Study of Induced Air Flotation for the removal of Oils from the effluents of Sweets and Dairy Industries

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Abstract:

The presence of oil and grease in the industrial effluents has a very bad impact on both the treatment units and the disposal media. One of the important oil/ water separation techniques is the Induced Air Flotation.

The principal aim of this paper is to determine the proper air flow rate for oil/ water separation, in a laboratory scale IAF batch system, for two types of industrial waste waters; Sweets and Dairy Industries. The impact of Alum as a coagulation agent, on the separation efficiency via flotation process, is also studied.

Results have shown that (3-5 l/min.) air flow rates are the optimal for having separation efficiencies between (77%- 80%) for effluent of Sweets industry, and (66%- 70%) for effluent of Dairy industry.

The addition of (0.5 g/l) Alum has proved significant influence on oil/ water separation efficiency, which could reach the values of (96%- 99%), using the air flow rates mentioned above, for Dairy and Sweets industrial effluents respectively.

Key words: Induced Air Flotation, Oil and grease, Coagulation, Oil/ Water Separation.

دراسة التطويف بالهواء المستحث لازالة الزيوت من المخلفات السائلة لصناعة الحلويات و صناعة الالبان

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الخلاصة

ينتج عن وجود الزيوت و الشحوم في المخلفات الصناعية السائلة تأثيرا سيئا على كل من وحدات المعالجة و اماكن الطرح. تمثل تقنية التطويف بالهواء المستحث احدى اهم وسائل فصل الزيوت عن الماء.

ان الهدف الاساس من هذا البحث هو استخراج التصريف الانسب للهواء لعملية فصل الزيت عن الماء من خلال نموذج مختبري لنظام التطويف بالهواء المستحث و لنوعين من المخلفات الصناعية السائلة (بشكل دفعات) الناتجة عن صناعة الحلويات و صناعة الالبان. اضافة لذلك، تمت دراسة تأثير اضافة الشب كعامل تخثير، على كفاءة عملية الفصل باسلوب التطويف بالهواء المستحث.

اظهرت نتائج البحث ان تصاريف الهواء (٣- ٥ لتر/دقيقة) هي الانسب للحصول على كفاءة فصل بين (٧٧%- ٨٠%) لمخلفات صناعة الحلويات، و (٦٦%- ٧٠%) لمخلفات صناعة الالبان. كما اثبتت اضافة

(٠،٥ غم/لتر) من الشب أثرا كبيرا في تحسين كفاءة الفصل بين الزيت و الماء، و التي وصلت الى القيم (٩٦%- ٩٩%) باستخدام التصاريف المذكورة آنفا، للمخلفات الصناعية السائلة لصناعتي الالبان و الحلويات على التوالي.

كلمات دلالة: التطويف بالهواء المستحّث، زيوت و شحوم، التخثير، فصل الزيوت عن الماء.

Introduction

Industrial effluents are often recognized as unfriendly to natural environment and considered as a source of numerous potential threats connected with possible environment degradation. Dairy processing and Sweets manufacturing plants, are only example places that produce “difficult” wastewater with large total load of organic pollutants like proteins or fats and chemicals used for cleaning and sanitizing processing equipments.

In general, food industry generates a considerable quantity of wastewater containing various pollutants. The pollutants in the animal origin raw materials processing wastewater are: biodegradable organic material, nitrogen in several chemical forms, fat and oils, phosphorus and chlorides.

In reference to food industry wastewater, treatment processes have to assure first of all required quality of discharged effluents. Costs analysis, and possible utilization of substances contained in wastewater are taken into consideration (WBG, 2007).

Experience of many plants which process raw materials of animal origin indicates that the best results of efficient technological wastewater treatment are achieved with combination of physical methods (i.e. screens, sieves, sedimentation tanks or flotation units) with chemical treatment. Fat flotation is often combined with addition of chemicals acting as coagulants and precipitants of pollutants (Begt, 2002). Some of the additional benefits for the application of ferric or aluminum salts in wastewater treatment are: precipitation of sulfur compounds, easier sludge dewatering, increased efficiency in elimination of pollutants, and reduction in energy consumption in the biological process applied as final stage of treatment. It is also important to understand some disadvantages of this methodology such as that, the addition of treatment chemicals may increase the total volume of sludge, large amounts of chemicals may need to be transported to the treatment location and polymers used can be expensive (Suarez et. al, 2008).

Air Flotation Process

When the primary target is oil removal, distinction should be made between the forms of oil. There are two forms of oil that can be found in wastewater. Free oil is oil that will separate naturally and float to the surface. Emulsified oil is oil that is held in suspension by a chemical substance (Detergents - Surfactants) or electrical energy.

When making an evaluation, free oil will normally separate by gravity and float to the surface in approximately 30 minutes. Emulsified oil is held in a molecular structure called a micelle and will not separate on its own. Hence, there is the need for a more sophisticated method of treating suspensions containing emulsified oils (Hayatdavoudi, 2006).

Induced Air Flotation (IAF) is a water treatment process that clarifies wastewaters (or other waters) by the removal of suspended matter such as oil or solids. The removal is achieved by injecting air bubbles into the water or wastewater in a flotation tank or basin. The small bubbles adhere to the suspended matter causing the suspended matter to float to the surface of the water where it may then be removed by a skimming device. The feed water to the IAF float tank is often (but not always) dosed with a coagulant (such as ferric chloride or Alum) to flocculate the suspended matter. Some IAF unit designs utilize parallel plate packing material to provide more separation surface and therefore to enhance the separation efficiency of the unit.

Coagulation

Oil droplets are negatively charged due to charged surfactants or adsorption of hydroxyl ions (Al-Shamrani, 2002). Repulsive electrostatic forces prevent coalescence. Introducing an opposite charge modifies the negative charge, encouraging oil droplets to coagulate and assisting in the attachment of coagulated oil droplets to the negative air bubbles (Rosa and Rubio, 2005). Air bubbles in water are considered to have a negative surface charge due to their negative zeta potential. When using metal coagulants, pH is crucial as it influences the nature of polymeric species formed upon dissolution of the metal coagulant in water. Previously lime has been used as a coagulant/precipitating agent but disadvantages include an increase sample pH and hardness, low COD removal capacity, and excessive sludge (Deglon, 2005). Aluminum salts are effective coagulating agents and are widely used in wastewater treatment (Al-Shamrani, 2002). When added to water, $A1^{+3}$ hydrates and reacts to form monomers, polymers and solid precipitates. These hydrophobic polymers have a large surface area, an amorphous structure and a positive charge. This allows for adsorption onto negative oil surfaces, rendering them insoluble. Charge neutralization leads to colloid destabilization.

Experimental setup and procedure

A (50x30x40 cm) tank is made for the air flotation process of industrial waste water. The tank has a tapered base so as to collect any expected sediments. Three sampling holes are made at the side of tank at elevations of (5, 15, and 30 cm) above the tapering start. Holes No. 1,2 and 3 are respectively considered for the bottom, middle and top layers of the flotation tank that shall be filled to the height of (35 cm) with waste water under consideration. Air is equipped via a (0.75 Kw) single phase compressor of (20 l/min under 8 bar) through air distributers that are placed at the bottom of the tank (above the tapered section). The air pressure is maintained constant through type (RC2, 217 W) pressure regulator so as not to disturb the air flotation process. A (0-15 l/min) rotameter is used for air flow measurements (**Fig. 1**). Three air flow rates (1, 3, and 5 l/min) are to be applied for (120 min) duration each.

Experimental procedure shall be as follows:

1. For each of the air flow rates, treated water sample is to be taken from each of the sampling side holes at periods (30, 60, 90 and 120 min) from the start of process.
2. OG concentration shall be measured for these samples so as to determine the effect of air flow rate and application time on Oil/ water separation process.
3. Steps 1 and 2 shall be repeated after the addition of different doses of Alum as a coagulant so as to determine the coagulation effect on oil/water separation..

The procedure mentioned above is to be applied for two types of industrial waste water, one of animal origin (Dairy industry, Abo Ghraib Factory-Baghdad), and the other is

of plant origin (Sweets industry, Laith Factory for Sweets Industry–private sector, Baghdad).
The wastewater pH is adjusted between 5.5 and 6.5 for the Aluminum compounds using H_2SO_4.

Results, Discussions and Conclusions
Effluent of Sweets industry is characterized of having OG concentration of (750- 790 mg/l), while that of Dairy industry is about (863- 900 mg/l). Temperature of these waste water is about (21-22 C) at the time of experiments.

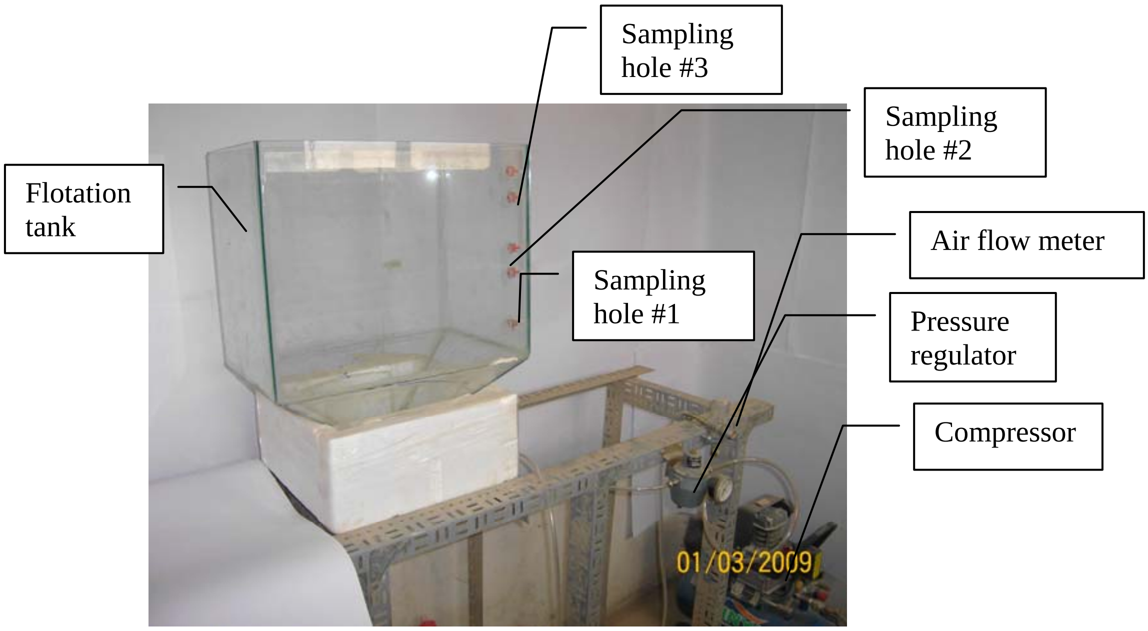

Fig.1. Experimental setup for the Induced Air Flotation System

First set of flotation experimental tests are made to determine the effect of different air flow rates (1, 3, and 5 l/min), on the oil/water separation process, at the three mentioned sampling holes of the flotation tank, for the waste waters of Sweets and Dairy industries (**Fig.2- 7**). For all three air flow rates, and as time passes, a clearer bottom layer appears; i.e. less oil concentration, while on the contrary; the oil concentration increases for the top layer.
Results have shown that oil/ water separation is more efficient with Sweets effluent compared with that of Dairy. This may be due to the unsaturated nature of the plant origin oils that results weaker bonds between their molecules compared with the stronger bonds between the saturated of animal oils.
The second set of flotation tests are made to determine the effect of adding Alum as a coagulant on the oil/water separation process at the bottom layer of the flotation tank, using the three air flow rates mentioned above (**Fig. 8-13**). These figures remark clearly that the addition of Alum has increased the oil/water separation significantly.
Many conclusions can be made based on these results. They can be listed as follows:

1. After the expiry of the first 30 min., distinction can be made between three different layers in oil concentration, in the flotation tank; namely top, middle

and bottom layers.

2. Oil/water separation occurs in a faster manner for the first 60 min., compared with that occurs for the rest time. The separation pursues slowly after the expiry of 90 min.
3. The oil concentration at the middle layer tends to increase for the first (40-60 min.), and decreases for the rest on time, during which the air droplets carry the oil up to the top layer.
4. Oil/ water separation due to IAF is more efficient for oils of plant origin compared with that of animal origin.
5. Oil/water separation increases significantly as air flow rate does. This increase tends to be lower for air flow rates above 3 l/min.
6. Separation efficiencies of (60%, 78% and 80%) may be gained by the use of air flow rates of 1, 3 and 5 l/min., respectively for the treatment of effluent of Sweets Industry.
7. Separation efficiencies of (54%, 67% and 70%) may be gained by the use of air flow rates of (1, 3 and 5 l/min.), respectively for the treatment of effluent of Dairy Industry.
8. No significant increase in efficiency can be achieved by increasing the air flow rate higher than (3 l/min.).
9. Addition of Alum has a significant effect on enhancing the oil/ water separation process. For all tests, (0.5 g/l) of Alum has shown the highest enhancement in the separation efficiency.
10. After the addition of (0.5 g/l) Alum, oil/ water separation efficiencies of (93%, 96%, and 98%) for the air flow rates of (1, 3, and 5 l/min.), respectively, can be achieved for the treatment of Sweets industry effluent.
11. After the addition of (0.5 g/l) Alum, oil/ water separation efficiencies of (91%, 95%, and 96%) for the air flow rates of (1, 3, and 5 l/min.), respectively, can be achieved for the treatment of Dairy industry effluent.

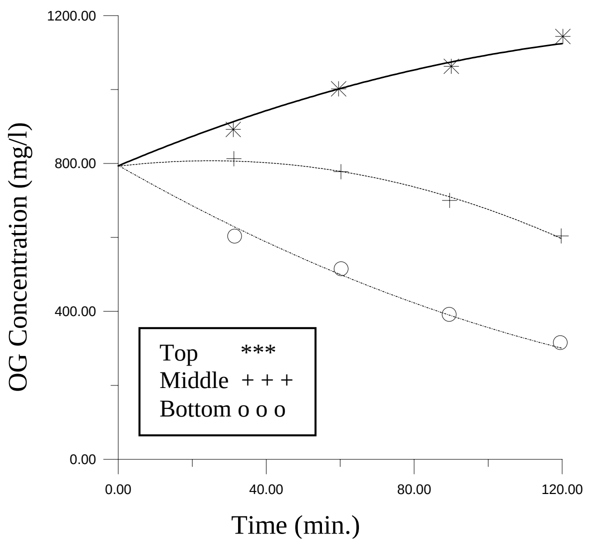

Fig.2 Oil concentration vs. time at different layers of flotation tank and (1 l/min) air flow rate for the effluent of Sweets industry.

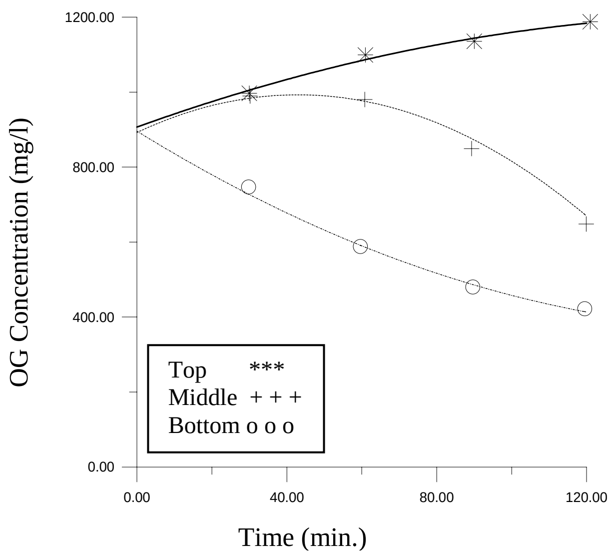

Fig.3 Oil concentration vs. time at different layers of flotation tank and (1 l/min) air flow rate for the effluent of Dairy industry.

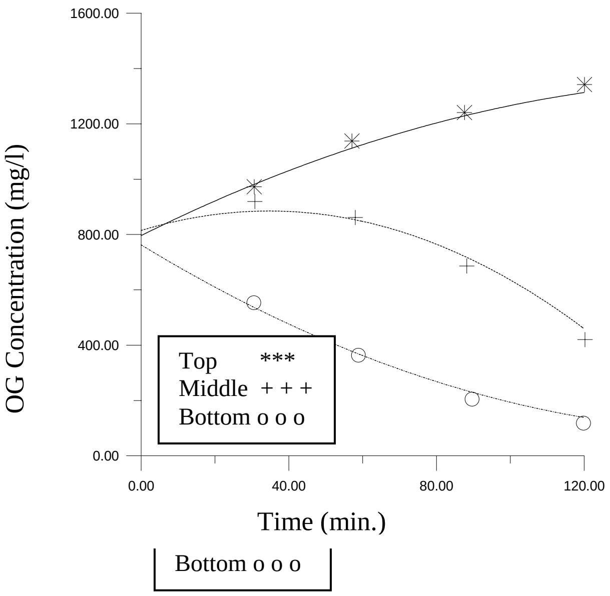

Fig.6 Oil concentration vs. time at different layers of flotation tank and (5 l/min) air flow rate for the effluent of Sweets industry.

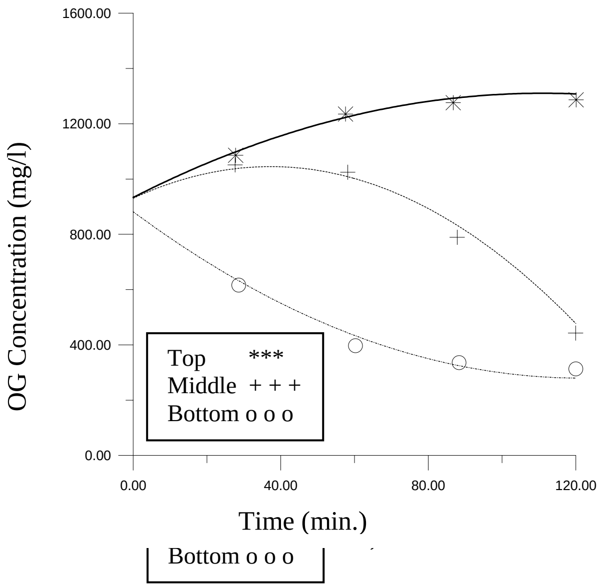

Fig.7 Oil concentration vs. time at different layers of flotation tank and (5 l/min) air flow rate for the effluent of Dairy industry.

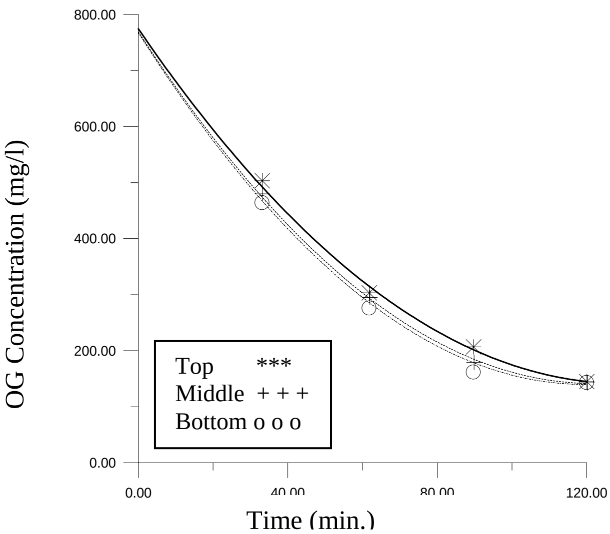

Fig. 8 Oil concentration at the bottom layer vs. time after using 0.2 g/l of Alum as a coagulant for effluent of Sweets Industry

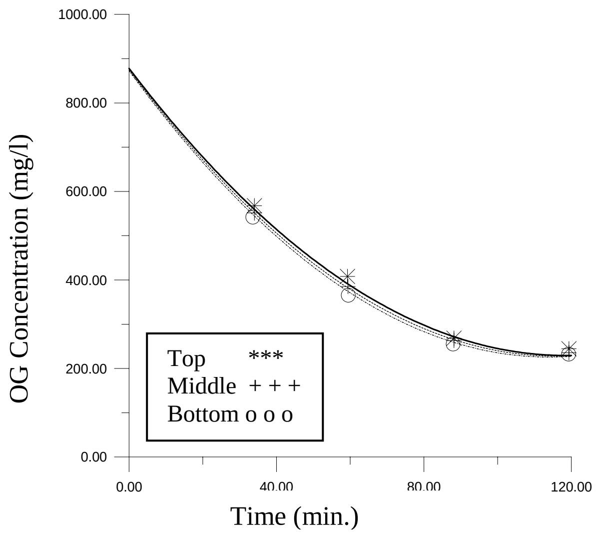

Fig. 9 Oil concentration at the bottom layer vs. time after using 0.2 g/l of Alum as a coagulant for effluent of Dairy Industry

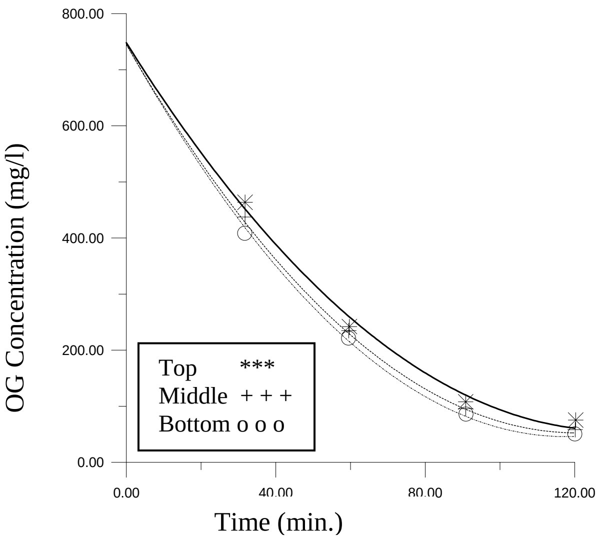

Fig. 10 Oil concentration at the bottom layer vs. time after using 0.4 g/l of Alum as a coagulant for effluent of Sweets Industry

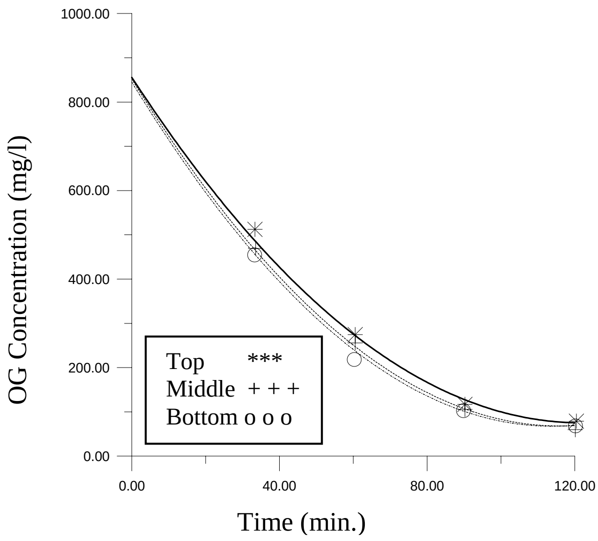

Fig. 11 Oil concentration at the bottom layer vs. time after using 0.4 g/l of Alum as a coagulant for effluent of Dairy Industry

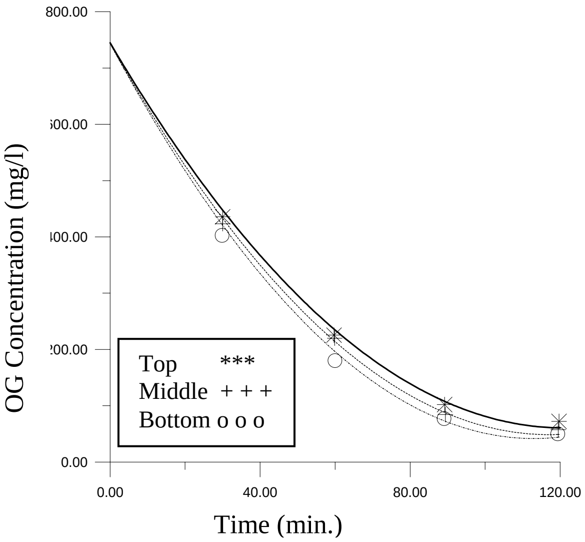

Fig. 12 Oil concentration at the bottom layer vs. time after using 0.5 g/l of Alum as a coagulant for effluent of Sweets Industry

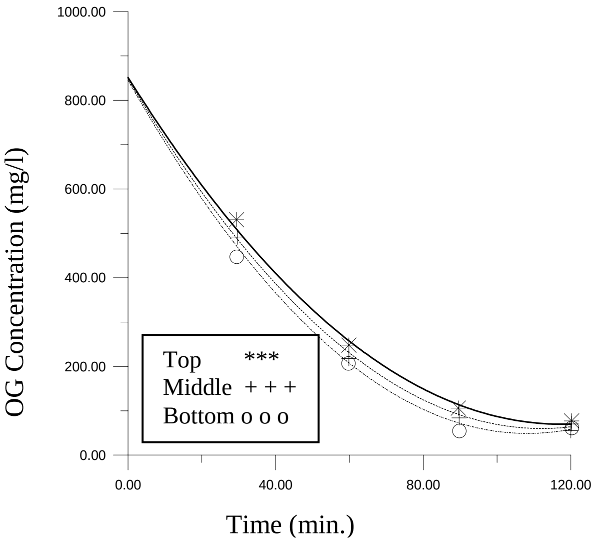

Fig. 13 Oil concentration at the bottom layer vs. time after using 0.5 g/l of Alum as a coagulant for effluent of Dairy Industry

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Notations

COD: Chemical Oxygen Demand.
IAF: Induced air Flotation.
OG: Oil and Grease.