling was carried out in two stages. Once in March of 2016 and then in July 2017. Sampling was carried out in a combined manner and during a one-day carwash period, in the middle of the week, sampling was done. Sampling was done while all the rifts of the carwashes were operating, so that half of them were initially dewatering the automobile and the other half parts were washing the car floor. Samples were taken immediately after the car wash and when they have not started collecting the channels. Samples were collected to determine physicochemical properties in glass containers of two liters. Physical parameters include temperature, turbidity, electrical conductivity, suspended solids, soluble solids and chemical parameters including pH, oil and grease content, surfactant and COD were tested. The temperature parameter was measured immediately after sampling in place. All tests in this study were conducted according to the Standard Method of Water and Wastewater Testing (Ed. 2005). Sedimentation Test Included discharging the wastewater sample into a 1-liter Imhoff hopper (a scaled conical glass container) and reading the volume of solids clarified is after an hour which is based on the unit of mg /L. The purpose of this test is to determine the amount of sediment-ability before and after purification (George, Franklin and David, 2011).

To do a jar test we need a laboratory stirrer or jar test machine with 6 containers and 6 beakers containing at least 1 liter capacity. In this study, the determination of the concentration of coagulants in the jar test was done using the following procedure. First, a beaker was placed under the jar machine and one liter of the intended wastewater was added to it. The stirrer was set at 120 rpm. Using the pipette, the intended coagulant was slowly added to beaker. As soon as the first clots were seen in beaker, the addition of coagulant was stopped and the consumed volume of coagulant was noted. This value was specified as the base value. As a result the concentrations of coagulants in the jar test were chosen in such a way that the base value to be 3 or 4. It should be noted that the concentration of coagulant in each beaker was more or less than the beaker before and after it with 50 mg/L (Aikins and Opoku Boakye, 2015). It should be noted that all the used materials have been made in Merck, Germany. The COD vial was provided by Aqualytic Company, Germany. Surfactant reagents were provided from HACH Company, Germany.

Findings

The results from studying the water consumption, in 10 selected carwashes, and in two measurements are presented in Table 1. As shown in Table 1, water consumption has increased in July.

Table 1: Average water consumption in carwashes in Karaj by studying washing nozzle in March 2016 and July 2017 in terms of liter for washing each car

Carwash code	March	July
1	93.31	99.96
2	46.98	47.71
3	106.75	116.72
4	91.96	99.41
5	73.14	114.36
6	103.71	106.41
7	106.16	100.65
8	100.86	8
9	129.65	9
10	117.53	106.18
Mean	97.01	100.16
Standard deviation	21.99	21.05

The codes of three selected carwashes were 1, 4, and 10 after samplings of March 2016, as well as three selected carwashes were 5, 6, and 8 after samplings in July 2017. Initial concentration of selected pollutants in selected carwashes after samplings of March 31 and July 2016 and July 2017 after re-sampling is given in Table 2.

Table 2: Concentration of selected pollutants in selected carwashes after sampling in March 2016 and July 2017

Carwash code	4	1	10	6	5	8
Volume of consumed water for washing each car (liter)	85.98	92.11	104.22	103.205	100.035	90.91
pH	7.48	7.61	7.93	7.31	7.26	7.45
Turbidity (NTU)	246	836	789	203	457	529
Electrical conductivity(microsimence/cm)	990	850	920	1050	1050	1000
TDS (mg/L)	517	440	470	530	520	510
TSS (mg/L)	4248	1104	3591	1147	1592	1864
Oil and grease (mg/L)	204	80	159	248	308	231
Surfactant (mg/L)	26	23.81	22.52	7.02	10.452	15.914
BOD (ml/L)	480	247	453	195	218	295

COD (mg/L)	943	564.2	813	586.3	728	1150

Efficiency of iron sulfate in removing turbidity and COD, with initial pH has been given in Table 3 for selected samples after sampling in March 2016. As shown in Table 3, iron sulfate could reduce higher 92.85% turbidity. Concentration of 450 mg /L iron sulfate has decreased initial NTU turbidity of 836 by 99.65%. Iron sulfate has also reduced above 67.87% COD. Concentration of 400 mg /L iron sulfate has reduced initial COD of 813 mg /L by 79.85%.

Table 3: Efficiency of iron sulfate in removal of turbidity and COD, with initial pH for selected samples after sampling in March 2016

Code carwash	4	4	4	1	1	10	10	10	standard
Iron sulfate concentration (mg/L)	350	400	450	300	450	300	350	400	-
Initial pH	7.48	7.48	7.48	7.61	7.61	7.93	7.93	7.93	-
Post-test pH	5.93	5.74	5.55	6.47	6.02	6.69	6.56	6.38	6-8.5
Initial turbidity	246	246	246	836	863	789	789	789	-
Post-test turbidity	17.6	11.3	8.34	3.08	2.93	3.06	3.24	2.14	50
Turbidity removal percentage	92.85	95.41	96.61	99.63	99.65	99.61	99.26	99.61	-
Initial TDS	520	520	520	440	440	470	470	470	-
Post-test TDS	570	570	580	490	510	510	520	530	-
Initial conductivity	990	990	990	850	850	920	920	920	-
Post-test conductivity	1130	1140	1160	980	1030	1030	1040	1060	-
Initial COD	943	943	943	564.2	564.2	813	813	813	-
Post-test COD	253.4	253.5	228.2	181.3	168.5	187.1	165.5	163.8	200
COD removal percentage	73.13	75.04	75.8	67.87	70.13	76.99	79.64	79.85	-

Efficiency of iron sulfate in removing turbidity and COD, with initial pH, has been given in Table 4 for selected samples following sampling on July 2017. As shown in this table, iron sulfate has succeeded to reduce above 96.92% turbidity. Concentration of 450 mg /L iron sulfate has decreased initial NTU turbidity of 529 by98.97%. Iron sulfate also could reduce 76.30% COD. Concentration of 450 mg /L iron sulfate has decreased initial COD by 1150 mg /L by 80/72%.

Table 4: Efficiency of iron sulfate in the removal of turbidity and COD, with initial pH for selected samples after sampling in July 2017

carwash code	6	6	6	5	5	5	8	8	8	standard
Iron sulfate concentration (mg/L)	200	250	300	300	350	400	350	400	450	-
Initial pH	7.28	7.28	7.28	7.26	7.26	7.26	7.45	7.45	7.45	-
Post-test pH	6.42	6.27	6.18	6.18	6.02	5.81	5.88	5.72	5.57	6-8.5
Initial turbidity	203	203	203	457	457	457	529	529	529	-
Post-test turbidity	5.05	5.99	6.17	12.7	9.04	5.31	16.3	8.5	5.43	50
Turbidity removal percentage	97.51	97.05	96.96	97.22	98.02	98.84	96.92	98.39	98.97	-
Initial TDS	530	530	530	520	520	520	510	510	510	-
Post-test TDS	540	550	560	540	550	560	560	570	580	-
Initial conductivity	1050	1050	1050	1050	1050	1050	1000	1000	1000	-
Post-test conductivity	1080	1100	1110	1080	1100	1120	1120	1150	1160	-
Initial COD	586.3	586.3	586.3	728	728	728	1150	1150	1150	-
Post-test COD	138	132.6	129.7	172.5	167.3	166.1	251.6	233	221.7	200
COD removal percentage	76.46	77.38	77.88	76.30	77.02	77.18	78.12	79.74	80.72	-

The efficiency of aluminum sulfate in removing turbidity and COD for selected samples after sampling in March 2016 is shown in Table 5. As shown in Table 5, aluminum sulfate has been able to reduce turbidity above 92.48%. Concentration of 500 mg/L of aluminum sulfate has decreased initial turbidity of NTU 789 by 99.67 percent. Aluminum sulfate has also reduced COD above 70.40%. Concentration of 500 mg /L of aluminum sulfate has decreased initial COD with 813 mg/L by 80.38% liters.

Table 5: Efficiency of aluminum sulfate in removing turbidity and COD, with initial pH, for selected samples following sampling in March 2016

carwash code	4	4	4	4	4	1	1	10	10	10	standard
Aluminum sulfate (mg/L)	300	350	400	450	500	300	450	400	450	500	-
Initial pH	7.48	7.48	7.48	7.48	7.48	7.61	7.61	7.93	7.93	7.93	-
Post-test pH	6.45	6.27	6.24	6.11	6.03	6.66	6.34	6.57	6.43	6.52	6-8.5
Initial turbidity	246	246	246	246	246	863	836	789	789	789	-
Post-test turbidity	18.5	13.2	13.6	10.5	7.71	5.38	6.87	5.87	4.24	2.62	50
Turbidity removal percentage	92.48	94.63	94.47	95.73	96.87	99.36	99.18	99.26	99.46	99.67	-
Initial TDS	520	520	520	520	520	440	440	470	470	470	-
Post-test TDS	520	540	550	560	580	480	500	510	530	550	-
Initial conductivity	990	990	990	990	990	850	850	920	920	920	-
Post-test conductivity	1050	1080	1110	1120	1150	810	1000	1030	1060	1100	-
Initial COD	943	943	943	943	943	564.2	564.2	813	813	813	-
Post-test COD	244.9	244.6	235.3	231.3	215.7	167	150.2	171.8	162.2	195.5	200
COD removal percentage	74.03	74.06	75.05	75.47	77.13	70.40	73.38	78.87	80.05	80.38	-

Efficiency of aluminum sulfate in removing turbidity and COD for selected samples after sampling in July 2017 is shown in Table 6. As shown in Table 6, aluminum sulfate has decreased turbidity above 96.09. Concentration of 350 mg /L aluminum sulfate has decreased initial turbidity of NTU 457 by 99.05%. Aluminum sulfate also reduced COD above 76.51%. Concentration of 450 mg/L of aluminum sulfate has decreased initial COD of 1150 mg/L by 81.70%.

Table 6: Efficiency of aluminum sulfate in the removal of turbidity and COD, with initial pH, for selected samples following the sampling in March 2017

carwash code	6	6	5	5	5	8	8	8	standard
Aluminum sulfate (mg/L)	350	400	300	350	400	350	400	450	-
Initial pH	7.28	7.28	7.26	7.26	7.26	7.45	7.45	7.45	-
Post-test pH	6.18	6.06	6.31	6.2	6.14	6.25	6.18	6.09	6-8.5
Initial turbidity	203	203	457	457	457	529	529	529	-
Post-test turbidity	10.8	7.93	6.11	4.33	4.82	12.2	7.4	5.31	50
Turbidity removal percentage	94.68	96.09	98.66	99.05	98.95	97.69	98.60	99.00	-
Initial TDS	530	530	520	520	520	510	510	510	-
Post-test TDS	550	560	530	540	550	540	550	560	-
Initial conductivity	1050	1050	1050	1050	1050	1000	1000	1000	-
Post-test conductivity	1100	1120	1070	1090	1100	1090	1110	1120	-
Initial COD	586.3	586.3	728	728	728	1150	1150	1150	-
Post-test COD	118.3	115.4	171	165.5	164.6	225.4	219.6	210.5	200
COD removal percentage	79.82	80.32	76.51	77.27	77.39	80.40	80.90	81.70	-

As shown in chart 1, iron sulfate with a concentration of 350 mg/L has removed 99.64% turbidity of homogeneous wastewater system of carwash with code 10 at pH equal to 9/5.

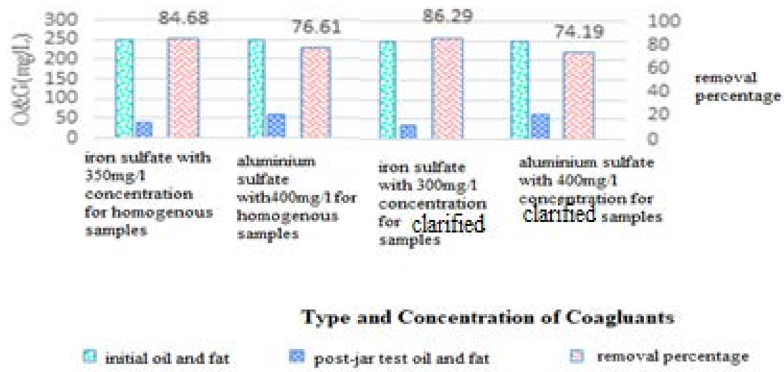

Chart 1: Reduced turbidity in the selected carwash with code number 10 following sampling in March 2016 under Jar test conditions

As shown in chart 2, iron sulfate with a concentration of 300 mg /L has removed 84.68% oil and grease of homogeneous wastewater of carwash with code number 6 at pH 7.31. Also, iron sulfate with a concentration of 250 mg /L has removed 86.29% of the oil and grease of wastewater clarified of code 6 at pH equal to 7.31.

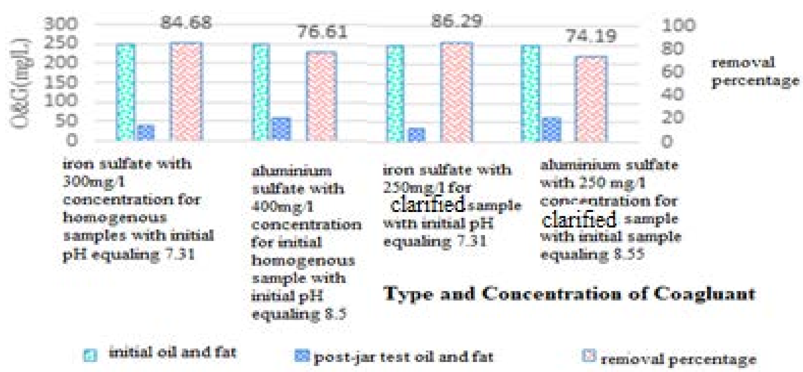

Chart 2: Reduction of oil and grease in selected carwashes with code 6 after sampling in July 2017 under conditions of jar test

As shown in chart 3, iron sulfate with concentration of 400 mg/L has removed 56.77% surfactant of homogeneous wastewater system of carwash with code 4 at pH equaling 9.5.

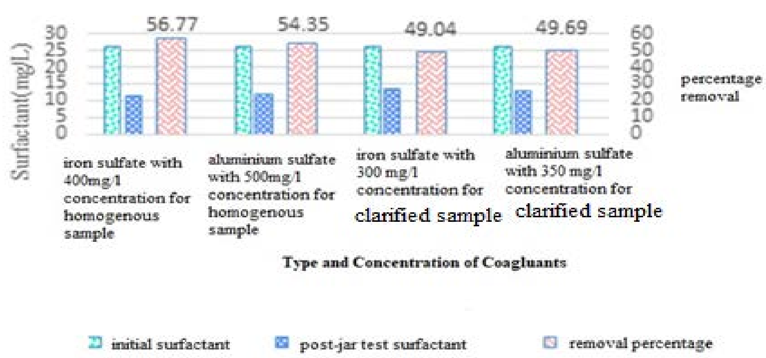

Chart 3: Reduction of surfactant, in selected carwash with code 4 after sampling in March 2016 under Jar test conditions

As shown in chart 4, aluminum sulfate with a concentration of 450 mg L has removed 82.03% COD of homogeneous wastewater system of carwash with code 8 at pH 8.5.

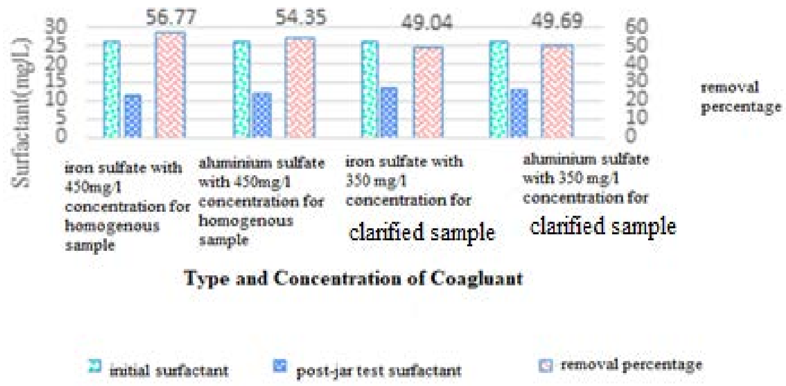

Chart 4: COD reduction rate in the selected carwash with code 8, after sampling in July 2017 under Jar test conditions

Discussion and Conclusion

The results of this study showed that in carwash with code number 2, despite the skill of working people, the cars were washed at lower quality and the reason for this was a low price of washing at this carwash station. Carwash 9 was located in a region where most of the car exhibitions are, so cars should be washed more carefully to be put up for sale at the exhibition, as a result for washing each car more, more water was consumed.

The mean value of pH in all sampling times was 7.78 ± 0.49. In a research by Torabi et al. (2016), in Yazd, the mean value of the wastewater generated from a carwash station was set at 8 ± 0.27. In a survey conducted by Beril Gonder (2017), in Turkey, the mean value of pH of wastewater generated from a carwash station equaled 8. Average electrical conductivity in total sampling times was $1401.5 \pm 229 \mu S/cm$. In a survey conducted by Torabi et al. (2016) in Yazd, the average EC of the wastewater generated from a carwash station was $984.36 \pm 97.33 \mu S/cm$. The amount of EC in Torabi's research was less than mean value of EC in this study, but it is within the scope measured in this study and there are carwashes in this study that have EC in this range. Average TDS in all sampling times was 705 ± 104.85 mg / l. In a review by Aikins et al. (2015) in Ghana, the mean value TDS of wastewater generated from 2 carwash stations was estimated about 650 mg/L. The TDS level in the carwashes studied in this research and other studies has significant fluctuations. This can be due to different atmospheric conditions in the studied areas in each research as well as weather fluctuations in different sampling days. Average turbidity in all sampling times equaled NTU 431 ± 286.6. In a study conducted by Golestani et al. (2014), in Quchan, average turbidity of the wastewater generated from a NTU 321 carwash station was determined. The reason for higher turbidity includes soil, mud and particles of the brake lining that are washed away from the car during washing (Al-Gheethi et al., 2016). The mean value of surfactant in all sampling times was 14.712 ± 5.92 mg/L. In the study done by Zaneti et al. (2011), in Brazil, mean value of wastewater surfactant generated by carwash stations was 11/7 ± 9 ml/L. According to a comparison with other similar studies it can be concluded that the amount of anionic surfactants is highly fluctuated and different in each carwash and in each area. The reason for this is the use or non-use of Nano-materials in carwashes. The mean value of oil and grease in all sampling times was 157.87 ± 47.42 mg /L. In a study by Rubi -Juarez et al. (2015), in Mexico, the average oil and grease of clarified wastewater generated from a carwash station was 368.89 mg/L. Average COD in all sampling times was 989.89 ± 337/4 mg /L. In a survey conducted by Vafadar et al. (2011) in Sowme'eh Sara city, the average wastewater COD from a carwash station was 580 mg/L. The main reason of lower COD concentration can be climatic conditions in Sowme'eh Sara region.

Under optimal conditions, all coagulants reduced homogenous wastewater turbidity and clarified wastewater above 97.41% and 75.22%, respectively. The highest removal percentage is related to iron sulfate coagulant and with concentration of 350 mg/L. The proposed method in this study has a higher efficiency for removing wastewater turbidity generated from carwashes and provides all standards for draining into absorbent well, use for irrigation and agricultural purposes, draining into surface water and reuse in carwashes. All coagulants reduced homogeneous wastewater oil and grease and wastewater clarified above 65%. The highest deletion rate was associated with iron sulfate coagulant with a concentration of 250 mg/L. In a study by Ahmadi Rad et al. (2014) the highest level of engine oil removal from carwash wastewater for emulsion with oil concentration of 3% and 5000v voltages with copper electrodes under AC electric field was obtained as 66.6% . The chemical coagulation method has a high ability to remove oil and grease from wastewater. But, due to higher concentration of oil and grease in wastewater caused by automobile washings, this method is not efficient. Also, dilution to reduce the concentration of oil and grease is not effective either. As a result, a complementary method such as DAF is suggested. Under optimal conditions, all coagulants reduced surfactant of homogeneous wastewater sludge and clarified wastewater above 18.09% and 22.49%, respectively. The highest deletion percentage was related to coagulant of iron sulfate with a concentration of 400 mg/L. In a study by Riyahi et al. (2008) the amount of surfactant removal in the wastewater generated from carwash using Nano-filtration at 8 atmosphere pressure and the temperature of 293 degree Kelvin was determined to be 100%. All coagulants decreased homogeneous wastewater COD and clarified wastewater above 65.38% and 56.40%, respectively. The highest deletion rate was related to aluminum sulfate coagulant at a concentration of 450 mg/L. In a study by Torabi et al. (2016), the removal efficiency of COD in the wastewater generated from carwash, using the ozonation process with a concentration of 1.1 mg/L at pH = 11 and a contact time of 90 minutes was determined as 68.57% . The best method for removing COD can be the use of electrical coagulation methods. The best way of using a complementary purification process is DAF process.

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