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PALM OIL MILL EFFLUENT TREATMENT TOWARDS ZERO DISCHARGE

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ABSTRACT

This study will concentrate on treating the POME by employing a combination of evaporation and adsorption techniques under vacuum condition. The raw effluent has a temperature of 80 - 85°C, thus by introducing a vacuum of 350 mm Hg, the effluent will evaporate without any addition of heat. Next, the adsorption process was carried out using four different types of adsorbent's in the vapour phase. Lastly, the experiment was also carried out in a pilot plant scale.

The distillate, (before adsorption) when analysed showed a 99% removal of most polluting parameters monitored except for pH, COD and BOD. This was tackled by the adsorption process which further reduced the pH, COD and BOD values. The effluent was able to be concentrated to as high as 25% solid content from the initial content of 3 - 5% solids. This will result in a recovery of 80% of the water content and also the POME volume will reduce by the same percentage. The concentrated effluent analysis showed a high content of nitrogen, phosphorus and potassium which can be used as feed material for the making of fertiliser. Lastly, the pilot plant scale experiments were done and the analysis showed the same results as the bench scale.

Key words: Palm Oil Mill Effluent, Vacuum Evaporation, Adsorption

1.0 INTRODUCTION

Malaysia is a fast developing country which is dependent on its industry. This country has been transformed from an agricultural depended economy to an industrial depending economy. Though the government is more interested in the development of the industrial aspect of the country, yet there is emphasis on agricultural products. Malaysia is the largest exporter of palm oil in the world. Palm oil is also Malaysia's largest agricultural product. Since the first plantation in 1917 at the Tennamaran Estate in Kuala Selangor, the palm oil industry began to grow very fast in Malaysia. In 1960, Malaysia produced 92,000 tonnes of edible oil from this product. By 1985, this figure had shot up to 4.1 million tonnes and 7.4 million tonnes in 1995 (1-6).

The extraction of palm oil from the palm fruit is a common known process and is widely applied in Malaysia. But this extraction process also creates a brown effluent which can devastate any aquatic life if dumped directly into our rivers. It is estimated that for every tonne of palm oil produced, 2.5 tonnes of wastewater is generated. Thus, with Malaysia's production of palm oil standing close to 8 million tonnes per annum, the amount of palm oil mill effluent (POME) generated would be equivalent to that of sewage discharged by a population of 22 million people (5 - 8).

Palm oil mill effluents are high volume liquid wastes which are non toxic but have an unpleasant odour. They are predominantly organic in nature and are highly polluting. The Biological and Chemical Oxygen Demand (BOD & COD) of this effluent is very high and so goes for the Total Nitrogen, Ammonical Nitrogen and Oil & Grease. The effluent is also acidic. Other than this the raw effluent is made up of a few anions and cations. As for the physical nature of the raw effluent, it is hot, has a bad aroma and is brown in colour. Thus, if such an effluent with it's quality and quantity were to be discharged into our rivers, all aquatic life will perish.

At present there are many method of treating this raw effluent. The most common method of treatment being employed is the biological treatment. Basically this method of treatment is by using a combine effect of the aerobic, anaerobic and facultative treatment pond, where at the end of the treatment the effluent is dumped into a nearby stream or river. Although this method of treatment is effective in solving the POME problem but it needs proper maintenance and monitoring. It is estimated that for a mill producing 300 tonnes of palm oil per day, the mill would require about 15 acres of land to set up it's treatment ponds. Thus, this large area will have to be taken from the farm land around the mill. Another problem with this method is the fact that the treatment process takes a long time. Along with this comes the problem of flies and mosquitoes breading in these ponds. Other then these few setbacks, the biological treatment process has been received and operating well in all palm oil mills.

Alternatives treatment methods have propped up in the recent past. These methods of treatment are new and under study. For example, there is a proposal to use this effluent direct on the farm land by overhead spraying or to allow it to dry up in open lagoons. There is also research being done to treat the effluent using filtration, centrifugation, heat assisted evaporation and also reverse osmosis. All of this methods have their plus and negative points.

This study will concentrate on utilising the physical and chemical characteristics of the POME to treat it. The raw effluent that comes from a mill is of 80 - 85°C. Thus, it is good to use this heat for evaporation. The principle behind evaporation is the fact that anything that has a boiling point of lower than the set boiling temperature than it will evaporate leaving all other substances which has a higher boiling point. By the evaporation method almost all pollutants can be removed and a clear and clean water can be obtained but it will still lack dissolved oxygen. It is expected that the distillate collected will have a value of BOD and COD in the range of 2000 mg/L.

The next step is to treat the distillate. The proposed method for treatment is by the adsorption method. This is a new process being introduced to the treatment of wastewater. Past studies have shown that activated carbon has played a vital role in the treatment of wastewater from many sources. Now there are many new adsorbents that have been discovered which can be used in the treatment of wastewater. Thus the next part of this study was to treat the distillate collected using the adsorption process.

2.0 MATERIALS AND METHODS

The raw effluent was obtained from Ladang Pengelli, which is a Felda Plantation in Bandar Tenggara, Johor. This effluent was collected in air tight cans and then stored in a refrigerator between 3 - 5°C. This was done to prevent any distortion to the effluent before the experiment could be carried out. Next the bench scale apparatus were set up. The evaporation process was carried out in a three neck flask which was placed on a heating mental which has a thermocouple and also a sensor to monitor and control the heat of the fluid in the flask. The sensor was inserted into the flask using the left neck together with a pressure gauge to monitor the vacuum pressure in the flask. The right neck was fitted with a thermometer. Lastly the centre neck was fitted with a adsorption column 1 ft. in length and with a inner diameter of 5 cm. This will ensure that all the vapour produced will pass through the adsorption column. The heating mental is used to maintain the POME in the flask at 80 - 85°C, which is the temperature of the raw effluent in an actual palm oil mill. Once the vapour produced has passed the adsorption column, is will be cooled using a condenser and the distillate collected. A vacuum pump is introduced at the end of the system to keep the system under a vacuum pressure of 350 mm Hg.

The experiments were divided into a few parts for various study to be carried out. In the first part, only evaporation was carried out without any adsorbent to study the effect of temperature and pressure. Next four different adsorbent was used at various weights to know their effect on treating the POME. Lastly the experiments were done on a bigger scale, which is the pilot plant size.

3.0 RESULTS AND DISCUSSIONS

3.1 Evaporation

The main aim of this study was to utilise the heat contained in the raw effluent to evaporate it. This was achieved by first heating the stored POME to a temperature of 80 - 85°C and then a vacuum of 350 mm Hg was introduced. At this pressure and temperature the POME will boil and evaporate automatically and the vapour can be cooled and collected. The analysis of the distillate, raw POME and also the concentrated sludge after evaporation was analysed and the results are shown in *Table I*.

TABLE I : EVAPORATION ANALYSIS DATA

Parameter Monitored	Distillate	Raw POME	Concentrated Sludge	Malaysian Environmental Standards
pH	3.94	4.89	4.65	5.0 - 9.0
COD	1,250	61,000	180,500	100
BOD_5	815	35,150	98,500	50
Total Solids	110	41,200	151,000	NA
Suspended Solids	1.5	20,650	54,200	100
Volatile Suspended Solids	1	16,000	45,500	NA
Ammonical Nitrogen	0.8	47	151	NA
Oil & Grease	8.5	10,500	38,800	10
Mg	0.2	442	1,020	1
Ca	0.1	71	199	NA
K	0.8	3,365	7,445	NA
F	32	591	4,750	NA
Cl	0.2	1,742	11,449	NA
NO_3	0.06	92	791	NA
SO_4	0.35	322	3,224	NA

* All units are in (mg/L) except for pH

The duration of the process was for 90 min and the adsorption column was filled with inert material only. The initial volume of POME used was 800 ml and 550 ml of distillate was collected. This will give a 70 % recovery of water from the effluent and the volume of the effluent too reduced by the same percentage. As for the parameters monitored, except for pH, COD and BOD, all other parameters showed a 99% removal in the distillate analysed. This shows that the evaporation process is successful in treating and also recovering water from wastewater. The quality of the distillate is as good as drinking water except that it is acidic and the dissolved oxygen in it is low. Another point is the fact that most of the polluting parameters checked in the distillate also shows that they are below the environmental standards.

Checks were carried out on the raw POME obtained from the factory and the analysis showed that the pollutant level of the wastewater is in the same range as other factories in Malaysia as sited in available literature. Lastly the concentrated sludge analysis showed that the solid content has rose from 4.1% to 15.1%. The analysis also showed that the sludge contained a high value of Nitrogen, Phosphorus and Calcium which is good to be used as feed material to the fertiliser industry or dumped directly into the palm oil estate.

3.2 Pressure and Temperature Influence Towards The Evaporation Process

The next step was to determine the effect of pressure and temperature on the evaporation process. All runs were for 30 min and a steady vapour production was achieved at the end of the run (50 ml) and the results of the distillate analysis are in *Table II*. From the results obtained, it can be said that pressure and temperature does not effect the quality of the distillate. The results show that all parameters monitored have a certain range. The pH of the distillate falls in the range of 3.24 to 3.34 and as for the COD and BOD the range is between 1200 to 1400 and 800 to 1000 mg/L respectively. This results show that the boiling point of most of the pollutants are much higher than 85°C. This is way they do not boil and contaminate the vapour produced. Though there is a limiting factor in the vacuum pump which could only give a suction power of 550 mm Hg, but it was sufficient to reduce the boiling point of the POME to 65°C which is ample of the collection of data for this study. From this results a conclusion was made that all further experiments will be carried out at the temperature of the raw effluent which is at 80 - 85°C and a vacuum of 350 mm Hg.

TABLE II : PRESSURE AND TEMPERATURE EFFECT ON POLLUTING PARAMETERS

Vacuum Pressure (mm Hg)	Corresponding Temperature (°C)	pH	COD (mg/L)	BOD (mg/L)	Total Solid (mg/L)	F (mg/L)	Cl (mg/L)	K (mg/L)
550	65	3.34	1420	1025	112	29	0.00	0.65
525	71	3.31	1340	920	101	26	0.09	0.71
490	75	3.32	1290	870	95	26	0.00	0.69
380	83	3.28	1380	960	107	27	0.10	0.80
330	85	3.24	1200	820	95	32	0.07	0.69
250	90	3.27	1160	810	102	31	0.03	0.76
130	95	3.29	1310	950	111	32	0.06	0.74
0	100	3.30	1330	980	94	34	0.07	0.69

3.3 Adsorption Process

The adsorption process was carried out to further treat the distillate on the three polluting parameters which are pH, COD and BOD. Four different adsorbents were used namely Activated Carbon, Natural Zeolite and syntactic Zeolite of the "A" and "X" types. The weight of adsorbent used and time of adsorption were varied for each adsorbent. The results are discussed in the following sections.

3.3.1 Effect of Adsorbents on pH

The effects of the various adsorbents on the pH of the distillate are shown in *Figures 1, 4, 7* and *10*. Each figure shows the effect of each adsorbent on pH. From the analysis of the four figures, it is quite clear that the "X" and "A" type Zeolite is efficient in neutralising the acidic distillate. As for the Natural Zeolite and Activated Carbon the effect of these adsorbents on pH is not too good. From the figures, it also shows that about 10 g of the "A" type Zeolite is enough to treat the vapour produced.

3.3.2 Effect of Adsorbents on COD

The effect of various adsorbents on the COD of the distillate are shown in *Figures 2, 5, 8* and *11*. From the figures, again the "X" and "A" type Zeolite has given the best results. The percentage of reduction is about 40 to 60% for these two adsorbents. As for the Natural Zeolite and Activated Carbon the percentage of reduction is much lower. Another point is that the COD value of the distillate after the treatment using various adsorbents was not enough to bring it to the level required by the Department of Environment of Malaysia. Although the "A" type Zeolite gave the best performance but study will still be needed in this department to further reduce the COD level to the environmental standards. This could be achieved by extending the period of adsorption or by increasing the amount of adsorbent used.

3.3.3 Effect of Adsorbents on BOD

The effect of various adsorbents on BOD is the same as COD as shown in Figures 3, 6, 9 and 12. The percentage of reduction is by 40 to 60%. It is known that COD and BOD are related to each other and there figures proves this phenomena. Again this polluting parameter is also not within the environmental standards but can be overcome by doing further studying on the adsorbents.

3.3.4 Effect of Adsorbent on Odour

After each adsorption run, the odour was of the distillate was checked. The initial distillate, before the going through the adsorption process had a bad odour. Only the "A" type Zeolite was able to remove the odour in the distillate. As for the other adsorbents, the odour was reduced but it was not completely taken off.

3.4 Pilot Plant Run

A pilot plant was set up according to the bench scale. There were a few improvements introduced to the pilot plant. Firstly a recycle stream was included and also the POME is now pre-heated in a vessel and then sent to flash tank. This modification was introduced to improve on the evaporation and also to make it into a continues process. The capacity of the plant was 50 L and the run was carried out for 5 hours. Two runs were carried out, the first was an evaporation process and then the adsorption column was fitted in to give the combine effect of evaporation and adsorption The distillate was collected and analysis was carried out on all three, the distillate, the raw POME and also the concentrated sludge.

TABLE III : PILOT PLANT EXPRIMENT ANALYSIS

Parameters Monitored	Distillate	Raw POME	Concentrated Sludge
pH	3.34	4.78	4.63
COD	1200	59000	181000
BOD_5	800	37200	100200
Total Solids	120	42000	160000
Suspended Solids	1.5	21000	55000
Volatile Suspended Solids	1	17000	46000
Ammonical Nitrogen	1	45	148
Oil & Grease	7	11300	40150
Mg	0.2	445	1050
Ca	0.1	70	205
K	0.9	3400	7249
F	28	580	4680
Cl	0.2	1750	12000
NO_3	0.1	89	769
SO_4	0.4	330	3300

* All units are in mg/L except for pH

The results of the analysis are shown in *Table III*. The results obtained from the pilot plant run shows the same results as that carried out in the bench scale. The distillate also responded well and in accordance to the data obtained in the bench scale when it was subjected to treatment using the "A" type Zeolite. This proves that this process can be run in the big scale and can be introduced to the industries.

4.0 CONCLUSION AND RECOMMENDATIONS

From the experiments carried out, it shows that the evaporation process combined with the adsorption process is a good solution to the problem posed by POME. All results showed good removal of pollutants and it also complied with environmental standards. A very good plus point is the fact that no energy is supplied to heat the POME but it's internal energy is used to vaporise it. The vapour which is produced can be used as a heat generator and could be a source of energy to the palm oil mill. Thus, full use can be made of the energy in the effluent to solve the wastewater problem. Using this method too there will be no effluent to be dumped because the distillate can be either recycled in the plant for process water and the concentrated sludge can be sold to the fertiliser company for a source of income. Thus, the effluent which was a problem in the past is now a income generating product of the palm oil mill.

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Figure 1: Time of Adsorption Vs pH for different weights of Activated Carbon

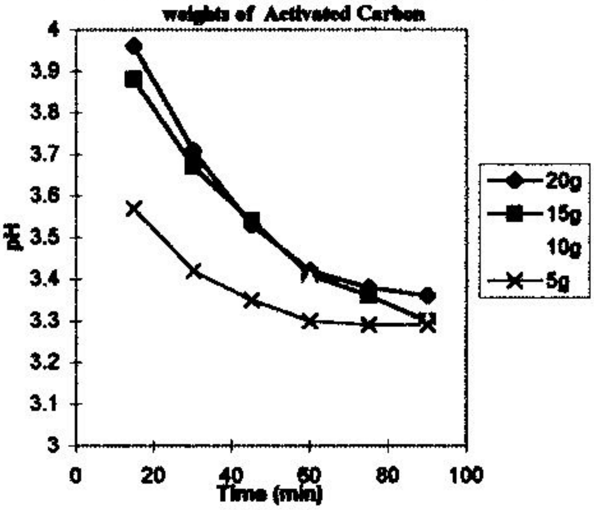

Figure 2: Time of Adsorption Vs COD for different weights of Activated Carbon

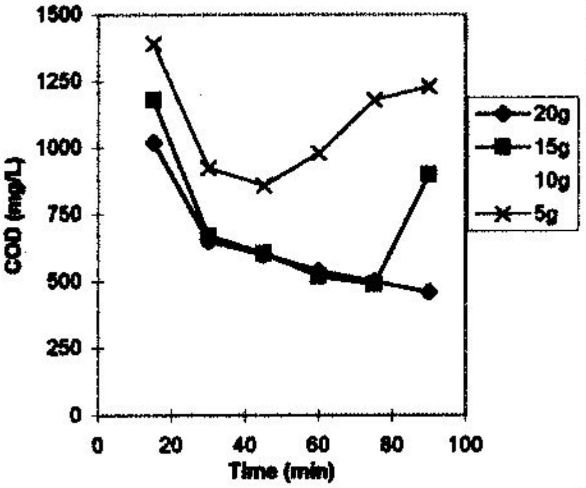

Figure 3: Time of Adsorption Vs BOD for different weights of Activated Carbon

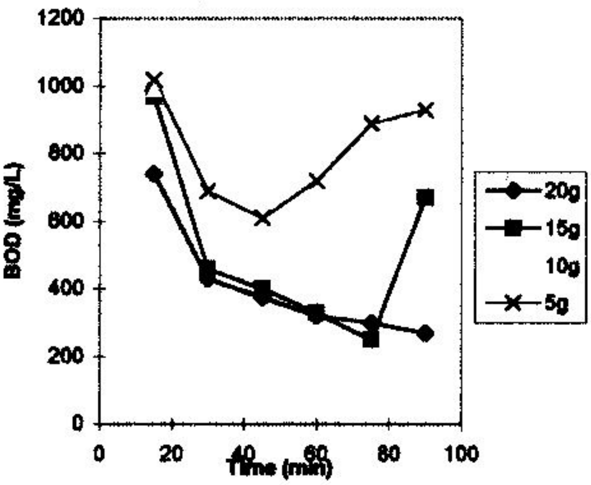

Figure 4: Time of Adsorption Vs pH for different weights of Natural Zeolite

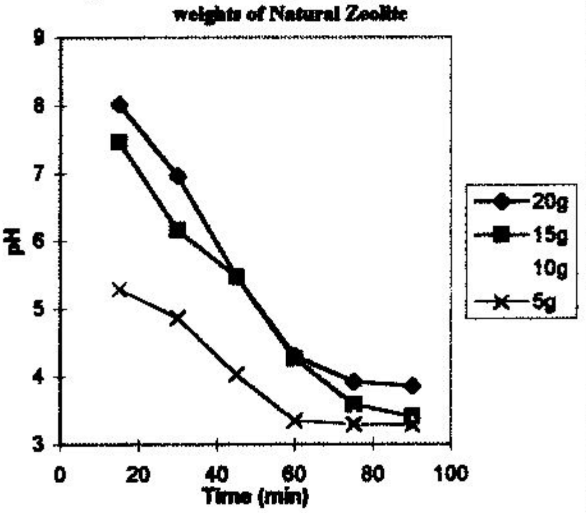

Figure 5: Time of Adsorption Vs COD for different weights of Natural Zeolite

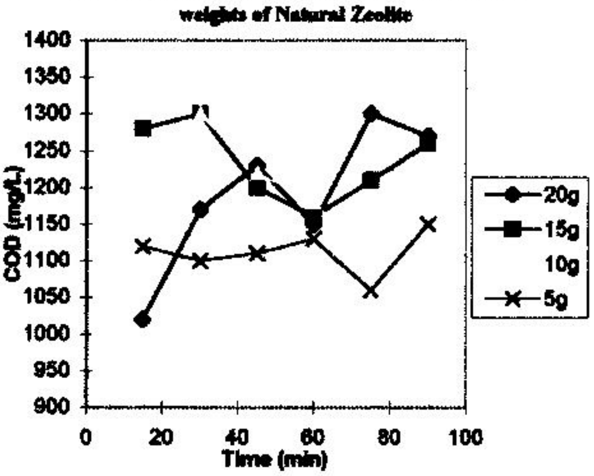

Figure 6: Time of Adsorption Vs BOD for different weights of Natural Zeolite

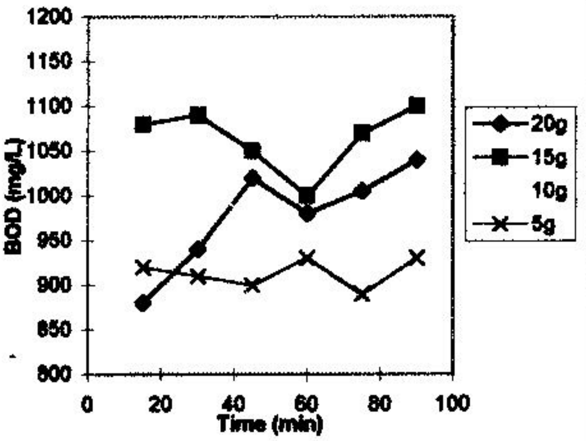

Figure 7: Time of Adsorption Vs pH for different weights of "A" Type Zeolite

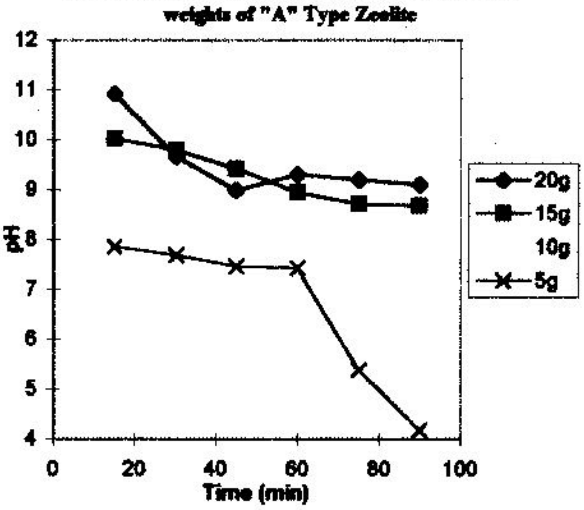

Figure 8: Time of Adsorption Vs COD for different weights of "A" Type Zeolite

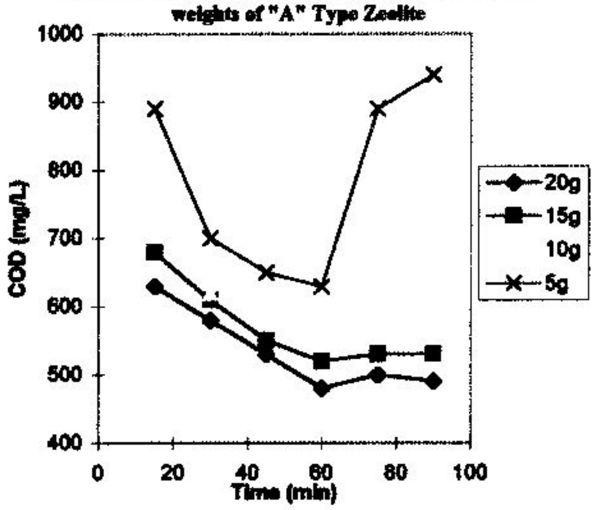

Figure 9: Time of Adsorption Vs BOD for different weights of "A" Type Zeolite

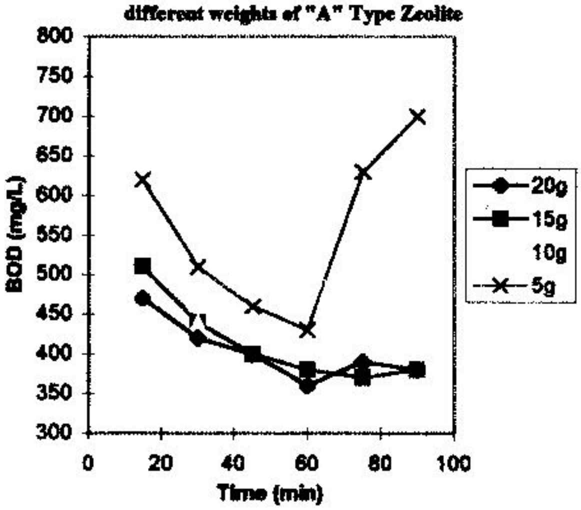

Figure 10: Time of Adsorption Vs pH for different weights of "X" Type Zeolite

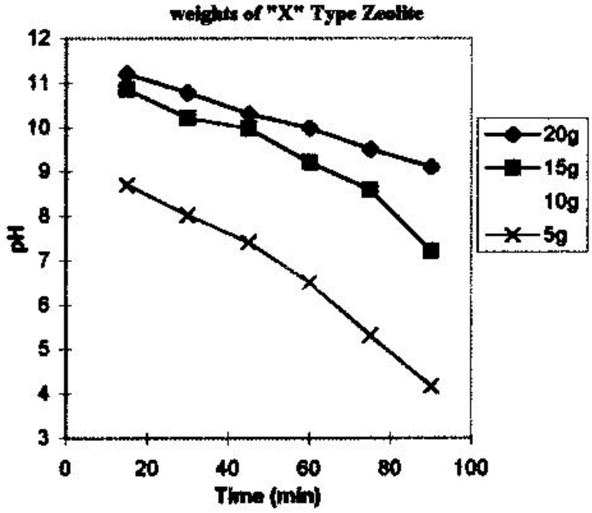

Figure 11: Time of Adsorption Vs COD for different weights of "X" Type Zeolite

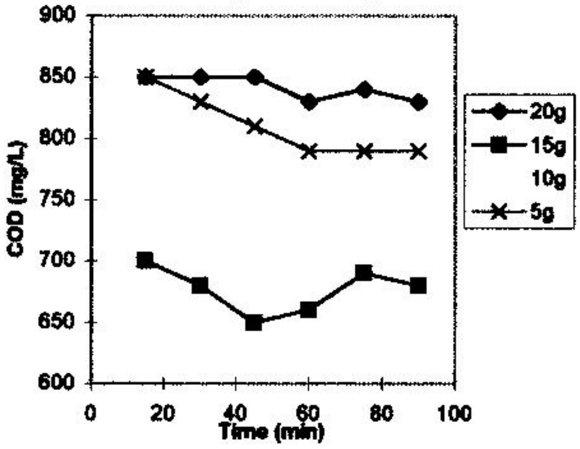

Figure 12: Time of Adsorption Vs BOD for different weights of "X" Type Zeolite