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Electrocoagulation Process for Treatment of Detergent and Phosphate

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Background & Aims of the Study: Detergent and phosphate are one of the main and vital threats (eutrophication phenomenon and production of synthetic foam) for the source of drinking water, agriculture and industrial uses in the Ahvaz, Iran that threaten human health. The aim of this study is evaluate to efficiency of the electrocoagulation (EC) process in the removal of detergent and phosphate from car wash effluent.

Materials & Methods: In this experimental study in a laboratory scale we used a glass tank with a volume of 2-4 liters (effective volume of 2 liters) containing 4 electrode-plate iron and aluminum (AL-AL, AL-Fe, Fe-Fe). Using a bipolar method to convert alternative electricity to direct current, electrodes were connected to a power supply. Daily samples were collected from different car wash sewage. Initial PHs of samples was from 7 to 9. At first, different tests were performed on primary samples. Reaction times were set for 90, 60, 30 minutes with middle intervals of 2 cm.

Results: According to result this study, percentage of phosphate removal in the EC with Al-Fe electrode with an optimum pH = 7 have been from 34 % phosphate removal (in the 10 Volt) to 78% phosphate removal (in the 30 Volt). Percentage of detergent removal in the EC with AL electrode with an optimum pH = 7 have been from 68 % detergent removal (in the 10 Volt) to 94% detergent removal (in the 30 Volt).

Conclusions: Altogether it was found that this method can be used as a confident and convenient method for treating car wash effluent and according to the highest removal efficiency of the process, effluent can be discharged safely into the environment.

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Background

The irregular detergent entry into groundwater and surface water resources is causing environmental serious problems, including the eutrophication phenomenon and production of synthetic foam (1-3). Household cleaning products and detergents in sewage are major sources of phosphorus (4-8). Remove phosphorus detergent compounds in the treatment basin will require the use of different and expensive units such as complex systems, aeration and pumping and treatment and disposal of the resulting sludge (9). Most detergents are slow biodegradable and there is no their fast break in conventional treatment

(10,11). Because of the availability conditions, especially in the pond aeration and mixing, foam is produced which disturbs the treatment process because of the high volume and also creates risks for the refinery workers (12,13). Therefore, treatment is particularly important for detergents and phosphorus wastewater to prevent environmental pollution, prevent degradation of groundwater and surface water resources and improve the performance treatment plants of municipal sewage (13-15). A wide range of water and wastewater treatment processes, including physical operations, biological, physical-chemical and chemical processes (such as chemical precipitation) have been identified to remove contaminants (16-19). In recent years due to environmental compatibility and the possibility of purification of liquids, gases and solids, the use of direct electricity in the water and wastewater treatment plants is developed, and it is known as an attractive method for coagulation or sedimentation, as an electrocoagulation/electrochemical method (10, 20-25). This method can be used widely for wastewater treatment containing BOD, COD, proteins, oils, detergents, paints and solutions containing heavy metals (13,17,21,26-27). Electrocoagulation is a process that consists of creating a drainage metal hydroxide fluke electrical due to dissolution of soluble anodes which are usually of iron or aluminum. This was met with limited success in the twentieth century; this method recently is accepted due to environmental restrictions on output wastewater (17,21,26). Studies on the use of EC in wastewater treatment have increased during recent decades about the kind of consumer electrodes and the effective factors have been used. In a similar work, Mansoorian et al studied the Removal of lead and zinc from battery industry wastewater using electrocoagulation process: Influence of direct and alternating current by using iron and stainless steel rod electrodes (25). Malakootian et al in their study had shown the relationship between electrocoagulation process using iron-rod electrodes and removing hardness from drinking water (10). Jay et al. offered a new bipolar electrocoagulation and electro-flotation process for wastewater laundry treatment. The electrocoagulation and electro-flotation processes were performed in a single reactor simultaneously. Performance parameters such as primary pH, hydraulic retention time (HRT) and flow intensity were examined (23). Irdimz et al. used the Taguchi method to determine the optimum conditions, phosphate removal from wastewater by EC with flat aluminum electrodes. Removal efficiency and a laboratory of phosphate from wastewater by electrocoagulation and flat aluminum electrodes are respectively 99.9 and 100% (27). Önder et al. studied possibility of removal of the surface-active agents (surfactants) from the solution model and polluted water sample with EC method by using Fe^{2+} ions. In these tests the efficiency of surface-active substances removal with a concentration of surfactant of 10 mg/L, reached 100 % (26). In order to remove the COD, phosphate and fat and turbidity from sewage treatment in the presence of hydrogen peroxide (H_2O_2) and poly aluminum chloride (PAC) as a coagulant aid method, Un et al. used an electrochemical method with soluble aluminum or iron electrodes. COD removal efficiency was in the range of 62% to 86%, while the removal rates of oil and fat and turbidity reached up to 100% (28). Sengil et al. studied the removal of COD and phosphate and fats from dairy wastewater by EC with direct current (DC). The removal efficiency of COD and grease was 98 and 98%, respectively (29). Mahvi et al. studied the usability of the electrocoagulation process using aluminum electrodes to remove heavy metal chromium in aquatic environments. The test results showed that the highest removal efficiency of chromium ions is at pH=3, and a potential difference of 40 v (20). Rahmany et al. studied efficiency of the electric coagulation method for the removal of Chromium Ario Blocks t color from waste. This study showed that color removal efficiency rates at pH are 3.5v and 30v; in addition, using pairs of iron and aluminum electrode at 30 minutes, the rates are 96% and 86%, respectively (21).

Aims of the study: In the present study, we investigate the influence of type of electrodes with different arrangements, voltage, and PH and retention time in removal of detergent and phosphate from car wash wastewater.

Materials & Methods

Laboratory materials

In this experimental study that conducted in a pilot project in the chemical laboratory, PH, voltage, retention time and effects of variables of electrode type were measured. Potassium dichromate ($K_2Cr_2O_7$), Potassium permanganate ($KMnO_4$), potassium hydroxide (KOH), potassium hydrogen phthalate ($C_8H_5KO_4$), silver sulfate (Ag_2SO_4), mercury sulfate ($HgSO_4$), sulfuric acid (H_2SO_4), 3-methyl-2-benzothiazoline hydrazine and Formaldehyde (HCHO) used in this study. Equipment that used in this study were photo spectrophotometric meter DR/5000, the AC power supply Tracking Dual JPS-302D, glass reactor electro coagulation, iron and aluminum plate electrodes, oven and magnetic mixer.

Sampling

Samples of wastewater were collected from different car washes in the city and transferred to the laboratory. Tests of phosphate and detergent were done on initial samples, and initial concentration was determined. To adjust the primary PH of the solution the sulfuric acid and one-tenth normal sodium hydroxide were used. Table 1 show the factors which were affect the electrocoagulation process including characteristics of the raw carwash wastewater, voltage, primary pH and retention time (Table 1).

Experimental apparatus

A lab-scale reactor with diameters of 15cm×15cm×15cm was used for doing this experiment. This reactor was made of glass with a thickness of 10mm with iron and aluminum electrodes with dimensions 12cm×10cm×2mm that were upright and a distance of 2cm from together that the end of each was connected to the DC power supply. Sewage mixing was done using a magnetic stirrer with a constant speed of 100rpm. Hydrochloric acid with a weight of 15% was used to clean the electrodes before starting the procedure. The test was assessed in the voltage range of 10,20,30 and arrangements of AL-AL, AL-Fe, Fe-Fe in the PH domains of 3, 7, and 11, and with the intervals 2 cm with a contact time of 30,60,90 min for each set of pairs of electrodes. In these tests due to the transmission voltage, flow rates were varied between 0.5 to 2 amps. In each set of experiments, samples were taken from the liquid inside the reactor at specified times; and after filtration according to the DR5000 UV- Vis HACH spectrophotometer the samples were prepared for testing the parameters; then, their values were determined using wavelengths specified by the device.

Table 1) Parameters measured and their range

Parameter	Range	Unit	Raw wastewater Mean ± S.D
pH	3,7,11	---	7.08±0.03
Steering time	30,60,90	Minutes	-
Voltage	10,20,30	Volt	-
Electrode Type	Al-AlFe-Fe،AL-Fe	---	-
Conductivity	-	(mS/cm)	7.6±2.4
Detergent	-	(mgL^{-1})	23±8.3
Phosphate	-	(mgL^{-1})	17±8.8

Results

First, results from changes is presented in pH=11, 7, 3 and reaction time=30, 60, 90 minutes and voltage=10, 20, 30 V and the 4 number of plates and the interval plates are 2 cm. In this study, voltage, contact time, type of electrode and pH in reducing turbidity and organic matter were discussed. The results of the various arrangements under optimal conditions have shown in Figures no. 1 to 6.

Changes in phosphate due to variations in input voltage during EC:

Figure 1 shows that increase in the removal of phosphate in the EC with an optimum pH=7 with aluminum electrode have been from 73% phosphate removal (in the 10 voltage) to 100% phosphate removal (in the 30 voltage), respectively.

According to Figure 2, phosphate removal in the EC with aluminum-iron electrode with an optimum pH=7 have been from 34% (in the 10 voltage) to 78% (in the 30 voltage), respectively.

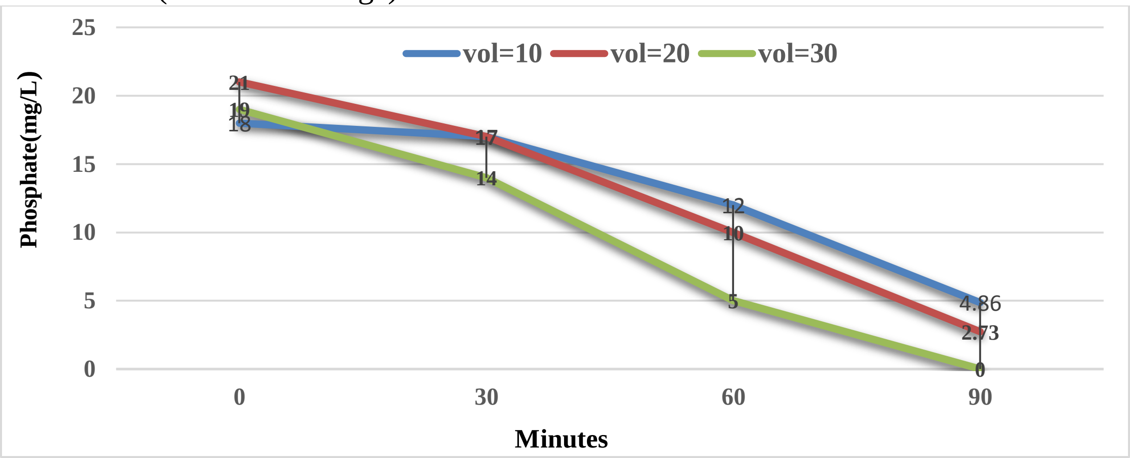

Figure 1) Phosphate changes in the EC with aluminum electrodes in the optimum pH =7

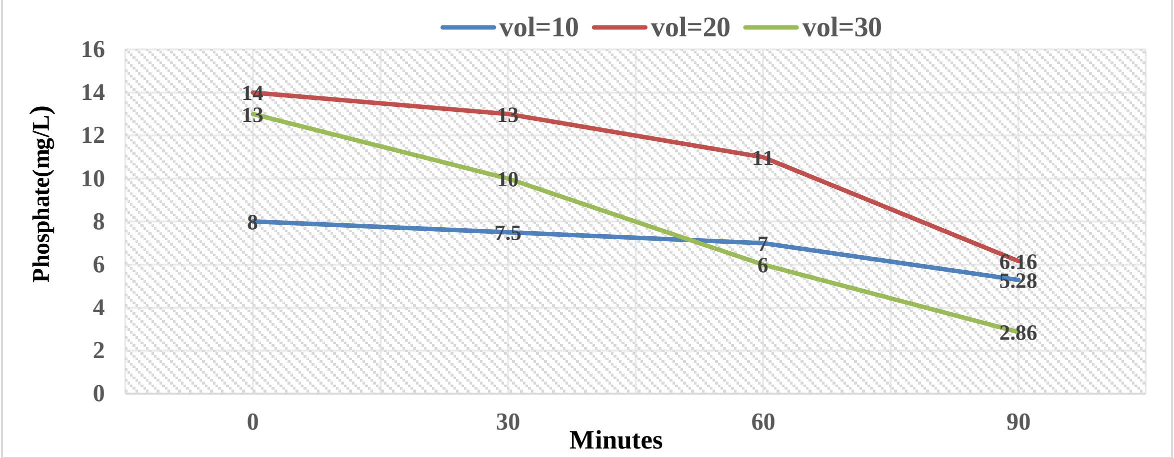

Figure 2) Changes in phosphate in the EC with electrodes made of aluminum – iron at the optimum pH=7

According to Figure 3, the removal of phosphate in the EC with aluminum-iron electrode with an optimum pH=7 have been from 34% (in the 10 voltage) to 63% (in the 30 voltage), respectively. Detergent concentration changes due to input voltage variations in during EC: According to Figure 4, percentage of detergent removal in the EC with aluminum electrode with an optimum pH=7 have been from 51% (in the 10 voltage) to 80% (in the 30 voltage), respectively. According to Figure 4, percentage of detergent removal in the EC with aluminum-iron electrode with an optimum pH=7 have been from 68% (in the 10 voltage) to 94% (in the 30 voltage), respectively.

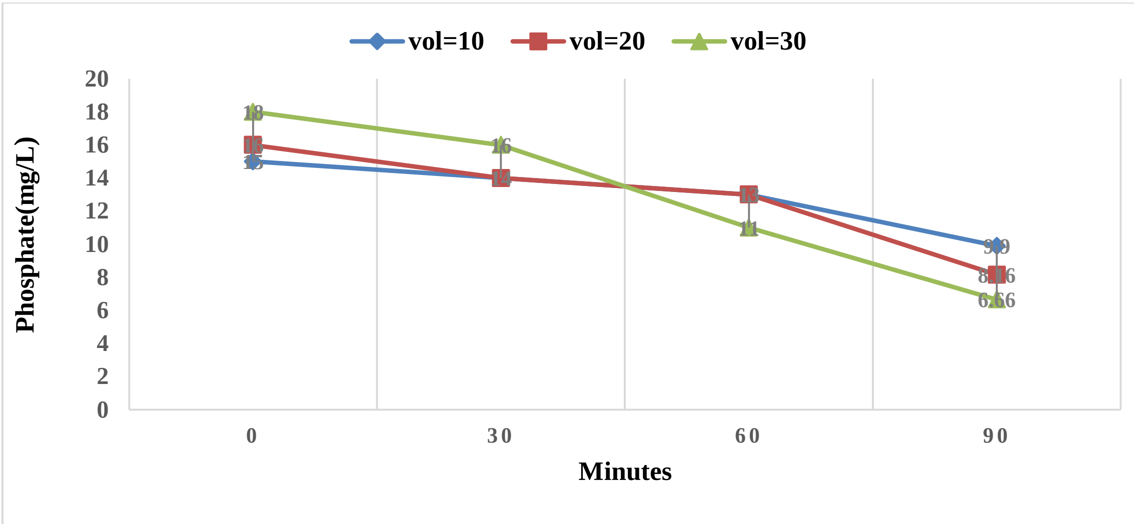

Figure 3) Changes in phosphate in the EC with iron electrodes in the optimum PH =7

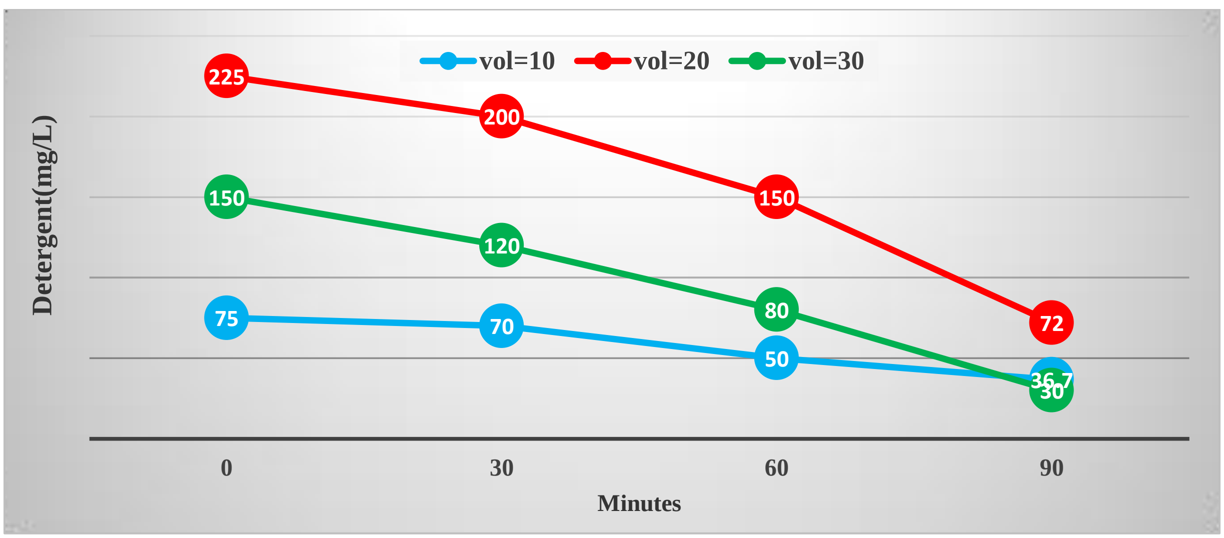

Figure 4) concentration of detergent in the EC with aluminum electrodes in the optimum pH=7

According to Figure 5, percentage of detergent removal in the EC with aluminum-iron electrode with an optimum pH=7 have been from 41% (in the 10 voltage) to 72% (in the 30 voltage), respectively. According to Figure 6, percentage of detergent removal in the EC with aluminum-iron electrode with an optimum pH=7 have been from 68% (in the 10 voltage) to 94% (in the 30 voltage), respectively.

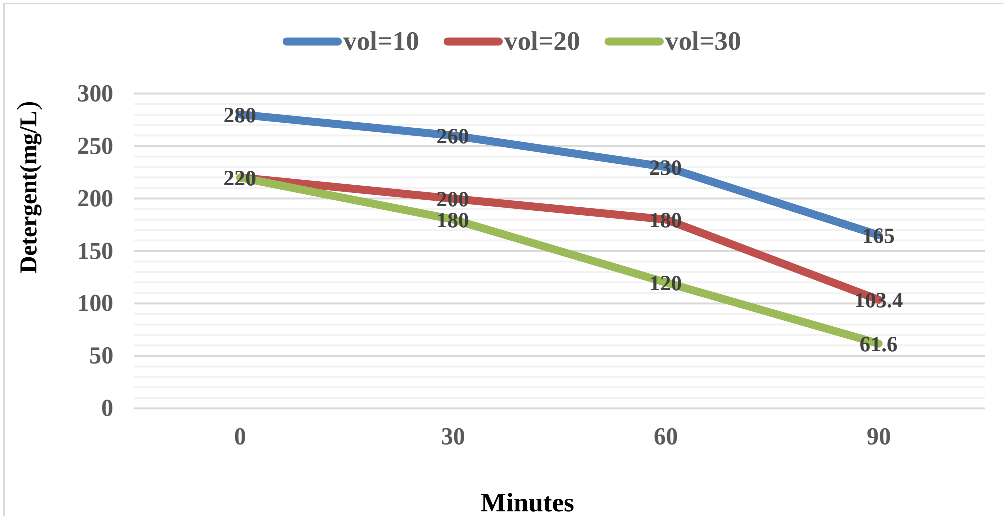

Figure 5) Changes in detergent concentration in the EC with aluminum-iron at the optimum pH electrode=7

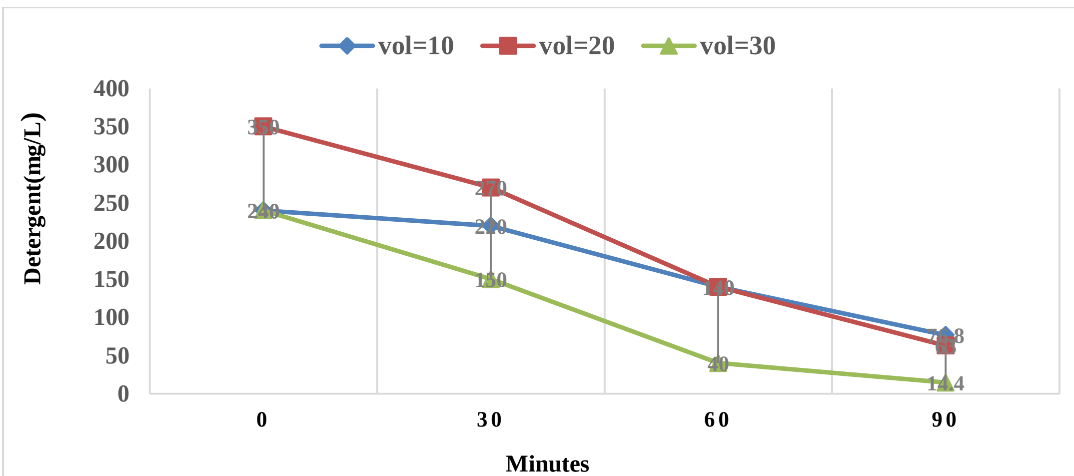

Figure 6) Changes in detergent concentration in the EC iron electrodes in the optimum pH=7

Discussion

Effect of electrode and array

The results of this experiment showed that use of the iron electrodes was appropriate for achieving the highest detergent removal. In the studies conducted by Singil et al. the removal percentage of detergent by using iron electrode was 98 (30). By using aluminum electrode, Nafa et al. attained a detergent removal efficiency of 76% (31). By using iron electrode, Cobarty et al. obtained a detergent removal efficiency of 54%, which is consistent with the results of this study. Önder et al. in their study showed that the removal efficiency in surfactants from water contaminated with iron electrodes was 100% (26).

The effect of voltage

According result our study, increasing the intensity of the current and voltage were affecting the treatment efficiency of detergent. Removal efficiency of detergent at natural pH for the iron electrode pair during 90 minutes at a voltage of 30 was nearly 93 %. By increasing the voltage potential the response is increasing. Some of organic compounds and suspended solids are taken from the molecule 3 (OH) Fe or 3 (OH) AL; then, they formed fluke by settling or flotation mechanisms and are separated by 2H taken in cathode (20-22). This behavior that filtration efficiency is influenced by voltage is proven by some researchers. Drouche et al. observed that the Al^{+3} amount is increased by increasing the voltage, thereby fluoride ions are eliminated effectively (32). As well as in studies conducted by Rahmani and Samarghandi on the effectiveness of electro-coagulation in removing the detergent from wastewater, they concluded that the percentage of detergent removal is increased due to increasing the voltage (33).

The effect of retention time

Based on result this study, increasing retention time cause the increased removal efficiency. Removal efficiency directly depends on the concentration of ions produced in the electrodes. With increasing time of electrolysis, the concentration of ions produced increases, thereby the hydroxide clots increase (16,21,27).

Effect of primary PH

According to the results, apart from the detergent and phosphate that had the greatest efficiency removal at acidic pH, detergent had the greatest efficiency removal at neutral PH. The experiments were performed at pH of 11, 7 and 3. In the course of the electrolysis when the electrodes of iron or aluminum are used, ions, iron and aluminum respectively, are produced at the anode and hydroxyl ion at the cathode. The effect of initial pH on the treatment of the PSW was. In a study conducted by Bayramoghlu on poultry slaughterhouse wastewater with aluminum electrode, a removal efficiency of 93% was obtained for 25 minutes and the current density of 150 mA per cubic meter in the initial pH=3 (34). Also in studies conducted by Kubaya on MCFsW, phosphate removal at pH of 5 was 86% with aluminum electrodes and the removal of detergent was 78% at pH of 5 with electrodes made of aluminum (34). In Adhoum et al. study, optimum pH was 6-4, which in this range, treatment olive oil mill wastewater without can be treated during the 25 minutes without the need to adjust the pH with COD and detergent removal efficiency of 76%, polyphenols removal efficiency of 91% and color removal efficiency of 95% (31).

Conclusion

In this study we evaluate to efficiency of the electrocoagulation (EC) process in the removal of detergent and phosphate from car wash effluent. According to the obtained results the average removal of detergent and phosphate were 93% and 78%, respectively. Reaction speed is used to express a reduction in the concentration of reactants and to an increase in the concentration.

Footnotes

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Conflict of Interest:
The authors declared no conflict of interest.

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