Treatment of effluents of construction industry using a combined filtration-electrocoagulation method

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Treatment of effluents of construction industry using a combined filtration-electrocoagulation method

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Abstract. One of the significant sources of water pollution is construction industry as it requires considerable freshwater amounts during manufacturing of concrete, mortars and other construction materials. Vast volume of the used water is discharged back to source of freshwater as extremely polluted effluent (high level of suspended solids and pH), which is categorized as hazardous wastewaters. Therefore, environmental regulations prevent discharging these effluents before conducting adequate treatment. As a result, efficient treatment solutions for these effluents become necessary in the field of construction industry. In this context, this research aims at treating construction industry effluents using an integrated method, which involves adsorption (AD) and electrochemical (EL) techniques, to treat effluents of concentration sites. Turbidity and chemical oxygen demand (COD) were selected as pollutants models due to their wide occurrence in this type of effluents. 200 mg of activated carbon (AC) and four aluminum electrodes were utilized to construct the adsorption and electrochemical units, respectively. Aluminum and AC were used here as they are economically efficient, safe, and have a proven efficiency in waters/wastewaters treatment. The influences of initial pH, retention time (RT) and electrolyzing time (ET) on the removal of COD and turbidity using the new method (AD-EL method) were examined. The results demonstrated the AD-EL decreased COD and turbidity by about 72% and 85%, respectively. The perfect conditions to reach this removal levels were pH, RT and ET of 6, 30 minutes and 20 minutes, respectively.

1. Introduction
Concrete is a very important element of the infrastructures of modern life, and it is very important to maintain the sustainability of the human civilization [1-4]. However, concrete industry is a considerable source of pollution for water resources because it needs significant quantity of clean water for construction activities, and, as a result, significant amount of substantially polluted effluent is discharged to the water sources (i.e., rivers and lakes) [5-7]. In addition, this industry produces huge amounts of solid wastes that represent a challenge for the local authorities [8-11] and high amounts of harmful gases that result in severe climates changes, which negatively reflected on water consumptions and pollutions [12-16]. Most of the needed water in the field of construction is consumed in the activities of concrete development, which needs amount of freshwater equivalent to half of the used cement (cement-water ratio of 2), and another vast quantity of freshwater is demanded for processes of concrete curing. In

addition, after each shift, it is fundamental to wash concrete mixers and truck-mixers using clean water [17]. It was proved that washing one truck-mixer, at the end of each shift, consumes about 1500 L of clean water [17, 18]. Furthermore, producing concrete in a truck-mixer with a capacity of 8 m^3 requires about 1600 L of clean water for each run of mixing [5, 17]. The significant amount of discharged effluents from the construction activities is not only the issue, but also the chemical properties of discharged effluents represent a grave concern. The pollutants in the discharged effluents from activities of concrete construction are high in suspended solids, organic matters and pH value (usually >11.5) [5, 18]. As a result, the discharged effluents from construction activities are categorized as hazardous wastewater, so it is not allowed to discharge them directly to the water resources. According to the legislation, it is mandatory for the construction industries to reuse more of their produced wastewaters, and many sectors of this industry are currently aiming to achieve zero-effluent goal [18, 19]. Accordingly, efficient solutions become necessary for the discharged effluents from the construction industry; these solutions could be treating, reusing or recycling of effluents. Most of the proposed solutions aimed at recycling or reusing the effluents of construction industry [5]. While, treatment of construction industry effluents is not a common solution yet. However, the literature shows a number of treatment studies, for example, Tsimas and Zervaki [17] treated the discharged effluents of construction industry utilizing a 2-stages treatment method. This method based on the concepts of the sedimentation and neutralization, in which the effluent was flowed in three tanks, so the fine partials of mud and cement were allowed to be precipitated. After that, the pH of effluents was minimized by neutralization manner using hydrochloric acid (HCl) and small volume of freshwater (0-20%). This method produces water with an adequate quality to be reused in producing concrete. However, it was mentioned that total solids content in the treated water, using this method, is more than 6%, which significantly affects concrete characteristics [19, 20]. As a result, the addition of coagulation process became necessary in order to separate the solids or reduce them to below 6%. de Paula, de Oliveira Ilha and Andrade [5] treated effluents of concrete plants utilizing a new method of treatment that relied on both coagulation and sedimentation processes. Aluminum sulfate and *Moringa oleifera* were used as coagulants in the process; and then the coagulated pollutants were removed by passing the solution in a sedimentation tank. The results demonstrated that the treated water is allowable to be used in flushing toilets or washing vehicles. However, the coagulation process cannot treat high loads of pollutants, and also the cost of the many artificial coagulants is relatively high, which limited the large-scale use of this method [21-24].

Hence, this study examines the ability of a new approach, which utilizes adsorption (AD) and electrochemical (EL) techniques, to minimizes (or eliminate) the turbidity and COD in the effluents of construction industry. As mentioned, the AD-EL system integrates AC-based adsorption unit and aluminum-based EL unit to achieve the planned goal. The AD and EL methods were selected in this investigation because of their advantages. For instance, the EL method is known for ease of operation [21, 22], cost-efficiency and speed of treatment [25, 26]. Also, in the EL treatment; chemicals are not necessary [27-29], production volume of sludge is small [28-30], and there is not production of secondary pollutants [30, 31]. Additionally, it is could be easily automated [32-34] that makes it possible to control it remotely using a proper technology, such as sensors [35-39]. The method of adsorption is economic, big wastewater volumes could be treated by this method, and the materials of adsorption are locally available even in poor countries [40, 41].

2. Methodology

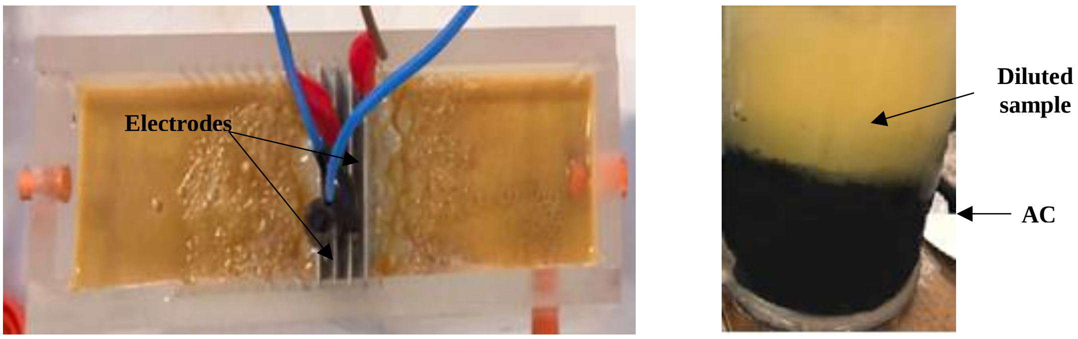
2.1. Preparation of diluted wastewater

A real effluents sample, which was obtained from a construction site in Liverpool City, UK, was used create diluted samples. The latter were used to run the AD-EL system. The fresh sample (obtained from the construction site) was collected, on daily bases, using a 5.0 L plastic storage canister (with level scale on the side). This sample was kept in a fridge as received, and diluted few minutes before the experiments time. The preparation of diluted sample was conducted by adding 0.10 L of the fresh sample to 0.9 L of deionized water, and stirred to homogenize the solution. To keep the experimental conditions constant, the initial turbidity and COD of the diluted samples were adjusted (if necessary) to 200 NTU and 500 mg/L using kaolinite and organic matter solution, respectively. As known, the effluents of concrete industry are very alkaline, so hydrochloric acid was applied to adjust the pH value of the diluted sample.

2.2. Experimental setup

To setup the experiments of the current investigation, two units were used, namely AD and EL. A 1600 mL cylindrical container, made from plastic, was used to run the AD experiments. To facilitate sample collection during the process of adsorption, tow outlets (valves) were made in this container; at its bottom and at a distance of 125 mm from its base. The desire amount of AC was put in the container, and then the diluted sample was added. However, it was noticed that the AC particles float on the surface of the diluted effluent samples because of its light density in comparison to that of wastewater. Therefore, fine stainless meshes were placed above and beneath the layer of AC to keep it in the desire place. After that, the container was left to start the adsorption process.

In terms of EL unit, the shape of the container of the EL unit was rectangular with a dimension of (100, 70, 200) mm for depth, width and length, respectively. Its working volume was 1400 mL and it was made from plastic. This container contained four electrodes, which were made from aluminum and their overall area was 244.8 cm^2. The electrodes were placed in the vertical direction inside the container keeping a space of 5 mm between each two electrodes. Electrodes were connected to a source of power (DC rectifier with 0-10 A and 0-30 V capacity), using wires, to derive the desire current. This container was supplied with two openings at a distance of 10 mm from the lower and upper edges, which were used for sampling process during the experiments. After each experiment, the electrodes were taken off from the container in order to be cleaned using diluted acid (HCl) and water. Then, they were placed back again inside the container to complete other experiments. Figure 1 shows AD and EL units.



A) Top view of the EC unit.

B) Zoomed section in the AD unit.

Figure 1. AD and EL units.

2.3. Turbidity and COD measurement

Turbidity and COD of diluted samples, before and during the treatment, were measured using a Turbidimeter (2100-Q) and a Hach-Lange spectrophotometer with a standard COD cuvette (LC-I400), respectively. All diluted or being treated samples were subjected for filtration process, on No. 2 Whatman filters, before testing turbidity of COD level to avoid any destruction in the results.

Level of turbidity was tested by pouring suitable volume of filtered sample into the vessel of Turbidimeter, and recorded the displayed reading. The COD concentration was calculated by pouring suitable volume of the filtered sample into the standard COD cuvette, and test the latter using the spectrophotometer.

2.4. AD-EL experiments

The treatment of the diluted sample was began initially in the AD unit, where a constant dose of AC of 200 mg/L was applied for the diluted samples for different retention times (RT) (10-90 minutes) and initial pH (4-9). The ambient temperature was kept constant between 20 and 22 ^{0}C.

Six samples were prepared with different values of initial pH (4-9) and treated in the AD unit for RT of 30 minutes. These experiments were conducted to calculate the best pH value. Then, to investigate the RT effect on tardily and COD removal by the AD, several diluted samples were treated in the AD for RT between 10 and 90 minutes at constant pH (from last experiments). Reduction in turbidity and COD levels were measured at 10 minutes-intervals; few milliliters of the wastewater being filtrated were taken, filtered and tested for turbidity and COD level according to the above stated procedures. These two phases allow the researcher to calculate the optimum RT and initial pH to run the AD unit.

Then, ability of the AD-EL unit to reduce the COD and turbidity levels in the diluted samples was examined at the best pH and RT values that calculated in the previous tests, while the EL process optimized for the effect of electrolyzing time (ET). The EL treatment was run for up to 20 minutes at constant current density (CD) and gap between electrodes (GBE) of 3.5 mA/cm^2 and 5mm, respectively. Magnitudes of CD, GBE and ET were selected basing on the previous researches [32, 42, 43]. Reduction in turbidity and COD levels, during the EL treatment, were measured at 5 minutes-intervals following the same steps in the AD experiments.

3. Results and discussion

3.1. AD experiments

3.1.1. Influences of pH

Diluted wastewater samples with various initial pH values (4, 5, 6, 7, 8 and 9) were treated in the AD unit to examine the impact of pH on the turbidity and COD removal.

Figure 2 demonstrates that the turbidity and COD removal, using the AC unit, increases significantly a moderate acidity level in comparison to moderate or high alkalinity levels. The removals of turbidity and COD were about 44% and 39% when the initial pH was 4.0. Increasing the pH level to 7.0 results in a slight decrement in the removals of these pollutants (to about 32 percent of COD and 38 percent of turbidity). At higher pH level, there was a significant decrement in the removals of these pollutants (25 percent of turbidity and 32 percent of COD). The increment in the COD and turbidity adsorption, on the particles of AC, at low values of pH is attributed to the increase in ions of hydrogen (positively charged) on the surfaces of the AC particles, which leads to electro-static attractions among AC particles and the negatively charged contaminants [45]. It is clear that a relatively large volume of acids is required to keep the pH at 4.0, which could negatively affect the environment (water sources). In addition, there was a relatively small difference in the removal efficiency (< 6%) at pH 6.0 and 4.0. Thus, the best value of pH, for the current experiments, is 6.0.

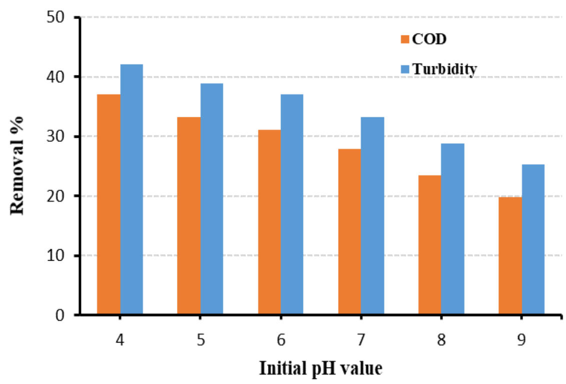


Figure 2. Variation of turbidity and COD levels with initial pH in the AC system.

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3.1.2. Influence of RT

To examine the effect of RT on the turbidity and COD adsorption by the AD system, a number of diluted samples with initial pH of 6.0 were treated for RT up to 90 minutes.

The experimental results are presented in Figure 3, which show considerable increment in removals turbidity and COD during the first 30 minutes of treatment, followed by a moderate increment between 30 and 70 minutes, and then a negligible increase was noticed after 70 minutes. For example, the removal of turbidity and COD was increased during the first 30 minutes by about 18% and 22%, respectively. However, COD and turbidity removals, over the rest of experiment period, were increased by about 23% and 14%, respectively. The moderate increment in turbidity and COD removal during the last 60 minutes of treatment is due to the relative saturation of adsorption sites on the AC particles with pollutants [44]. Basing on these results, 30 minutes was selected as the best RT value.

3.1.3. AD-El treatment

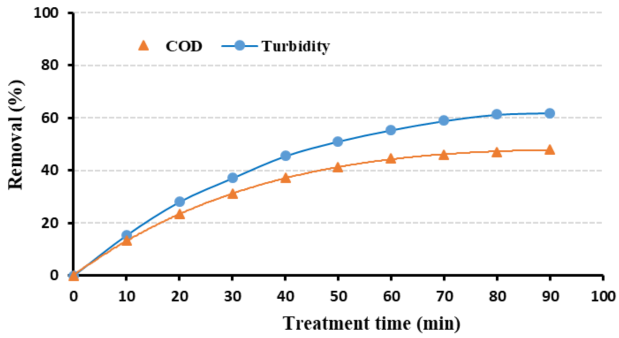

Figure 3. Va AC system.

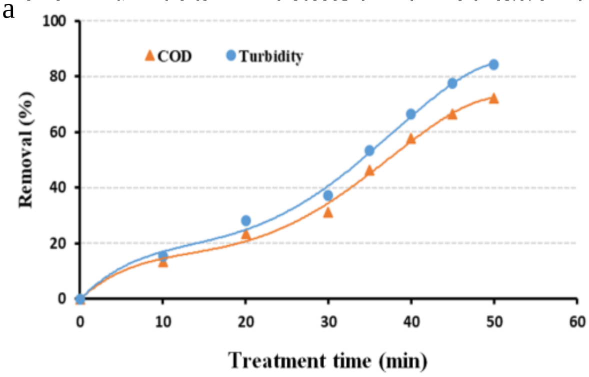

Figure 4. Remediation of diluted samples from turbidity and COD using AD-EL.

This part of research investigates the capacity of the new AD-EL system to remove COD of turbidity from effluents of construction industry. The purpose of applying this new method, AD-EL, is to reach efficient removals of turbidity and COD at reasonable time. The initial turbidity level and concentration of COD were 200 NTU and 500 mg/L, respectively. Firstly, these samples were treated in the AD unit with AC dosage of 200 mg/L, initial pH of 6.0 and RT of 30 minutes. Then, this sample was electrolyzed in the EL unit for 20 minutes at the mentioned conditions in section 2.4 of this study. Figure 4 illustrates the results of these experiments. It is obvious from figure 4 that the maximum removals of turbidity and COD were about 85% and 72%, respectively. Also, it could be noticed that there was a sharp increase in the removals of these contaminants after 30 minutes of treatment, which is the beginning of the EL treatment. The reason of this sharp upsurge belongs to the known speed of the EL process in removing pollutants [31, 32].

In summary, these results emphasize the efficiency and speed of the new combined method (AD-EL) in remediation of construction effluents from the COD and turbidity.

4. Conclusions

This research aims at studying the capacity of a new AD-EL system (integrated AD and EL units) to decrease (or eliminate) turbidity and COD levels in the effluents of construction industry. According to the results experimental phase of this study confirmed the following important points:

1- Turbidity and COD were moderately removed (44.4% of turbidity and 39.2% of COD) using the AD method, which based on AC as adsorption media.
2- Increasing the time of treatment or decreasing the pH of solution makes the AD method more efficient.
3- Application of integrated AD and EL techniques substantially improved the removals of turbidity and COD from construction effluents (84.5% of turbidity and 72.3% of COD).
4- The combined method, AD-EL, efficiently performed when the initial pH is slightly acidic level (4.0-6.0) and the treatment time is ≥ 50 minutes.

For future studies, the authors recommend investigating the effects of samples' temperatures, space between electrodes, voltages and AC dosages on the performance of the AD-EL system.

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