Where the percentage of Ant removal (*R*, percentage) and the Ant value before and after treatment (C_0 and C, mg/L) expressed.
Kinetics reaction models are calculated according to the following Equns (2) and (3):

$$\ln C_t = \ln C_0 - K_1 t \quad (2)$$

$$\frac{1}{C_t} = K_1 t + \frac{1}{C_0} \quad (3)$$

Where C_0 and C_t are the concentration of Ant at the beginning and after time t of the reaction, respectively. K_1 and K_2 are the first, and second order reaction constants, respectively. Values of K_1 and K_2 can be calculated from the slope of the plots ln C_t versus t, and $1/C_t$ versus t, respectively.
Electrodes are rinsed with distilled water after conducting all tests.

3. Results and discussion

3.1. Effect of electrode materials

Image 2 shows the effects of anode and cathode electrode materials on the Ant removal at the experimental conditions given in Table 2. AS-AS as anode-cathode electrodes produce the mean of the lowest Ant removal (0.2%), while Zn-Cu as anode-cathode electrodes produce the mean of the highest Ant removal (100%) at similar experimental conditions (Table 2). Ant removal in the electrochemical reactor is seriously affected by the electrode material. Therefore, the material which would produce an oxidation reduction potential just sufficient to decay to carbon dioxide and water will be the preferred material. Mossavi et al. [13] select Al, iron (Fe), and steel (AS) electrodes for the study of TPH removal. TPH reduction rates using As-Fe as anode-cathode electrodes reached to the highest TPH removal of 91.5%. When Zn-Cu is applied the •OH radicals react directly with Ant molecules and results in an enhancement of the Ant removal which can be attributed to the indirect oxidation mainly, due to chlorine production. The Ant reduction rate relates to electrolytic activity rate of anode material due to generating different values of •OH radicals at anode surface. Vieira Dos Santos et al [14] report similar results. Souza Duarte et al. [15] report that electrochemical oxidation relates to electrocatalytic activity of anode material. The higher removal with aluminium and iron electrodes may be due to their greater electron donating capacity.

3.2. Effect of wáter pH

Electrochemical experiments are carried out an initial pH values in the range of 4 to 10 at the experimental conditions given in Table 2. The results are indicated in Image 3. In the case of the Zn-Cu as anode-cathode electrodes, the mean Ant removal increases from 72% to 100% when the pH increased from 4 to 7. Ant removal in the electrochemical reactor is mainly influenced by the water pH. The mean Ant removal is very low at low and at high pH. The optimum pH is 7. This phenomenon is attributed to increasing •OH concentration at pH 7. Therefore, higher increase of the water pH would reduce the Ant removal efficiency. The mean Ant removal sharply increases when the pH is increased from 4 to 7. The mean Ant removal slowly decreases when the pH is increased from 7 to 10. This finding support that electrochemical efficiency is a function of pH. The Ant is an insoluble molecule. Thus these are decreased by indirect electrochemical in the presence of chlorine. El-Kashi et al. [16] report the highest acid red 18 reduction at pH 4 in an electro-photo-catalytic rector. AlSalka et al. [17] report the optimum (the best) pH for removing PAH_S is almost 8. The possible electro reduction mechanism for Ant removal is described as follows: in the electrochemical reactor, the main reaction at the anode is oxygen evolution:

$4OH^- \leftrightarrow O_2 + 2H_2O + 4e^-$

$2OH^- + Cl^- \leftrightarrow ClO^- + H_2O + 2e^-$

The main reaction at the cathode is hydrogen evolution:

$2H_2O + 2e^- \leftrightarrow H_2 + 2OH^-$

High current density can result in producing free radicals such as •OH, •O, H^+ and H_2O_2. The electrochemical reaction of Ant is:

$HClO + Ant \leftrightarrow CO_2 + H_2O + Products$

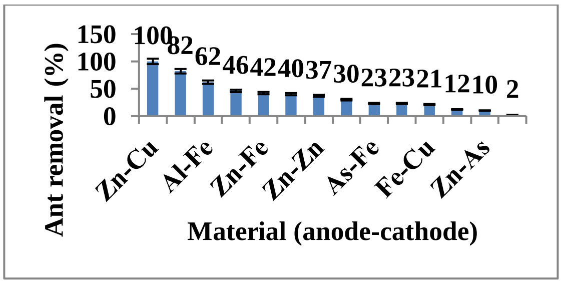

Image 2. The effect of electrodes material on the Ant removal in the batch electrochemical reactor

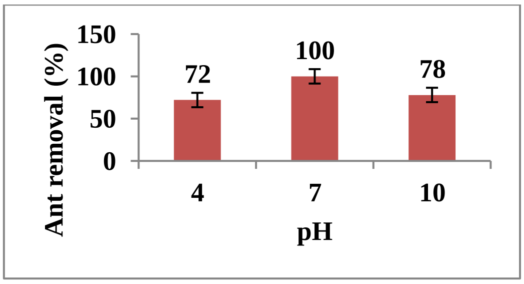

Image 3. The effect of water pH on the Ant removal in the batch electrochemical reactor

3.3. Effect of current density

Electrochemical experiments are carried out at a current density levels in the range from 1 to 8 mA/cm^2 at the experimental conditions given in Table 2. The efficiency of Ant removal increases as the current density and time increase. The results are indicated in Image 4. In the case of the Zn-Cu as anode-cathode electrodes, the mean Ant removal increases from 57% to 100% when the current density increases from 1 to 8 mA/cm^2. Performance and economy of Ant removal in the electrochemical reactor is influenced by the current density. Tran et al. [18] also report the similar results. Ant removal in the electrochemical reactor is mainly effected by the current density. Similar effects of current density on the electrochemical are also reported by Mansouri *et al*. [19], and Cerqueira *et al.* [20]. The increase of mean Ant removal as a result of increase in the current density is related to the rate increase of the hydrogen gas evolution in cathode electrode (Cu). Therefore, hydrogen gas evolution is enhanced, increasing the reduction conditions based on the mechanisms given. In other hand, the dissolution of anode electrode enhances at high current densities according to Faraday's law, and significantly leads to decaying Ant. The Ant removal as a function of current density is proportional to the Ant concentration in water. Bazrafshan [21] also reports the similar results.

3.4. Anode weight loss

Image 5 shows the value of anode weight loss in the electrochemical reactor at the experimental conditions given in Table 2. The anode consumed mass increases with increasing current density. In the case of the Zn-Cu as anode-cathode electrodes, the mean anode weight loss increases from 3 mg to 23 mg when the current density increases from 1 to 8 mA/cm^2. The increase of mean Ant removal as a result of increase in the current density is related to the rate increase of the consumed anode (Zn). Giwa et al. [22] also reports the similar results. It can be concluded that the mean anode weight loss from 3 to 8 mg as a result of increase in the current density from 1 to 3 mA/cm^2 follows linear equation. The mean anode weight loss from 8 to 23 mg as a result of increase in the current density from 3 to 8 mA/cm^2 never follows linear equation.

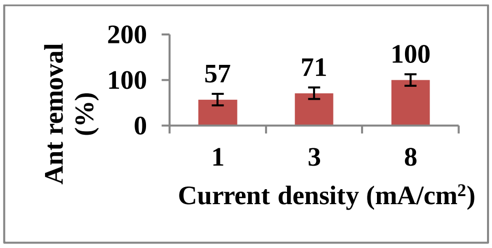

Image 4. The effect of current densities on the Ant removal in the batch electrochemical reactor

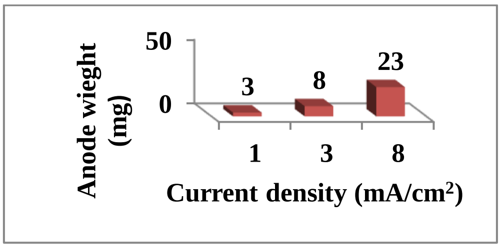

Figure 5. The anode weight lost in the batch electrochemical reactor as a function of current densities

3.5. Effect of time

Electrochemical experiments are carried out as a function of the time levels in the range of 20 to 60 min at the experimental conditions given in Table 2. The efficiency of Ant removal increases as the time increases. The results are indicated in Image 6. In the case of the Zn-Cu as anode-cathode electrodes, the mean Ant removal increases from 33% to 100% when the time increases from 20 to 60 min. The increase of mean Ant removal as a result of increase in the current density is related to the amount decrease of time that can be attributed to increasing opportunity for adsorption / desorption reactive material specious and blocking current. The increase of mean Ant removal with increase in the time is expected and can be attributed to the amount increase of the pH with increasing electrochemical reaction time.

3.6. Oxidation reduction potential (ORP)

Image 7 shows the effects of anode and cathode electrode materials on the ORP value at the experimental conditions given in Table 2. As found in Image 7, As-As as anode-cathode electrodes produce the mean of the lowest ORP value (+13 mV), while Zn-Cu as anode-cathode electrodes produce the mean of the highest ORP value (-309 mV) at similar experimental conditions (Table 2). It seems that under high reducing environment (ORP -309 mV) with Zn-Cu as anode-cathode electrodes Ant rapidly converts to products. As expected, for the correlation coefficient (R^2) increased, accordingly the experimental data fitted better are increased.

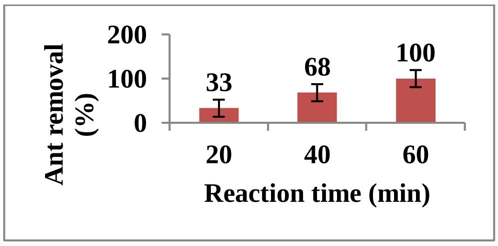

Image 6. The effect of time on the Phe removal in the batch electrochemical reactor

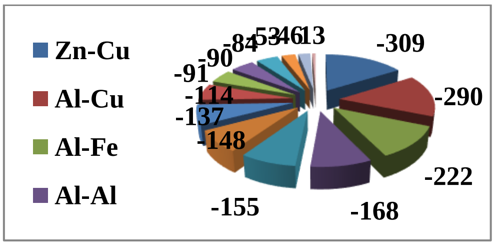

Image 7. The effect of electrodes material on the ORP value in the batch electrochemical reactor

3.7. Kinetic studies

Image 8 shows the plots of the kinetics first, and second order reaction models fitted with the Ant removal experimental data in batch electrochemical reactor at the experiments conditions given in Table 2. The experimental data fit better to the first order reaction. The results of Ant removal efficiency by Taguchi model showed that reaction time was the most important variable. This reactor shows an exponential shape applying the Zn-Cu as anode-cathode electrodes, indicating first-order kinetics and mass transfer control. Text describing, say, the experimental observations, the experimental conditions etc. typically would follow the introduction. Muff and Søgaard [23] reports that naphthalene decomposition in all electrolytes is followed second order reaction kinetics but fluoranthene and pyrene is followed first order kinetics.

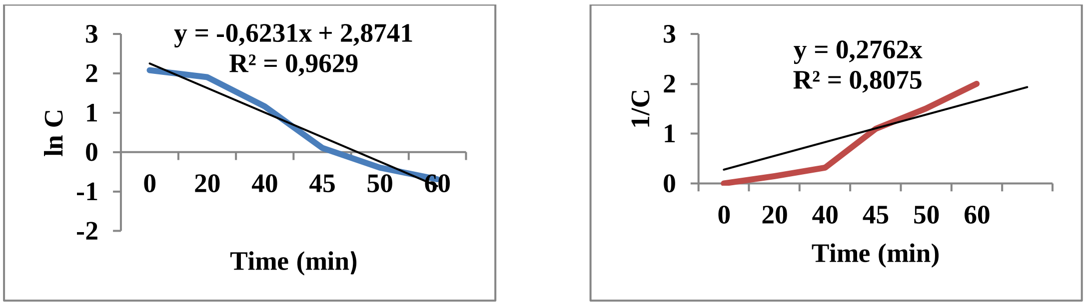

Image 8. The plots of first, and second order reaction models fitted with the Ant removal experimental data in batch electrochemical reactor (experimental conditions: 25 °C, pH: 7, reaction time: 0-60 min)

4. Conclusions

The chemical reduction of Ant from urbane drinking water is investigated in an electrochemical reactor in batch and monopolar electrodes connection mode. Several operational variables are examined for the effects on process reduction efficiency. The following conclusions are obtained from the experiments:

1. The highest removal of Ant is given with applying Zn-Cu as anode-cathode electrodes (100%).
2. The reaction time significantly effects on Ant reduction during the process; reduction of Ant enhances with increasing reaction time, for given experimental conditions.
3. The pH has a significant effect on Ant reduction, with the highest reduction obtained at pH 7.
4. The 8 mA/cm^2 current density achieves the highest removal of Ant during the reactor with applying Zn-Cu as anode-cathode electrodes (100%).
5. Ant reduction follows a first-order rate equation during reactor.
6. The removal mechanism is attributed to increasing reduction conditions as result of hydrogen evolution at the cathode.
7. The electrochemical reactor, in batch and monopolar electrodes connection mode, is showed to be an efficient and viable process for meeting a high degree of Ant reduction from drinking water and be considered as a promising technology for treating Phe-polluted drinking water.
8. There is necessity for new investigations about other removal mechanisms are not considered in this report.

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