

Dedication

To the soul of my father
and to my mother

Acknowledgements

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Abstract

The environment is considered as man's important asset that must be protected for his life support. Unfortunately, the situation is different where oil refinery and petrochemical plants operate. Environmental pollution in these areas poses serious threat to the ecosystem, often with undesirable effects. This study, therefore, was undertaken in order to investigate the quality of the liquid effluents released from Khartoum Refinery and their potential impacts on the surrounding environment. The results of this study provide a better understanding of pollutants load in the effluents generated by Khartoum Refinery and the corresponding potential environmental consequences. Effluents and sediments sampling and subsequent laboratory analyses were performed to evaluate the pollutants levels in both the effluents and sediments. Geological, geographical, and topographic data collection and field survey were conducted to assess the potential environmental impact of the effluent. 9 composite effluent samples were collected from the monitoring pond (MP), which is the final station for the treated effluent inside the refinery, and analysed for physical parameters (Temperature, pH, TS, TDS, TSS, conductivity, and turbidity), inorganics (alkalinity, hardness, chloride, sulfate, cyanide, and sulfide), nutrients (ammonia, nitrate, nitrite, ortho phosphate, and total phosphorus), and organics (BOD, COD, oil and grease, and phenols). Effluent samples were also collected from the oxidation ponds, (27 composite each from 15 grab samples), that receives the effluent from MP outside the refinery, and analysed for the same parameters in addition to heavy metals (Cr, Cd, Ni, Fe, Pb, Zn, Ba, Ag, Se and Cu), which were also measured in the sediment samples collected from the oxidation ponds A, B, and C (3 samples, each was a composite of 5 grab samples).

Based on the results of MP effluent analyses, it was observed that the effluent was alkaline (pH 8.47) and characterized by high levels exceeded the national and international standard limits, for temperature increase (12°C), TSS (56 mg/L), conductivity (746.6 $\mu\text{S}/\text{cm}$), turbidity (43.25 NTU), sulfide (9.07 mg/L), ammonia-nitrogen (83.17 mg/L), BOD (41.2 mg/L), COD (611.33 mg/L), and phenols (39.72 mg/L). The rest of the parameters ranged from low to relatively high concentrations. Effluent quality survey in the oxidation ponds demonstrated removal efficiencies of 50%, 55.9%, 71%, 98.9%, 98.6%, 92.6%, 87%, 45.46%, 46.4%, and 99.8% for temperature increase, turbidity, alkalinity, hardness, sulfide, ammonia, BOD, COD, oil/grease, and phenols, respectively. Despite the biodegradation capability of oxidation ponds, it was obvious that, the levels of many effective pollution parameters were increased to be above the maximum permissible limits. pH, TS, TDS, TSS, conductivity, chloride, sulfate, cyanide, nitrate, nitrite, orthophosphate, and total phosphorus were increased by 16.8%, 574.6%, 638.9%, 278.6%, 289.6%, 1,045.7%, 2,197.6%, 7.7%, 149,200%, 18,323%, 900%, and 129.2%, respectively, besides high residual COD of 333.33 mg/L. Heavy metals were generally found in low concentrations in oxidation ponds effluents, but the sediment was heavily polluted with Ba, Cr, and Cu and moderately polluted with Ni, Zn, and Fe.

Through this research, it is concluded that Khatoum Petroleum Refinery discharge low quality effluent and did not comply with the national and international standard limits in terms of many pollution parameters which could adversely impact the surrounding environment, although some parameters were within the acceptable limits, and recommendations are made for the development of future policies with regard to effluent management and for further research as well.

المستخلص

تعتبر البيئة ثروة مهمة للإنسان ينبغي حمايتها لأنها تدعم حياته. للأسف إن الوضع غير ذلك في مناطق مصافي البترول ومصانع البتروكيماويات ، حيث التلوث البيئي الذي يشكل تهديداً خطيراً على النظام الإيكولوجي. لذلك فقد اجريت هذه الدراسة للتحقيق في جودة المخلفات السائلة لمصفاة الخرطوم للبترول والتأثيرات الضاره المحتملة لتلك المخلفات على البيئة المجاوره لمنطقة المصفاة. نتائج هذه الدراسة تزودنا بفهم افضل لكمية الملوثات في هذه المخلفات السائلة وما يمكن ان يقابلها من تبعات سلبية على البيئة. أخذت عينات من المخلفات السائلة والرواسب وتم تحليلها لتقييم مستوى الملوثات فيها. جمعت بيانات جيولوجية ، جغرافية وتوبوغرافية بالاضافة إلي المسح الحقلي و ذلك لتقييم الآثار البيئية المحتملة علي المنطقة. جمعت 9 عينات مركبة من المخلفات السائلة من حوض المراقبة والذي يمثل المحطة الاخيرة للمخلفات السائلة داخل المصفاة. حللت هذه العينات لمعرفة مستويات المتغيرات الفيزيائية (العكوره ، التوصيلية ، المواد الصلبة العالقة الكلية، المواد الصلبة الذائبة الكلية، المواد الصلبة الكلية ، الرقم الهيدروجيني ،زيادة درجة الحرارة)،اللاعضوية (القلوية ، العسر ،الكلوريد، الكبريتات، السيانيد والكبريتيد)،المغذيات (الامونيا ،النترات،النتريت ،اورثو فوسفات والفسفور الكلي) والعضوية (الاحتياج الحيوي للاكسجين ، الاحتياج الكيميائي للاكسجين ، الزيوت والدهون والفينولات) . ايضاً جمعت 27 عينة مركبة كل واحدة مركبة من 15 عينة فرعية من المخلفات السائلة من برك الاكسدة والتي تستقبل المخلفات السائلة القادمة من حوض المراقبة . حللت هذه العينات لقياس مستوى نفس المتغيرات السابقة بالاضافة إلي العناصر الثقيلة (الكروم ، الكاديوم ، النيكل ، الحديد ، الرصاص ، الخارصين، الباريوم، الفضة، السيلينيوم والنحاس) والتي تم تقديرها أيضاً في عينات الرواسب التي جمعت من برك الاكسدة A،B و C (3عينات مركبة كل واحدة من 5 عينات فرعية).

إستناداً على نتائج تحاليل عينات المخلفات السائلة في حوض المراقبة، فقد لوحظ أن المخلفات قلوية (pH 8.47)، وتتميز بمستويات عاليه تجاوزت الحدود القياسية الوطنية والعالمية بالنسبة لكل من الزيادة في درجة الحرارة(12°C) ، المواد الصلبة العالقة الكلية (56 mg/L)، التوصيلية (746.6 µS/cm)، العكورة (43.25 NTU)الكبريتيد (9.07 mg/L)، نيتروجين

الأمونيا (83.17 mg/L)، الاحتياج الحيوي للأكسجين (41.2 mg/L)، الاحتياج الكيميائي للأكسجين (611.33 mg/L)، والفينولات (39.72 mg/L). بقية المتغيرات ترواحت من المستوى المنخفض إلى المستوى العالي نسبياً. مسح الجودة للمخلفات السائلة في برك الأكسدة أظهر كفاءة إزاله 50%، 55.9%، 71.2%، 98.9%، 98.6%، 92.6%، 87%، 45.46%، 46.4% و 99.8% بالنسبة لزيادة درجة الحرارة، العكوره، القلوية، العسر، الكبريتيد، الأمونيا، الاحتياج الحيوي للأكسجين، الاحتياج الكيميائي للأكسجين، الزيوت والدهون والفينولات على التوالي. بالرغم من قدره العالية لبرك الأكسدة في التحلل الحيوي، إلا أنه كان واضحاً ارتفاع مستويات العديد من متغيرات التلوث المؤثره لدرجة تجاوزها للحدود القصوى المسموح بها. pH، TS، TDS، TSS، التوصيلية، الكلوريد، الكبريتات، السيانيد، النترات، النتريت، أورثوفوسفات، الفسفور الكلي زادت بمقدار 16.8%، 574.6، 638.9%، 278.6%، 289.6%، 1,045.7%، 2,197.6، 7.7%، 149,200%، 18,323%، 900%، 129.2% على التوالي، بالإضافة إلى مستوى عالي من فضلة الاحتياج الكيميائي للأكسجين بلغت 333.33 mg/L. العناصر الثقيلة عموماً وجدت بتراكيز منخفضه في المخلفات السائلة لبرك الأكسدة ولكن الرواسب وجدت ملوثة بشدة بالباريوم والكروم والنحاس وملوثة بدرجة معتدله بالنيكل والخاصين والحديد.

خلال هذا البحث يستنتج بأن مصفاة الخرطوم للبترول تفرغ مخلفات سائلة بجودة منخفضه لا تمثل للحدود القياسية الوطنية و العالمية بالنسبة للعديد من متغيرات التلوث والتي يمكن أن تؤثر سلباً على البيئة المحيطة بمنطقة المصفاة بالرغم من أن بعض المتغيرات كانت ضمن الحدود المقبولة، كما قدمت التوصيات لتطوير السياسات المستقبلية بالنسبة لإدارة المخلفات السائلة وكذلك التوصيات للبحث المستقبلي.

Table of Contents

Dedication	i
Acknowledgement	ii
Abstract (English)	iii
Abstract (Arabic)	v
Contents	vii
List of Tables	x
List of Figures	xii
Abbreviations	xiv

Chapter 1: Introduction

1.1 General	1
1.2 Environmental Pollution	3
1.3 Industrial Pollution	8
1.4 Petroleum Refining Industry	9
1.5 Khartoum Petroleum Refinery	11
1.6 Statement of the Problem	13
1.7 Research Aims and Objectives	14
1.8 Research Questions	15
1.9 Scope of the Study	15
1.10 Limitations of the Study	16
1.11 Significance of the Study	16
1.12 Description of the Study Area	17

Chapter 2: Literature Review

2.1 Crude Oil Composition	23
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2.2	Petroleum Refinery Operations	27
2.3	Petroleum Refinery Liquid Effluents.....	35
2.4	Environmental Impact of Refinery Effluents	38
2.5	Toxicity of Refinery Effluents.....	41

Chapter 3: Research Methodology

3.1	Research Design.....	43
3.2	Methods of Data Collection.....	44
3.3	Sampling Sites	44
3.4	Effluent Samples Collection and Pretreatment	46
3.5	Sediment Samples Collection and Pretreatment	48
3.6	Effluent Analysis	49
3.6.1	Physical parameters.....	50
3.6.2	Inorganics	53
3.6.3	Nutrients	61
3.6.4	Organics.....	68
3.6.5	Heavy metals	78
3.7	Sediment Analysis.....	79

Chapter 4: Results and Discussion

4.1	Monitoring Pond (MP) Effluent Quality.....	82
4.1.1	Physical parameters.....	83
4.1.2	Inorganics	91
4.1.3	Nutrients	100
4.1.4	Organics.....	109
4.2	Oxidation Ponds Effluents Quality	115
4.2.1	Physical parameters.....	116

4.2.2	Inorganics	121
4.2.3	Nutrients	127
4.2.4	Organics.....	132
4.2.5	Heavy metals	136
4.3	Sediment Quality	139
4.3.1	Quality control	139
4.3.2	Heavy metals in oxidation ponds sediments	139

Chapter 5: Conclusions and Recommendations

5.1	Conclusions.....	146
5.2	Recommendations For Future Research	149
	References	151

List of Tables

Table 3.1	Alkalinity relationships.....	55
Table 4.1	The relationship between temperature and oxygen solubility.....	85
Table 4.2	The physical quality of the MP effluents and comparison with National Sudanese standards and International standards	86
Table 4.3	The inorganics quality of the MP effluents and comparison with National Sudanese standards and International standards.....	92
Table 4.4	The nutrients quality of the MP effluents and comparison with National Sudanese standards and International standards	101
Table 4.5	The organics quality of the MP effluents and comparison with National Sudanese standards and International standards	109
Table 4.6	The physical quality of the oxidation ponds effluents and comparison with National Sudanese standards and International standards.....	117
Table 4.7	The inorganics quality of the oxidation ponds effluents in(mg/L) and comparison with National Sudanese standards and International standards	122
Table 4.8	The nutrients quality of the oxidation ponds effluents in (mg/L) and comparison with National Sudanese standards and International standards	128
Table 4.9	The organics quality of the oxidation ponds effluents in(mg/L) and comparison with National Sudanese standards and International standards	133
Table 4.10	The heavy metals quality of the oxidation ponds effluents in(mg/L) and comparison with National Sudanese standards and International standards	137
Table 4.11	Total metal determinations in reference samples.....	139

Table 4.12 Total metal concentrations in sediment samples (in mg/kg dry weight).....	141
Table 4.13 Comparison of average concentration of heavy metals obtained in this research with US EPA Sediment Quality Guidelines (in mg/kg dry weight).....	142

List of Figures

Figure 1.1	Illustration of the close relationships among the air, water, and earth environments with each other and with living systems, as well as the tie-in with technology (the anthrosphere)	2
Figure 1.2	Aerial view of Khartoum Petroleum Refinery	12
Figure 1.3	The map of Sudan showing the location of Khartoum State	18
Figure 1.4	The map of Khartoum State showing the study area	19
Figure 1.5	Satellite view of the Site and external neighbourhood of Khartoum Refinery	20
Figure 2.1	Typical refinery flow diagram	32
Figure 2.2	Schematic diagram of generic sequence for treating petroleum refinery effluent	34
Figure 3.1	Satellite view of Khartoum Refinery showing the main sampling sites; MP and the oxidation ponds. Also wastewater treatment plant (WWTP) can be seen	45
Figure 3.2	Satellite view of the oxidation ponds showing pond (A), pond (B), pond (C), and sampling points in each pond	46
Figure 3.3	Manual sampler used in effluent samples collection	47
Figure 3.4	Analytical scheme for differentiation of various phosphorus forms in water and wastewater	65
Figure 4.1	Comparison between the physical parameters levels in the effluents of MP effluent and the oxidation ponds effluents	119
Figure 4.2	Comparison between inorganics levels in MP effluent and the oxidation ponds effluents	124
Figure 4.3	Comparison between nutrients levels in MP effluent and the oxidation ponds effluents	129

Figure 4.4	Comparison between organics concentrations in MP effluent and the oxidation ponds effluents.....	134
Figure 4.5	Khartoum State flooded areas.....	144

Abbreviations

API	American Petroleum Institute
ATSDR	Agency for Toxic Substances and Disease Registry
BLS	Base Line Study
BOD ₅	5-day Biochemical Oxygen Demand
CBS	Central Bureau of Statistics
CCME	Canadian Council of Ministers of the Environment
CDU	Crude Distillation Unit
CNPC	China National Petroleum Corporation
COD	Chemical Oxygen Demand
CPI	Corrugated Plate Interceptor
CPL	Central Petroleum Laboratories
DAF	Dissolved Air Flotation
DO	Dissolved Oxygen
EIA	Environmental Impact Assessment
EPA	Environmental Protection Authority, Australia.
EU Commission	European Commission
FAO	Food and Agriculture Organization of the United Nations
FEPA	Federal Environmental Protection Agency, Nigeria
HDT	Diesel Hydrotreating Unit
IAEA	International Atomic Energy Agency
IAF	Induced Air Flotation
IFC	International Finance Corporation, World Bank Group
KRC	Khartoum Refinery Company
LPG	Liquefied Petroleum Gas
MEF	Ministry of Environment & Forests, India
MEM	Ministry of Energy & Mining, Sudan

MOSC	Mobil Oily Sludge Coking
MP	Monitoring Pond
Oil & G	Oil and Grease
OME	Ontario Ministry of the Environment, Canada
P–reactive	Reactive Phosphorus
P _{ortho}	Ortho Phosphate
P _{total}	Total Phosphorus
REF	Catalytic Reforming Unit
RFCC	Residue Fluidize Catalytic Cracking
SARA	Saturates, Aromatics, Resins and Asphaltenes
SGRA	Sudan Geological Research Authority
SQGs	Sediment Quality Guidelines
TDS	Total Dissolved Solids
TOC	Total Organic Carbon
TS	Total Solids
TSS	Total Suspended Solids
UIA	Un-ionised Ammonia
UNDP	United Nations Development Programme
WB	World Bank
WHO	World Health Organization
WWTP	Wastewater Treatment Plant