WASTE WATER RECLAMATION AND REUSE IN PETROLEUM REFINERY AT ALGEILI AREA NORTH OF KHARTOUM

BY:
FARIS GURASHI FARIS [1] ISAM MOHAMMED ABDEL-MAGID[2]

ABSTRACT:

This study was conducted at Khartoum Petroleum Refinery at Algeili, North of Khartoum. The study discusses waste water treatment methods in the refinery as well as final disposal methods applied on reclaimed water. Waste water reuse in irrigation was presented in the study as well as its effect on plants and crops.

The objective of this study is to assess the methods of waste water treatment adopted in the evnvironment at evaporation ponds near the refinery. After tests and experiments done on the waste water treatment units and evaporation ponds, the treatent by plant gave good results of water reclamation. 99.6 percent of oil was removed during the processes, 99.76 percent of volatile phenol was eliminated, and COD value decreased by 77.4 percent, however, it increased once more at the evaporation ponds due to algae presence and high temperature. PH value had also increased at the ponds for the same reason. Therefore the study recommends adopting wastewater reuse methods for irrigation. Such methods preserve the environment and might minimize the effect of groundwater recharge from heavy-flow point source into negligible-flow non-point source and hence causes less contamination.

[1]OMDURMAN ISLAMIC UNIVERSITY

[2]SUDAN UNIVERSITY OF SCIENCE & TECHNOLOGY, (SUST).

ملخص:

أجريت هذه الدراسة في منطقة الخرطوم بحري لمحطة تكرير النفط بالجيلي. وناقشت الدراسة أساليب معالجة المياه العادمة في محطة التكرير بالاضافة إلى نظم التخلص النهائي المستخدمة لإعادة الاستخدام والدوران. وأبرزت الدراسة أثر استخدام المياه العادمة في ري النباتات والمحاصيل.

إن هدف هذه الدراسة هو تقييم نظم معالجة المياه العادمة المستخدمة في محطة تكرير النفط بالخرطوم، ودراسة نوعية المياه المعاد استخدامها وآثارها البيئية في برك البخر بالخرطوم من محطة التكرير، وبعد اجراء التحاليل والاختبارات على وحدات معالجة المياه العادمة وبرك البخر أشارت الدراسة إلى النتائج الحيوية للمعالجة بالنباتات حيث أزيلت 99.6 بالمائة من الزيوت والشحوم خلال العملية، و99.76 بالمائة من الفينول المتطاير بالاضافة إلى تقليل حاجة الأكسجين الكيميائي بحوالي 77.4 بالمائة. رغما عن ذلك فقد زادت المقادير مرة أخرى في برك البخر بسبب وجود الطحالب ودرجات الحرارة العالية. كما زاد الرقم الهيدروجيني في البرك لنفس الأسباب ومن ثم فقد أوصت الدراسة باعتماد إعادة استخدام المياه العادمة المعالجة للري لاسيما وهذه الطرق تحافظ على البيئة وسوف تقلل من آثار التغذية الجوفية من دفق قوي من مصدر نقطة إلى دفق منعدم من مصادر متنوعه ومن ثم يضمحل التلوث.

INTRODUCTION:

Oil pollutes water almost in all steps of production, from upsream to downstream. Water is used for drilling purposes, it facilitates and cleans the path of drilling Water is also injected in wells for oil production, as well as large amount of conaminated water is produced during production operations, leaving behind a vast amount of ponds. Several treatment processes should be undertaken before disposal.

Refining is an important step in oil production. Water is used here for several purposes at different stages of refining. An appreciable amount of wastewater is left behind. In the process, pollution of water resources and the environment nearby is expected.

LITERATURE REVIEW:

In oil refinery, water is usually used in various unit operations. In many of these units water or more often steam comes into direct contact with crude oil and products derived from it. Also, chemical reactions take place in certain units and as a result of these reactions by-products will be formed and eventually end up in wastewater streams.

In short, one can expect wastewater stream coming out from the refinery to be loaded with different types of pollutants at various concentrations. Usually wastewater is discharged from refinery either to nearby seawater, or river. Alternatively it is discharged to municipal sewage system. In Sudan it is discharged into evaporation ponds. Before the discharge, the wastewater must be treated in the refinery itself especially when the effluent is to be released in the environment.

SOURCES OF OILY WATER IN THE REFINERY:

There are two main sources of oily wastewater in refinery (Anas, 1998)

- Oily wastewater which comes from the process itself, where water is used in the process at high flow rate for different purposes.
- Other sources result from spillage and leakage of oil from tanks and different units, as well as washing water.

TREATMENT PROCESSES IN THE REFINERY:

The aim of these processes is to control the quality of wastewater effluent according to standards and guidelines. The quality control includes the oil content, toxic materials, color, taste, and odor as well as **PH**, biochemical oxygen demand **(BOD)**, chemical oxygen demand **(COD)** and the degree of turbidity.

Wastewater treatment processes at petroleum refineries can be divided into three main divisions:

1- Direct petroleum treatment operations processes

These processes include the elimination of hydrogen sulfides gas and extraction of alcoholic sulfates and neturalization using caustic soda. These processes should be included in the design of treatment operators to reduce wastewater effluent problems.

2- Unflocculated oil separation, and sludge removal processes:

These processes include oil separation equipment, and oil separation tanks, by using settlement methods, as well as water separation from drain mixture at the top of oil storage tanks (ballast water separators).

3- Special separation processes for the remaining oil, and for the elimination of phenols and sulfates, and all other impurities. Also in this process the BOD and COD are reduced to the acceptable limits to improve the color, taste, and odor of the effluent.

Table 1 represents a sample of wastewater standards from a petroleum refinery before discharge (chalabi, 1986).

TABLE (1): SAMPLE OF WASTE WATER STANDARDS FROM A PETROL REFINERY:

Constituent	Unit
1- pH	6.5 - 8.5
2- Total Oil	15 mg/l
3- Phenols	0.2 mg/l
4- Sulfates	0.5 mg/l
5- Alcoholic Sulfates	0.5 mg/l

WASTEWATER REUSE:

The use of treated wastewater elluent for irrigated agriculture offers an opportunity to conserve water resources. Water reclamation can also provide and alternative to be disposed in areas where surface waters have a limited capacity to assimilate the contaminants. The sludge that results from waste water treatment applied to farmland, can improve the physical properties and agricultural productivity of soils, and its agricultural use provides an alternative to disposal options, such as incineration, or land-filling (Rowe & Abdul-Majid, 1995).

The application of wastewater effluents to soils may pose some risk of ground water contamination by viruses and bacteria, however, that risk can be minimized (NAS, 1996) by adequate disinfections of reclaimed wastewater and by slow infiltration rates.

BEHAVIOR OF SOIL AND PLANTS EXPOSED TO CHEMICAL CONSTITUTE IN RECLAIMED WATER.

Atlas (1981), stated that there are factors which appear to be important in encouraging high decomposition rates of petroleum hydrocarbon (a mixture of aliphatic, aromatic, asphaltic compounds in soil). These factors are temperature, concentrations, adequate supply of essential nutrients, and availability of oxygen. There is a little evidence for significant leachig of petroleum organic compounds from the upper soil layer.

Many of the organic compounds are chemically or biologically degraded or volatilized from the soil during the cropping season. Because the fraction of sludge bome-toxic organics that does remaining soil has low bioavailability, absorption by crops is negligible. In some cases, volatile toxic organics may contaminate plant's tissue through absorption of volatilized compounds, however management practice such as incorporation of sludge with soil and application of sludge before plant sprouting will substantially reduce any plant exposure to volatile organic compounds. (NAS, 1996).

Available data indicate that potentially harmful toxic organics pollutants do not enter edible portions of plant that are irrigated with treatment municipal waste watér, irrigation of vegetation in test plot with wastewater has shown no accumulation of Poly-nuclear Aromatic hydrocarbon (PAHs), especially Benzo (a) pyrene (Il'nit skit et al., 1974). In a study of Aldehydes and other organics at agricultural land treatment sites, (Dodlina et al., 1976) found no uptake of Acetaldehyde, Crotonaldehyde, and Benzoaldehyde in the above ground portion of potatoes, and corn. Cyclohexanone, and Cyclohexnol could be found in corn plants four days after irrigation but no later. Dichloromethane was taken up by beets and cereal, but was metabolized and absent within about two weeks after irrigation.

HEALTH CONCERNS ABOUT CHEMICAL CONSTITUTE IN RECLAIMED WATER:

There are many chemical constitutes that enter the waste water stream that are of potential concern for human health. These substances include organic chemicals, inorganic trace elements, and nitrogen. Conventional agricultural practices such as the use of fertilizers also have potential to introduce additional chemical constitutents to soil.

The degree from which the constituents from wastewater present a risk to human health depends on their concentration in reclaimed water and the fate and transfer of these chemicals from wastewater sources to human receptors via various exposure pathogen (Isam, 2001)8.

There is a number of environmental processes that, when added to the soil, can interrupt the entry of toxic organic chemicals into food chain (Lessage & Jackson, 1992). Organic chemicals from wastewater may be destroyed directly after land application by biodegradation and chemical-and-photo-oxidation. Organic compounds may also be volatilized, immobilized onto solid particles by sorption processes, or transported (leached) unaltered through the soil column to reach the ground water. In more complex mechanisms, sorbed organics may subsequently be chemically or photo chemeically degraded, microbialy decomposed or desorbed.

STUDY CASE: KHARTOUM REFINERY:

Khartoum refinery is located 70 km north of Khartoum State. It occupies an area of 5.5 km . The refinery is 2.5 km east of the railway lines and is 12.5 km away from the river Nile. The refinery plant is occupying half square kilometer while the remaining 8 km are reserved for buildings and extensions. Another 8 km were reserved for marketing companies and other projects related directly to the work at the refinery including a power station and housing compounds.

The maximum design capacity of the refinery is 50 thousands barrels/day i.e. 2.5 million tons a year.

There are five main units at the Khartoum refinery supported by other utility units.

The five main units are :

1. Crude Distillation Unit and its maximum design capacity is 2.5 million tons of crude oil per year.
2. Reforming Unit, with design capacity of 15 thousand tons per year.
3. Diesel Hydro treating Unit, with 400 thousand tons per year designing capacity.
4. Residue Fluid Catalytic Cracking Unit with a design capaity of 1 800 000 tons a year.
5. Sour Water stripper with a design capacity of 400 thousand tons per year.

The Utility units of the refinery constitute power generation station, 36 megawatt, and a water purification and pumping station, 1500m3/hr.

WATER AND WASTE WATER IN KHARTOUM REFINERY:

Waste water in Khartoum refinery is divided into two main categories, A, and B.

A- 1- Water Contaminated with Oil

 1- Oil Contaminated with Water

B- 1- Domestic Waste water.

 2- Cooling Water Blow Down

2- Boiler Water and Boiler Feed Water (BW & BFW) Blow Down

WATER USAGE IN THE REFINERY:-

Water is used in the refinery for the following purposes:

1- Cooling purposes.

2- Steam Generation

3- Oil Washing

4- Domestic Use

5- Fire Fighting

SOURCES OF WASTE WATER ASSOCIATED WITH VARIOUS PRODUCTION UNITS:

1- Crude Tank: Crude oil normally contains traces of water, an average of 0.05% per weight. The crude intake in the refinery is approximately 7500t/day. Therefore, the quantity of water per day would be:

$$(0.05/100)*7500 = 3.75 \text{ tons/day}$$

2- Desalting: In this process water is added to dissolve salts in the crude oil, then by using electric desalter water is separated from oil.

3- Crude Distilling Unit [CDU]: It is one of the refinery's most active units. It implies the intake of crude oil heated at 360 degrees, accompanied by steam, which will produce a gas usually known as the refinery's gas. Air-cooling and water-cooling will be preceded for cooling down the product. Sour water is then directed to the sour water stripper.

4- Reforming Unit: Reforming unit does not use water in the process. Therefore, there is no wastewater source from this unit.

5- Diesel Hydro Treating Unit [DHT]: Diesel Hydro Treating Unit uses a furnace and a reactor for the removal of Sulfur, Nitrogen, and Olefins from the product. The product will be air-cooled and water cooled, and then it undergoes water wash. Wastewater will be discharged to the drainage system.

6- Residue Fluid Catalytic Cracking: long residue produced from the previous unit is directed to a reactor in the RFCC unit for molecules cracking. Water is discharged similar to CDU.

7- Utility units in Khartoum refinery:

1- Cooling Water System
2- Power Station
3- Boilers

8- Other sources:

1- Rainwater
2- Cleaning "washing" Water.

MATERIALS AND METHODS:

Efficiency of removal was conducted, along with chemical analysis for a period of one month. Each treatment unit in the wastewater treatment plant was thoroughly investigated and analyzed. Investigation also included the final disposal of treated effluent. The treated effluent was disposed into three oxidation ponds 500m from the refinery. Evaporation, dimensions and chemical analysis were worked out, and general environmental obnservations were remarked.

Four samples had been taken from four different units in the treatment plant on daily basis, as will be described later in this article. Three samples were taken from the oxidation pond. An experiment of Broad beans growth was also worked out during the study, to discuss the feasibility of water reuse for agricultural irrigation.

The three **Oxidation Ponds** in Khartoum refinery situated at three decreasing levels. During construction, plastic layer had been installed at the bottom and the sides of the ponds to prevent water seepage. The area of the ponds is 0.78km^2. The flow is evenly disributed to preserve a 1.2m water level. Meteorological experiments of the area, estimated the evaporation rate to be 17.1mm/day.

Samples had been arbitrarily taken from the ponds and checked for the following tests:

PH, Oil Content, Sulfur Vontent, **COD**, **BOD**5, Volatile Phenol, Ammonia-Nitrogen, Sulfur, Volatile Phenol, Ammonia-Nitrogen, Suspended Solids, Phosphorous, Total Dissolved Solids, and microbiological tests.

Seed-growth experiment of Broad beans had been conducted for all three samples to promote water reuse in specific crops. Remarks on the evaporated water and the size of the ponds were taken during the study.

RESULTS & DISCUSSIONS:

TREATMENT UNITS:

As mentioned previously, the quantity and quality of incoming wastewater to the treatment plant from production units, varies widely according to the state of production and quality of crude oil in the refinery. Nevertheless, results showed stability in treatment control. At the oily wastewater screen, oil content had a wide range (i.e from>1000 to <90 mg/1) during chemical analysis tests.

Here are the results obtained from the first monitoring point of wastewater in the study.

TABLE(2): RESULTS OF WASTEWATER SAMPLES TAKEN FROM OILY-WATER SCREEN BASIN.

No.	Oil Mg/1	Volatile Phenol mg/1	COD Mg/1	PH	Sulfur Mg/1
1	96.89	39.49	341	8.95	0
2	700.23	13.53	443	8.9	0
3	609.38	23.22	577	7.8	3.2
4	1123.86	14.31	378	8.1	1.2
5	1322.8	12.98	317	8.4	0
Average	770.63	20.704	411.2	8.35	0.88

The importance of these results shown in table 2 is the identification of raw wastewater before treatment. Further treatment is gravity separation of oil. In this process oil was removed and separated for reuse, and waste water was sent for dissolved air flotation first and second stage (DAFI & DAF2).

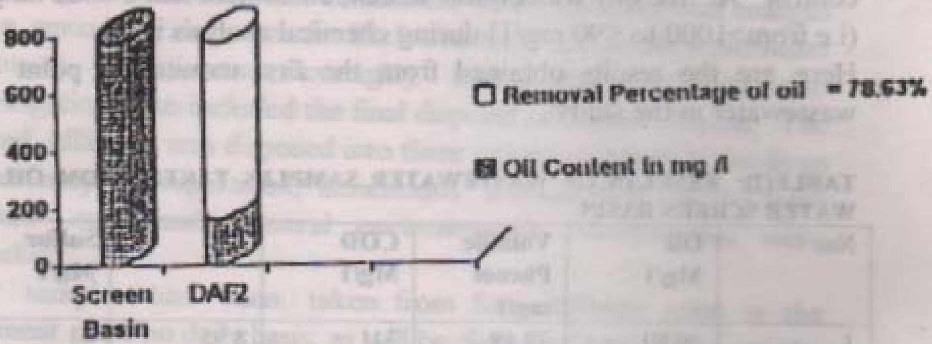
Results of samples tests of waste water taken from the out take of DAF2 as presented in table 3 were as follows:

Note: Quality Index provided in the study is according to the Chinese National Standards.

TABLE (3): RESULTS OF WASTE WATER SAMPLES TAKEN FROM DAF2.

No.	Oil mg/1
1	53.8
2	285.7
3	121.11
4	179
5	183.7
Average	164.662

The average percentage of removal would be:



FIG(1): AVERAGE OIL REMOVAL PERCENTAGE FROM INTAKE POINT AT SCREEN BASIN TO DAF2 STAGE.

The high removal percentage was an outcome of the physical method (gravity separation) and Chemo-Physical methods (injection of air and emulsifiers). Oil discharged from DAF2 is not useful any more for reuse, because the emulsifiers increase the temperature of the product, and hence the characteristics of oil deterioration.

The third monitoring point, was the Bio-Chemical unit in Khartoum Refinery. Samples were taken from the outlet and the results obtained were as follows in table 4:

TABLE (4): REUSLTS OF SAMPLES TAKEN FROM THE BIOCHEMICAL UNIT.

No.	Oil mg/l	COD mg/l	BOD mg/l	Phenol mg/l	Suspended solids mg/l	NH3-N mg/l	Sludge comp.%	pH
1	6.5	272	9.8	0	41	3.2	19	6.13
2	19.59	381	14.2	0.1	32	1.4	32	7.5
3	16.94	117	17.2	0	29	15.4	30	6.16
4	21.67	91.1	19.1	0.1	18	2.8	29	7.15
Average	16.18	215	15	0.05	30	5.7	27.5	6.74

After the results of the Bio-chemical unit, the wastewater effluent was by then improved by far. The Anaerobic and aerobic units in the bio-chemical unit had extensively reduced chemical constiutents of the wastewater, where at this point wastewater was discharged clean and ordorless to the sedimentation tank. The effluent was discharged afterwards to the filters and hence to the supervision basin.

The supervision basin is considered the most important monitoring check point at wastewater treatment plant, and the results of the samples taken from it check the whole previous processes. This is due to the fact that the effluent is discharged right way to the environment through the oxidation ponds.

If the results were not satisfying, the by-pass pipeline connected to the basin send back the effluent for further treatment by repeating the previous processes once again.

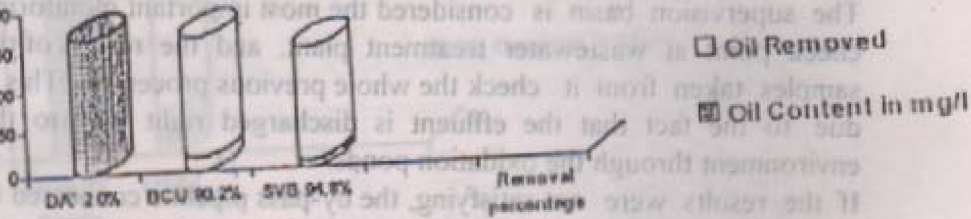
These processes are repeated according to the degree of contamination of the effluent.

Samples taken from the supervision basin had results as in table 5 below.

TABLE (5): RESULTS OF SAMPLES TAKEN FROM SUPERVISION BASIN

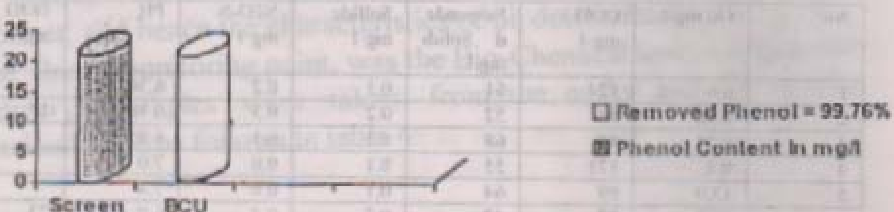
No.	Oil mg/l	COD mg/l	Suspended Solids mg/l	Sulfide mg/l	NH3-N mg/l	PH	BOD mg/l
1	6.6	124	61	0.1	0.2	6.36	
2	6.98	90	52	0.2	0.3	6.16	15
3	6.23	84	68	0.1	0.1	6.95	
4	9.4	171	55	0.1	0.0	7.0	
5	13.9	99	64	0.1	0.0	7.4	
6	10.9	67	42	0.2	0.4	6.0	23
7	4.4	83	53	0.2	0.1	6.3	
8	15.1	92	55	0.3	0.5	6.2	
9	17.2	133	100	0.3	0.1	7.0	
10	9.7	65	50	0.1	0.1	6.7	
11	8.4	86	77	0.2	0.1	6.6	7
12	4.2	44	70	0.1	0.1	6.0	
13	5.2	70	55	0.1	0.6	6.0	
14	3.6	94	32	0.1	0.3	5.6	
Average	8.7	93	64	0.16	0.23	6.45	15
Quality Index	10	150	70	0.5	15	6-9	260

As shown from the previous results, the oil content had been enormously reduced from DAF2 to supervision basin. Fig.2 shows the removal percentage of oil at these stages;



FIG(2): OIL REMOVAL PERCENTAGES FROM BIOCHEMICAL UNIT TO SUPERVISION BASIN.

The Volatile Phenol removal from oily water screen basin and the biochemical unit was as follows:



FIG(3): VOLATILE PHENOL REMOVAL FROM ONLY-WATER SCREEN TO BIOCHEMICAL UNIT. OXIDATION PONDS.

The Oxidation Ponds at Khartoum Refinery are the final disposal terminals of treated wastewater effluent discharged from the treatment plant. The ponds are about 1100m in length and 625m wide. The effluent is odorless, and greenish in color. No traces of oil (i.e. oil films) could be seen.

The total area of the ponds is about 687500m2. A level of 1.2m is always maintained through even distribution of wastewater effluent into the ponds, by using control valves. There are embankments 3m wide around he three ponds, which would make the total surface area of the effluent to be:

$$\{[625*1100]-[(3*4*625)+(3*21100)]\}=673400m^2$$

Multiplied by the depth (i.e.1.2m), the volume of treated effluent would be:

$$673400*1.2=825,000m^3$$

The peak evaporation index of the area is 17.1mm/day. Therefore the daily evaporated water from the ponds would approximately be:

$$673400*17.1*(1/10^3)=11515.14m^3/day$$

This result varies at different times of the year, making peak values at very hot dry weathers. The index drops in cold and humid weather to 16 mm/day 10774.4m³/day. Therefore, the average daily-evaporated volume of effluent would be approximately equal to 11144m3/day.

Sources of daily discharged waste water to the ponds were:

1- Production wastewater discharged from the treatment plant.

2- Blow-Down "circulating" Water

The daily amount of production water (Q1) discharged to the ponds is calculated approximately as follows:

$$Q1=Wav*Q1av$$
$$=30*170=5100m3/day$$

Where,

Wav: The average working hours of production pumps per day.

Qtav The average discharge of production wastewater per (m1/day).

While the daily amount of blow-down waste water (Q2) is approximately:

$$Q2 = Wav2*Q2av$$
$$= 47*130=6110m^3/day$$

Where,

Wav2: The average working hours of blow-down pumps per day.
Q2av: The average discharge of blow-down waste water per (m3/day)

Therefore the total daily average discharge of waste water effluent to the oxidation ponds (Q) would be:

$$Q = Q1 + Q2$$
$$= 5100 + 6110 = 11210\ m^3/day.$$

The results showed that there had been a slight increase of incoming wastewater to that of evaporated one, which implied a continuous increase of waste water onto the ponds.

Water quality of the oxidation ponds had been tested through samples taken from the ponds. These samples were chemically analyzed for different chemical constitutents that were suspected to be present at the ponds. Table 6 shows tests conducted and results that had been obtained:

TABLE (6): TESTS & RESULTS OF THE FIRST SAMPLE TAKEN FROM THE POND

No.	Test	Result	Unit
1	PH	9.2	No
2	Oil	2.18	mg/l
3	Sulfur	0	mg/l
4	COD	351	mg/l
5	BOD5	23	mg/l
6	V Phenol	0.04	mg/l
7	NH3-N	0.701	mg/l
8	S.Solids	93	mg/l
9	P	1.02	mg/l
10	TDS	1103	Mg/l

The previous sample was taken from the first pond, which is situated at the lowest level of the three ponds. Results obtained on this sample were all acceptable ones, only the PH, and COD seemed to be slightly raised from the standard index. This is due to the presence of algae. A filtered sample tested for COD obtained acceptable results. Microscopic test that had been conducted on this sample indicated the dense presence of algae on the sample.

The second sample had been taken from the second pond (the middle one), it is elevated 2m approximately above the first pond. The treated effluent look more green than the first pond. No odor or oil films can be detected by human senses.

TABLE (7): SHOWING THE TESTS CONDUCTED AND THE REUSLTS OBTAINED FOR THE SAMPLE:

No.	Test	Result	Unit
1	PH	10.2	No
2	Oil	3.5	mg/l
3	Sulfur	0.8	mg/l
4	COD	377	mg/l
5	BOD5	39	mg/l
6	V.Phenol	0.08	mg/l
7	NH3-N	7.40	mg/l
8	S.Solids	325	mg/l
9	P	0.34	mg/l
10	TDS	1166	mg/l

Microscopically, algae presence on this sample was denser than than the previous one. That is why more COD and pH value were received during testing. Temperature, and sunlight also affect the value of COD and PH (i.e. the results vary during the day). Other results were acceptable according to the quality index.

The third pond had the most algae presence between other ponds. It is also elevated 2m above the previous pond. The water at this pond was odorless and green in color. Tests and results are described at table 8:

TABLE (8): TESTS & RESULTS OF THE THIRD SAMPLE TAKEN FROM THE THIRD POND.

No.	Test	Result	Unit
1	PH	10.3	No
2	Oil	3.54	mg/l
3	Sulfur	0.8	mg/l
4	COD	340	mg/l
5	BOD5	14	mg/l
6	V.Phenol	0.005	mg/l
7	NH3-N	3.7	mg/l
8	S.Solids	431	mg/l
9	P	0	mg/l
10	TDS	897	mg/l

Birds swimming on the ponds and plants growing at the sides of the ponds were observed during testing. Microorganisms were found along with dense presence of algae at microscopic test conducted for the three ponds.

There were slight differences on the effluent quality of each ponds, as well as in color (i.e. algae presence). The average results of the effluent of the three ponds together would be shown in table 9.

Results from the treatment plant showed that there was no sulfur content on the waste water coming from it. However, one does assume that sulfur content on the samples taken from the ponds were coming from the blow-down water. Nevertheless the result was acceptable to quaity index guidelines. Oil content and volatile phenol values were acceptable for discharge standards, and can be discharged into waterways.

The algae presence at the ponds increased the COD, PH, and Suspended Solids values; on the other hand algae presence is an indication of good qulity wastewater effluent.

To translate the results into real-time experience and to open doors for effluent reuse for agricultural pruposes or artificial groundwater recharge, and depending on the previous results, an experiement of broad beans growth was conducted.

TABLE (9): AVERAGE RESULTS OF THE THREE SAMPLES TAKEN FROM THE PONDS

No.	Test	Result	Unit
1	PH	9.9	No
2	Oil	3.07	mg/l
3	Sulfur	0.53	mg/l
4	COD	356	mg/l
5	BOD5	25	mg/l
6	V.Phenol	0.042	mg/l
7	NH3-N	3.93	mg/l
8	S.Solids	283	mg/l
9	P	0.45	mg/l
10	TDS	1055.3	mg/l

Broad Beans-Growth Experiment and Results:

The first sample was tap-water sample referred to as blank sample (sample 0) kept on a pitry dish. Broad beans were dumped at sample 0. The second sample was from the first oxidation pond, referred to as, sample 1. The third and the fourth sample were from the second, and the third ponds, referred to as, sample 2, and sampe 3 respectively. Small equal broad beans had been dumped on these samples, where all sampes hold the broad beans on pitry dishes for the same period of time. All samples from the ponds had been taken randomly. Time of the experiment before removing the sample for photography was three days.

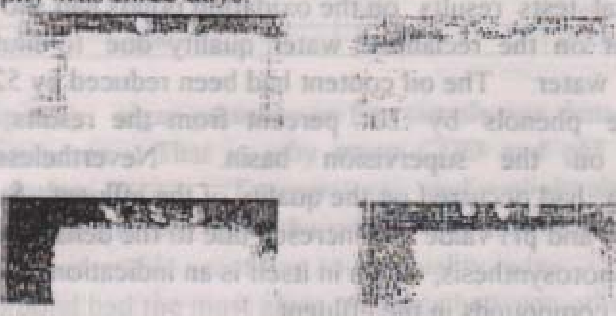


FIG (4): ROOTS GROWTH ON BOARD BEANS FOR FOUR SAMPLES.

As shown on firgure 4, the results of the experiment were very encouraging. Some samples from the ponds showed even better results than tap water itself. This is clearly seen at the growing roots and the healthy textures of broad beans.

6. CONCLUSIONS & RECOMMENDATIONS:

The study of petroleum waste water effluent management in Khartoum refinery had investigated the various wastewater treatment plant in the refinery, as well as terminal disposal point of reclaimed wastewater at the oxidation ponds. Based on the results, reclaimed water reuse for agricultural irrigation would be considered. Conclusions drawn from this study can be summarized as follows:-

Preliminary Physical Treatment Units: In the process, an average of 78 percent of oil content had been removed with minimum losses policy. The useful removed oil had been sent, for reuse, to the crude oil tank.

Biochemical Treatment Units: At the end of this process, volatile phenols content in wastewater was removed to as high as 99.76 percent, and oil content was reduced other chemical constiutents such as COD, BOD, SS, NH3-N, had all been quite acceptable according to known guidelines.

Secondary Physical Treatement: These units are the sedimentation tanks, and the mechanical filters.

OXIDATION PONDS:

The chemical tests results on the oxidation ponds had shown some improvement on the reclaimed water quality due to dilution with blow-down water. The oil content had been reduced by 52 percent and volatile phenols by 16 percent from the results obtained previously on the supervision basin. Nevertheless., some deterioration had occurred on the quality of the effluent. Suspended solids, COD, and pH value had incresed due to the dense presence of algae and photosynthesis, which in itself is an indication of reduction of inorganic compounds in the effluent.

Seed-Growth Experiment: To enhance the credibility of the previous results, broad beans growth experiment had been conducted, and the results obtained had showed that the reclaimed water at the oxidation ponds had satisfied good quality water of irrigational characteristics, which could be reused for some agricultural purposes.

RECOMMENDATIONS:

For optimum results concerning the core of the study, the writers recommend the following:

1. The installation of monitoring wells at different distances scattered at downstream areas to record the groundwater quality of the underlying growundwater basin.
2. Reuse of reclaimed water at oxidation ponds for forestry irrigation. Camphor trees at eastside of refinery are recommended.

3. Installation of several flow meters for each unit at the waste water treatment plant for better monitoring of the quantitities, and quality at each unit.
4. Expanding the varieties of chemical tests to include more trace elements, and organic compounds.

SUGGESTIONS FOR FURTHER STUDY

1. Studying the types of algae and bacteria present on the oxidation ponds and trying to genetically modify it so as to reduce the organic compounds through degradation or ingestion.
2. Analysis of more organic compounds such as Poly-nuclear Aromatic Hydrocarbon (PAH), Aldehydes and other organics might be done to study their effect on differet crops.
3. Study to increase the efficiency of the biochemical unit at the refinery is recommended.
4. A statistical model to monitor and predict the contamination of groundwater upstream to downstrem through observation wells records, are highly recommended for further studies at the Khartoum Refinery.

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