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Smart Sensor for Monitoring Integrated Wastewater

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Abstract. The commonly used wastewater treatment technology is coagulation-flocculation. This method weakness is in high processing costs and large sludge volumes. The more effective alternative method is electrocoagulation. Electrocoagulation is a coagulation method using electric current through an electrochemical process. The working principle of electrocoagulation is the dissolution of anode metal (M+) which reacts to hydroxyl ion (OH-) to form coagulant. In this study, the treated integrated wastewater by electrocoagulation method using aluminium and stainless electrodes. This process was conducted in continuous where integrated wastewater was placed in electrochemical cells containing smart sensors. Parameters varied are smart sensor pH, total dissolved solid, total suspended solids, chemical oxygen demand, biological oxygen demand and heavy metals (Fe and Pb). The optimum conditions for the aluminum and stainless steel electrodes are 12 volt voltage and 150 minute process time. The results show that pH decrease until 6.52, TDS 340 mg/L, BOD5 14,2 mg/L, COD 52 mg/L, PO4 1.884 mg/L and heavy metal contents Pb 0.009 mg/L and Fe 0.18 mg/L. The result of this research has fulfilled the environmental quality standard.

1. Introduction

Industrial, domestic and other activities have negative impacts on organisms that depend on water resources. Therefore, quality management and protection of water resources are required. Pollution control caused by integrated wastewater requires to get serious attention to be studied and investigated to qualify the environmental quality standards set by the government. It requires the integrated treatments between the government, the industries, and the communities. It also requires wastewater treatment technology to reduce the level of pollutants contained in these wastes [1-3].

The addition of chemical materials into the wastewater required to be processed still has many disadvantages. For example, the utilization of chemical material such as alum as a coagulant can reduce the pH value of the treated water. Because of it, a base solution is required to increase the pH value, which can increase the operational cost. There are still many disadvantages to the method of adding these chemical materials. A cheap, easy, effective, and innovative wastewater treatment method is required in treating wastewater before being disposed to the environment. One of the methods to solve that problem was the electrocoagulation method [4-6].

Electrocoagulation method is formed by dissolving anode metal which then it interacts simultaneously with hydroxide ion and hydrogen gas produced from the cathode. Electrocoagulation can treat various pollutants such as suspended solids, heavy metal, ink, organic materials, oil, fat, ion, and radionuclides. Pollutant characteristics affect the mechanism of the process. For example, ion-shaped pollutants will be reduced through the precipitation process while the charged suspended solids will be absorbed into charged coagulants [7-9].

Electrocoagulation is an electrochemical water treatment method where the active coagulant such as the metal ion (usually iron or aluminium) is released at the anode into the solution while the electrolysis reaction occurred at the cathode in the form of hydrogen gas released [10,12].

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Electrocoagulation is a complex process involving chemical and physics phenomena by using electrodes to produce ion for wastewater treatment [13-15].

2. Materials and Method

Integrated wastewater treatment research is commonly conducted by using electrocoagulation process. The electrodes used are aluminium and stainless steel electrodes. The smart transducer used is a pH sensor. The data retrieval process is taken 30 times each process with a variety of electrodes, voltage and processing time in waste water treatment. The research is carried out with an experimental design as follows:

1. Integrated liquid waste sampling in 4 different industries in South Sumatra.
2. Initial characterization of integrated waste water with parameters in the form of pH, TDS, TSS, BOD5, COD, PO4, Fe levels and Pb levels.
3. After the classification and characterization of the integrated wastewater is completed, the next step to be carried out is electrocoagulation process.
4. Characterization of integrated wastewater after being processed with parameters in the form of pH, TDS, TSS, BOD5, COD, PO4, Fe content and Pb levels.

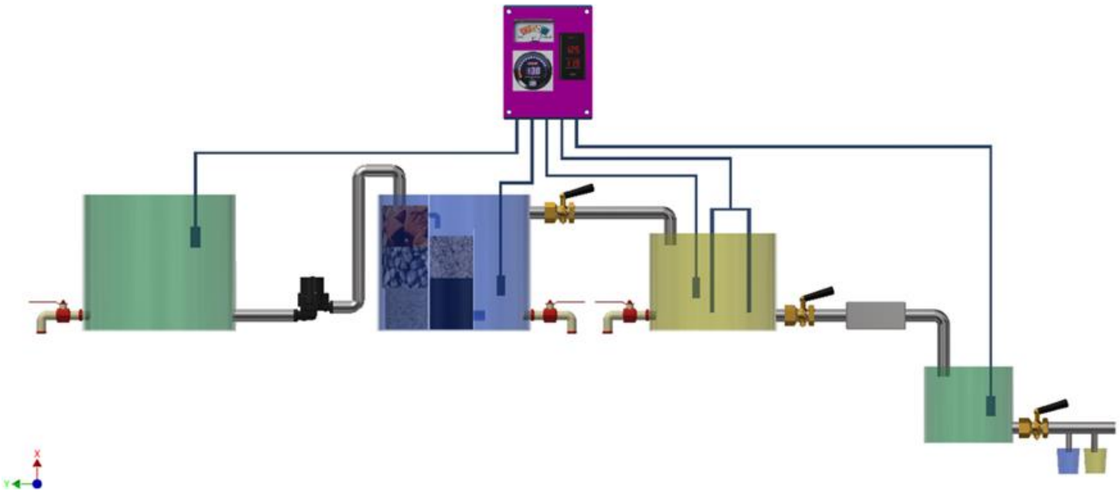

Figure 1. Electrocoagulation Equipment Scheme

3. Results and Discussion

3.1. Initial Characterization of Integrated Waste

Preliminary analysis was carried out on integrated wastewater before processing by electrocoagulation method by analyzing the values of pH, TDS, TSS, BOD5, COD, PO4, Fe levels and Pb levels. The results of the analysis is shown on Table 1 [11].

Table 1. Initial Characterization of Integrated Waste

No	Parameter	Unit	Result	Quality Standards*	Inspection Standards
1	pH	-	4,61	6 – 9	SNI 06-6989.11-2004
2	TDS	mg/L	3081	2000	SNI 06-6989.27-2004
3	TSS	mg/L	80	200	SNI 06-6898.3-2004
4	BOD_5	mg/L	140,4	50	SNI 06-2503-1991
5	COD	mg/L	432	100	SNI 6989.2-2009
6	PO_4	mg/L	2,912	-	SNI 06-6989.31-2004
7	Fe	mg/L	0,32	5	SNI 6989.4:2009
8	Pb	mg/L	0,07	0,1	SNI 6989.8:2009

Source: *South Sumatera Governor Act No. 08 Year 2012

From the results of the initial integrated waste water analysis in Table 1, it can be seen that the TSS, PO4, Fe and Pb levels do not exceed the integrated wastewater quality standards while the values of pH, COD, BOD5 and TDS need to be taken into consideration because the pH value is still too acidic and the TDS value obtained is above the quality standard for integrated liquid waste.

The pH value obtained also needs to be taken into consideration because it is still acidic, so further processing is needed to process the pH value, the final pH is expected to be in a neutral position. If the pH value is not in a neutral condition, the waste will affect environmental or water conditions, this effect can disrupt the life of organisms in the water including corrosive effect to metals. A too high Total dissolved solid (TDS) can cause changes to the color, taste and unpleasant smell of investigated waste water. The pH value obtained also needs to be considered because it is still acidic. Further processing is needed to be carried out, so that the pH reaches a neutral position. If the pH value is not in a neutral condition, the waste can affect environmental or water conditions, can disrupt the life of organisms in the water and corrosive effect to metals. A too high Biological oxygen demand (BOD) and Chemical oxygen demand (COD) can cause damage and contamination to aquatic biota by this untreated well waste, causing the life in these waters can be disrupted.

3.2. Results of Integrated Liquid Waste Processing with Electrocoagulation Process Using Aluminum Electrodes

3.2.1. Effect of Process Voltage and Time on pH

Figure 2 shows the pH value in the initial sample is quite acidic at 4.61 so that if it is disposed of directly into the environment it can contaminate the surrounding environment.

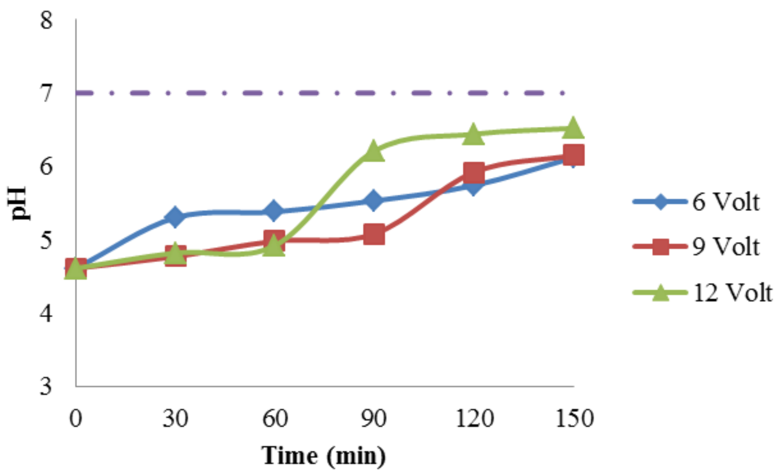

Figure 2. Effect of Process Voltage and Time on pH

After processing waste water using electrocoagulation method, the treated waste water has increased the pH. The results obtained have an increased pH in each voltage variations. The increase in pH value in the electrocoagulation process occurs because of the alkalization process of Al3 + ions which are added/dissolved in water so that a reaction occurs with hydroxide ions from hydrolysis of water which produces Al(OH)3 and hydrogen ions. The greater the current used, the more Al3 + is dissolved so that the H+ ions that are formed are also increasing. In this electrocoagulation process, hydrogen gas formation occurs at the cathode. The electrocoagulation method will also produce hydroxide ions (OH-), the greater the voltage used, the faster the reaction will occur and the more OH- produced will increase the pH in the waste.

In this study, the pH of waste tends to increase with increasing operating time and current strength used with pH ranging from 5-7. Therefore, the longer the operating time, the concentration of waste will decrease and the pH value will tend to rise. The best results in increasing pH are at a voltage of 12 volts with a processing time of 150 minutes. This result was chosen because at a voltage of 12 volts with a processing time of 150 minutes produces a pH of 6.52 which is close to a neutral pH of water.

3.2.2. Effect of Process Voltage and Time on TDS
TDS is dissolved and colloidal materials in the form of chemical compounds and other materials left unfiltered on filter paper with a diameter of 0.45 micrometers. TDS is usually caused by inorganic materials in the form of ions in the waters. The ions that are usually found in the waters include sodium, calcium, magnesium, bicarbonate, carbonate, silica and so on. TDS is not desirable in water bodies because it can cause color, taste, unpleasant odor.

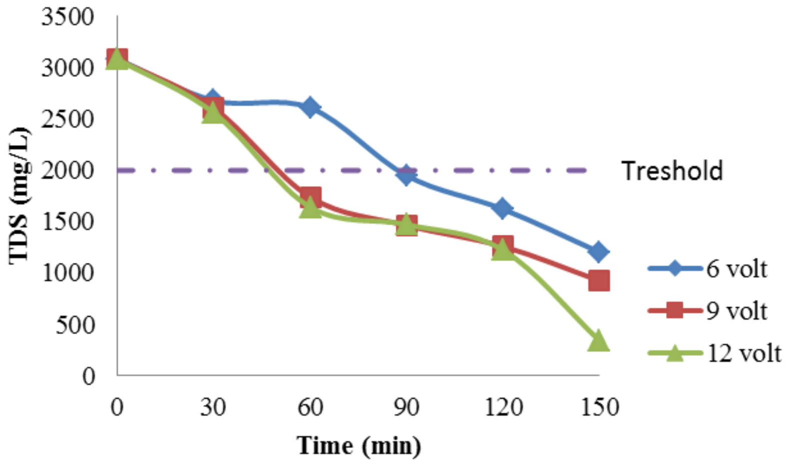

Figure 3. Effect of Process Voltage and Time on TDS

In Figure 3, it can be seen that the TDS value in the initial sample passes the environmental quality standard so that if it is disposed of directly into the surrounding environment, it will affect the surrounding environment both on land and in the soil waters. After processing using the electrocoagulation method, the TDS value of the treated waste decreases according to the increase in stress and the length of time the process is carried out. This is due to the ability of aluminium electrodes to react with ions such as Fe, Pb and other ions so that the ions are reduced. This electrocoagulation method is also able to reduce concentrated color levels of waste and unpleasant odors if observed directly. At 30 minutes processing time with a voltage of 6, 9 and 12 volts is still above the environmental quality standard. This is due to the small processing time so that the treated waste has not been fully reacted with the electrode. During process time 60 minutes with a voltage of 6 volts is still above the environmental quality standard. This is due to the inaccurate treatment of waste so that the results obtained are still above the environmental quality standards.

The optimum condition in reducing TDS is at a voltage of 12 volts with a processing time of 150 minutes. This result was chosen because at a voltage of 12 volts with a processing time of 150 minutes produces a TDS 340 value which is the smallest value on the results obtained.

3.2.3. Effects of Process Voltage and Time on TSS
TSS is a solid suspended in water in the form of organic and inorganic materials. TSS values which are too high can cause turbidity in the water. The turbidity of the water is not expected in the soil waters because if it is too thick it can reduce or inhibit sunlight from entering the water so that it can interfere with the development of aquatic biota. Analysis of suspended solids content (TSS) is important in the need to regulate and determine the biological and physical waste treatment processes and one of the key requirements for licensing waste water into the environment.

In the initial characterization, TSS levels did not exceed environmental quality standards. This is due to good waste sampling and also fresh waste conditions when analyzed. Figure 4 shows the decrease in TSS results obtained. The longer the processing time and the higher the stress, the concentration of TSS decreases. This is caused by aluminium electrodes which react well when the treatment process takes place and a good filtering process resulting in a decrease in the results obtained.

The optimum conditions obtained from variations in voltage and processing time are with a voltage of 12 volts with a processing time of 150 minutes. This indicates that the higher the voltage and processing time, the results obtained will be more optimal.

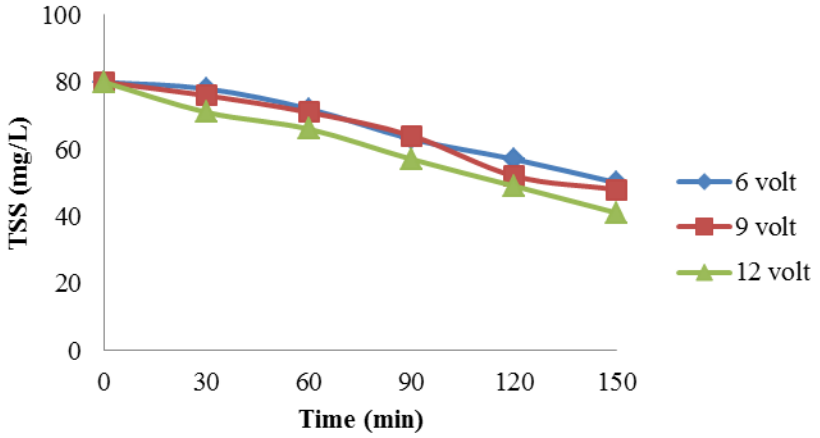

Figure 4. Effect of Process Voltage and Time on TSS

3.2.4. Effect of Process Voltage and Time on BOD5

BOD5 is the amount of oxygen needed by bacteria during decomposition of organic compounds in aerobic conditions for 5 days. BOD measurements were carried out for 5 days because for 5 days the amount of organic compounds described had reached 70%.

In Figure 5, a decrease in BOD5 levels was obtained. In the initial analysis of BOD5 levels, the concentration of BOD5 obtained exceeded the environmental quality standards possessed by integrated liquid waste. A high BOD5 value indicates that there are many organic compounds in waste, so that a lot of oxygen is needed by microorganisms to break down the organic compounds. If oxygen is widely used to decompose these organic compounds, the amount of oxygen contained in water will be a little which results in water biota lacking oxygen in water.

The optimum conditions obtained from variations in voltage and processing time are with a voltage of 12 volts with a processing time of 150 minutes which is 14.2 mg/L.

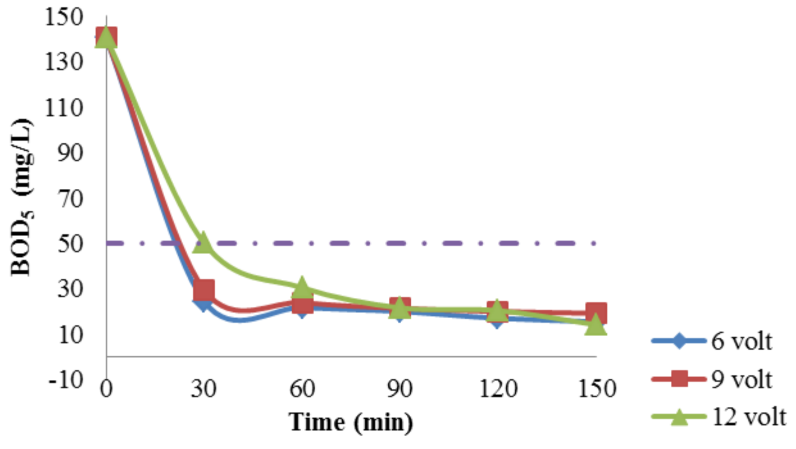

Figure 5. Effect of Process Voltage and Time on BOD_5

3.2.5. Effect of Process Voltage and Time on COD

COD (Chemical oxygen demand) is the total amount of oxygen needed to oxidize all organic material contained in the waters, into CO2 and H2O.

In Figure 6, the initial COD value obtained exceeds the environmental quality standard. This indicates that waste must be treated first before being disposed of directly into the environment. After processing with the electrocoagulation method, the treated waste water has concentration decreased. The decrease in concentration is due to oxidation and reduction processes in the electrocoagulation process. At electrodes, gases such as oxygen and hydrogen are formed which will affect COD reduction. This decrease is also due to the flocculation formed by ionic organic compounds bind to positive coagulant ions.

The optimum conditions obtained from variations in stress and processing time in reducing COD concentration are with a voltage of 12 volts with a process time of 150 minutes which is 52 mg / L. This indicates that the greater the voltage and processing time, the COD concentration will decrease.

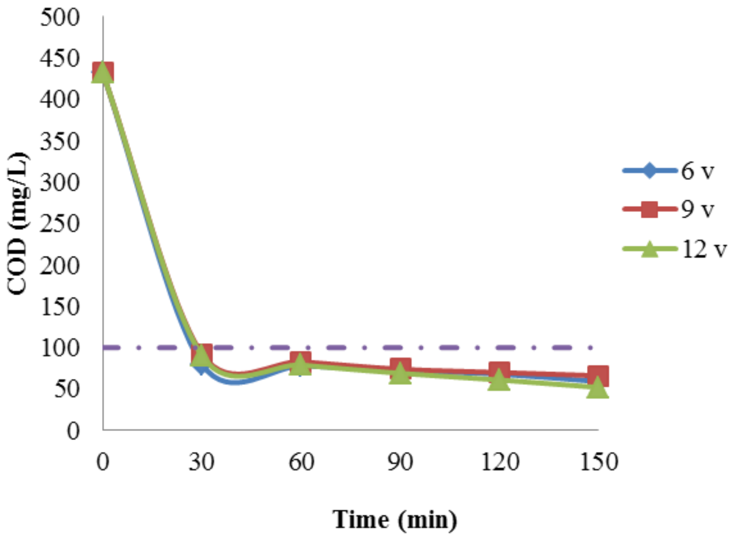

Figure 6. Effect of Process Voltage and Time on COD

3.2.6. Effect of Process Voltage and Time on PO4

Phosphate (PO4) is one of the constituents or content in detergent, namely as a compound builder. Phosphate content in this process must be considered because if the phosphate content contained in the waste is too high it can pollute the environment. A too high Phosphates content will cause eutrophication, an environmental problems that can cause damage to aquatic ecosystems where plants grow very fast.

Figure 7 shows the results obtained the decreased phosphate concentration. The decrease in phosphate concentration in the electrocoagulation process occurs because Al3+ ions react with PO43- forming AlPO4 which is difficult to dissolve finally can be easily separated.

The optimum conditions obtained from variations in voltage and processing time in reducing PO4 concentration are with a voltage of 12 volts with a processing time of 150 minutes which is 1.882 mg/L. The optimum condition occurs at a voltage of 12 volts due to the reaction that occurs between aluminum and phosphate electrodes which are good at a voltage of 12 volts and a processing time of 150 minutes, the phosphate in the waste water can easily be separated.

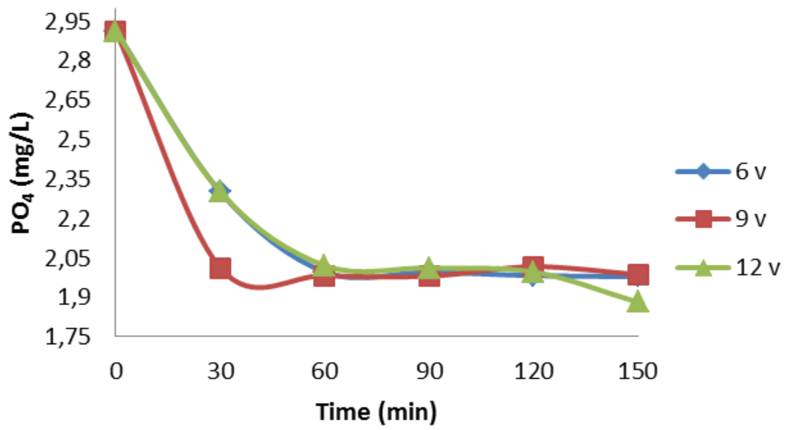

Figure 7. Effect of Process Voltage and Time on PO_4

3.2.7. Effect of Process Voltage and Time on Fe levels

The main purpose of this treatment is to compare the decrease / increase of Fe metal content in integrated wastewater with variations in current strength and processing time so that the conditions that are most effective in reducing Fe metal content are known. The optimum conditions obtained are at a voltage of 12 volts with a processing time of 150 minutes. The results obtained after processing this waste is a decrease in the concentration of Fe metal content in the waste. But the decrease in concentration that occurs tends to be constant. This happens because the electrode performance decreases. The application of aluminum electrode can reduce the Fe ions content in the waste water. The impact of this condition causes a decrease in the magnitude of the magnetic field. When the magnetic field between the two electrodes is still quite large, the ionic system of the dominant metals competes for attachment to the electrode and the oxidation process at the anode is still large, even though the solution appears to be more turbid, but the turbidity is due to dirt, in part. Large turbidity is caused by Al (OH)3 flocculation which eventually settles and happens.

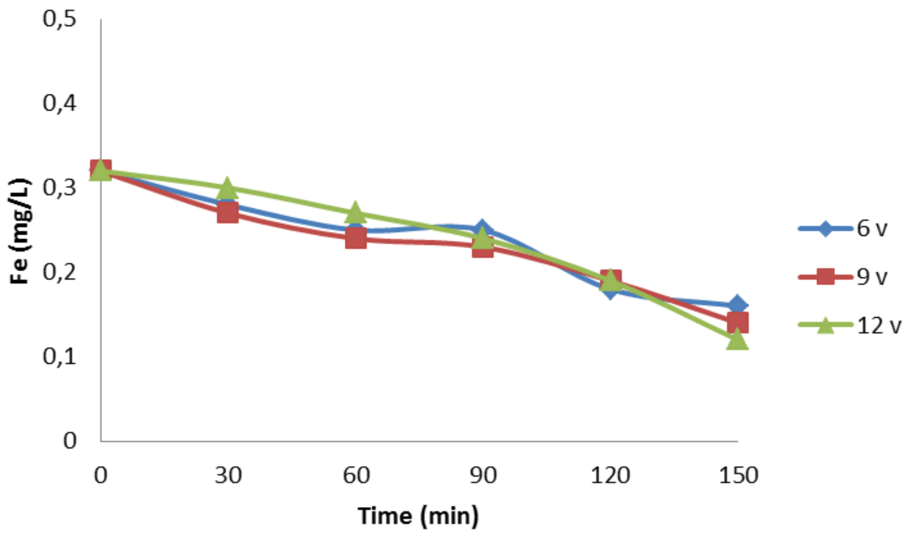

Figure 8. Effect of Process Voltage and Time on Fe levels

3.2.8. Effect of Process Voltage and Time on Pb levels

Pb heavy metal substance and their compounds can be naturally found in water content and also as a result of human activities. Water containing Pb compounds or ions can cause the amount of Pb in the water body to exceed the proper or normal concentration. This can result in the aquatic biota pollution.

In Figure 9, the results obtained after analyzing shows a Pb heavy metals content are decreasing. The longer the processing time and the higher the stress, the concentration of Pb metal decreases. From the initial analysis value is 0.07 mg / L to 0.009 after 150 minutes of applying a voltage of 12 volts, the optimum condition for Pb heavy metal analysis can be achieved. The decrease in Pb concentration is due to the good reactivity of aluminum electrodes in processing heavy metals. It is like treating Fe and PO4 in which the aluminum electrode pulls the heavy metal like a magnet.

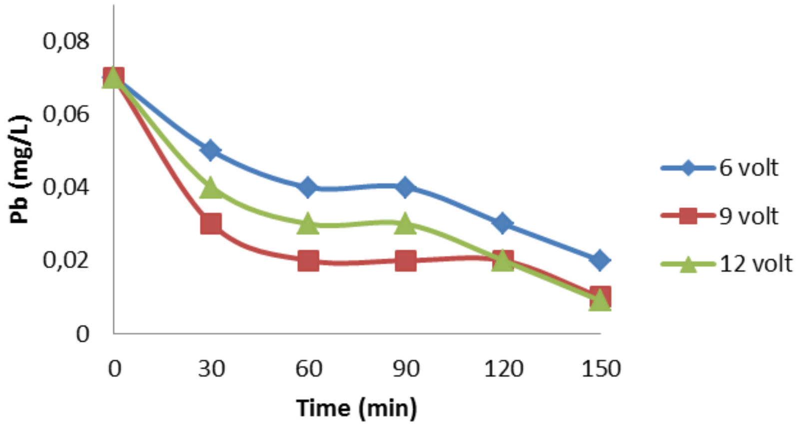

Figure 9. Effect of Process Voltage and Time on Pb levels

4. Conclusions

The optimum condition of electrocoagulation method using smart sensor and aluminium-stainless steel electrodes are 12 volt voltage and 150 min process time. Decreased levels of total dissolved solid (TDS) reached 340 mg/L, biological oxygen demands (BOD5) 14.2 mg/L, chemical oxygen demands (COD) 52 mg/L, PO4 1.884 mg/L, Pb metal 0.009 mg/L, Fe metal 0.18 mg/L, and raised pH values to 6.52.

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