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The Impacts of Oil Produced Water and Drilling Chemicals on Natural Environment - Paloch Oil Field (Block 3&7) Melut County- Upper Nile State – South Sudan.

***Othow Mayik Awet Anyong^{a*}: Mohammed Abdo Desogi^b: Yasir Yousif Abdalla^b:
Magoub Suleiman Mohammedian^b***

^a College of Forestry and Range Science, Upper Nile University– Renk- South Sudan

^b College of Forestry and Range Science, Sudan University of Science and Technology

Abstract

This study was carried at northern Upper Nile State, Melut county, Paloch Oil Field Block (3&7) during the period 2015 - 2018. The main objective of the study was to investigate the impacts of oil produced water and drilling chemicals on natural environment in Paloch Oil Field (Block 3&7) Melut county- Upper Nile State – South Sudan. For data collection the area was divided into four strata as follows: Site1: area affected by produced water. Site2: area affected by Wells mud and cutting water. Site3: area affected by mining and drilling chemicals. Site4: area not affected by any factor (control area). The samples obtained were oil produced water, drilling mud and cutting water from well site, chemical yard water and control water (river Nile water). Also a questionnaire was prepared and distributed to stakeholders, community leaders, foresters, farmers, nomads and the oil company representative; and 80 respondents were interviewed (0,2% of total population), general observations were recorded and the water samples were analyzed. The study found that, large area of natural forest were uprooted and cleared felled for making ponds of oil produced water, all trees within the pond were dried up totally, agricultural and range lands have been converted into large ponds, holes (Pits), the life of native have been threaten by polluted and contaminated water. Chemical analysis of water samples revealed that, the percentage of Potassium element is very high in well site (99.8%) that is resulted from concentration of potassium chloride in drilling mud and cutting water, the percentage of Nitrogen were found high in the soil of site affected by oil produced water (78%). Also the mismanagement of drilling mud pit, oil produced water and chemical residuals increase the rate of oil related diseases, oil produced water areas are not fenced, chemical yard is not properly managed (gate is broken and chemicals are exposed to direct sun heat and rain water) Chemical containers are used by the ignorant native for carrying drinking water and milk. The study recommended that the oil produced water should be fence, treated and reinjected into oil wells also treated water can be used for irrigation of forest plantations for rehabilitation and restoration of affected sites. Hydrocarbon and heavy metals can be remediated by using bioremediation plants such (*Phragmite Australia*, *Hibiscus cannabinus* and *Vetiveria zizanioides*) chemical yard should be protected and maintain.

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Key word:; Natural environment, oil produced water, forest plantations, drilling chemicals, oil exploration and operation

1. Introduction:

Forests are fundamental life form of the world's biodiversity and have multifunctional role in conservation and stability of natural environment through stabilized climate, regulate water cycle, provide habitat of millions of living organisms, produce oxygen, act as carbon sinks which help clean the air from other pollutants and provide excellent barriers against noise pollution, and **prevent erosion through** slowing water runoff, forest are also sources of many useful products include woods inform of timbers, rubber, resins and medicinal products which are an important part of the economy. Forest is main components of natural environment in which the petroleum is usually mined. Being petroleum an essential commodity that powers the expanding global economy in fields of manufactories, transportation the demand and reliant on it increased then threaten the natural environment as it composition is made of complex molecules, when burned produce relatively high levels of carbon dioxide, sulphur dioxide, and nitrogen oxide. (Elredaisy, 2010). Petroleum production caused local Environmental degradation which contributes to resource scarcity; changes in the land use systems and led to the loss of traditional livelihoods for the Agri-silvo-pastoralists in the area. Surface water contaminated by produced water and oil spill because most of which has been discharged untreated into the environment. (Laurance, 2010) Well drilling affects the environment by the toxic drilling muds which contain radionuclide's which comprise of Uranium, radium, and radon. (Bliss.2014). The modern petroleum industry began in 1859 in Pennsylvania, when Edwin L. Drake constructed the first oil well, a facility for extracting petroleum from natural deposits.(Thaws, 2017). Petroleum exploitation in Sudan started in the late 1954 in the Red Sea with Italian oil major Agip Mineraria Oceanic Oil and Sudanese Company, The first major find was only made in 1980 by the USA company Chevron, north of Bentiue in Western Upper Nile State (Unity State), further finds were made in 1982, 70km north of Bentiue in the Heglig district, (UNEP, 2005). In 2003 the China National Petroleum Corporation (CNPC) announced the discovery of oil field in blocks 3 and 7 east of the White Nile, oil production was on average 270,000 b/d and 304, 000 b/d in 2004 respectively. Oil-rich areas in the Melut Basin have suffered the same pattern of oil-related environmental problems that include; destruction of natural forest and wildlife habitat, soil degradation and pollution by hydrocarbons and other chemical waste. Most of these problems are caused by produced water which contains large amounts of dissolved salts, hydrocarbons, trace metals, radio-nuclides and toxic chemicals. The produced water is recycled by injecting it into the subsurface to maintain the pressure of oil reservoirs, which enhances oil recovery. (Kharaka. 2005). The Heglig oil facility alone, generates 10 million cubic meters of produced water a year. Water levels have risen as the Heglig oil field has matured, and the facility's reed bed technology is no longer able to handle the increasing quantity of produced water (UNEP, 2007). Contaminated water and chemicals residual threatens not only the vast marshland of the sampey, but also the region's inhabitants: after consuming contaminated water, livestock have died and civilians have fallen violently ill, building further resentment against the oil sector. (Patey. 2012).

Table 1. Oil production statistics in South Sudan's Melut basin (Block 3 & 7):

Daily Crude Production

<i>Block (FPF)</i>	<i>Gross (BBL/D)</i>	<i>Crude (BBL/D)</i>	<i>Water (BBL/D)</i>	<i>Gas (M³/D)</i>
<i>Adar Yale</i>	59571	12448	47123	26918
<i>Gumry</i>	43862	12652	31210	27850
<i>Moleeta</i>	80571	19106	61465	30304
<i>Paloich</i>	39660	84987	311653	283345
<i>Total</i>	580644	129193	451451	368417

Source: (Loro ,2018).

As the most of the southern Sudanese people, and their livestock, depend on the untreated water of the river Nile for their drinking needs and any leakage will affect their lives (Pelz Daniel, 2017). Machar Marches is one of the most important wetland in the world which can be affected by oil exploration. (ECOS.2006). There are several drilling and processing chemical used in oil production, most of which contaminate the land, water, and air, causing health problems for workers and people living near mining areas. (Ruland, 2017). Toxic chemicals used in mining include: cyanide used in blasting tunnels heavy metals caused a swelling in the throat (goiter), kill fish and plants along rivers and making water unsafe for drinking and bathing. Barium Sulphate used to increase the density of drilling fluids, it caused breathing difficulties, increased blood pressures.(Hesperian 2018). Hydrogen cyanide anhydrous is highly toxic if inhaled, swallowed or absorbed through skin. Runoff from fire control or dilution water may be corrosive and/or toxic and cause pollution. (ERG, 2016). The oil related heavy metals such as lead, cadmium and copper have been reported to affect cellular organelles and components.

2. Material and methods**Study area**

The study is located in the Melut and Maban Counties which lies between latitude 10o 44" N, and longitude 32o 20" E with population of 49,242 people according to 2008 census. The region is one of wide, flat and low lying plains with black cotton soils, covered by Savannah grasslands and acacia trees (Harrison and Jackson, 1958). The area is situated in the semi arid zone with two distinct seasons, rainy season (wet) starts at May to October with annual average precipitation rains between 450 to 550 mm, p.a. and dry season starts at November to April. The area varies in temperature its main annual is 26.5 0C, relative humidity percentage is lowest in April and highest in August. (Department of Meteorology, Renk County 2010). The winds prevail from different directions at different times of the year. The north-east or northerly and north westerly trade winds of moderate velocity prevail during winter, where as the south and south-east winds prevail during autumn. Clouds prevail almost 8 months in the year, started before the beginning of the rainy season.

Research objective:

The main objective of this study was to investigate the environmental impact of oil produced water and mining and drilling chemicals upon the natural environment which include natural forest, the human, domestic animals health, and the biodiversity at Block 3 & 7 Melut County.

Research Question:

The research started inform of questions such; is there any impact of petroleum mining and operation on natural environment? What are the types of these impacts? What are the roots causes of these impacts? What are the possible measures and action can be taken to mitigate these impacts? What are the roles of stakeholder, community leaders, government, and oil companies toward mitigating these impacts?

Material: Several types of research materials and methods were used and applied for data collection, data management and data analysis, four water samples were taken from four different sites and analyzed then oil produced water site were re-divided into three substratum and analyzed to detect the NPK and three heavy metals.

Method:

Several methods were used; these include the Literatures reviews as secondary data obtained from archives, internet report of the previous study then general observations were observed, recorded and extensive interviews were conducted. A questionnaire was used to collect the data and 80 respondents were interviewed, with approximately 0.2% of local population, including foresters, pastoralists, agriculturists, community leaders, and petroleum's company representatives. The multi-site and multi-species study was used and stratified random sampling plan was adopted for a destructed and contaminated sites. Four strata were chosen as follows: Site1: area affected by produced water. Site2: area affected by Wells mud and cutting water. Site3: area affected by mining and drilling chemicals. Site4: area not affected by any factor (control area). The samples obtained were oil produced water, soil and leaves. NPK and three heavy metals (Lead, Cadmium and Copper) were analazed.

Data Analysis: Description and Variable calculation:

The data were analyzed by statistical package of social sciences (SPSS) software, the analysis of data were on main impact of petroleum produced water on natural environment, forest, animals and human being. NPK in water, soil and leaves samples was analayzed to find their percentage. Also three heavy metals (lead, cadmium and copper) in these samples were analayzed in laboratory. The statistics obtained were used for finding extent of degradation and pollution, the statistic of normalization data, descriptive data, chart, graphs and simple correlation were drawn using the same statistical software. Also frequency and percentage of variable is calculated.

3: Result and discussion:

The general observations:

The followings observed during the field visit.

All tree species within produce water are dried because of rise in level of water, water salinity effect. Photo. Most of rigs drilling mud pits and cutting water pits were not fenced and left exposed to human being, domestic animals, and other living organism. See photo No:1 All these living organisms are in high risk because these mud and cutting water are contaminated with residual of drilling chemicals which can be harmful to human being, domestic, and wild animals. Most of forest, agriculture and grazing land around the

wells, and roads networks were converted to pond and holes, these ponds disrupted the natural drainage in the area. Some of them are full with water during rainy season which causes death accident to children and some animals. Field monitoring cameras are not functional therefore there are random movement of native and domestics animals inside and around the ponds of produced water and wells surface. See Pho No: 2



Photo No: 1



Photo No: 2



Photo No: 3



Photo No: 4

Drilling chemical containers such tankers and plastic liners are used by natives for drinking water, carrying milk and covering roofs of their houses see photo No: 3 and 4. The local communities are not aware about the risk resulted from the uses of chemical containers. The living standard of local community is very poor even though some of them engage in oil production activities as workers, drivers and guards they live in small hut which made up of local material such as wood and grasses without proper door. There is no fence around the houses, no pit latrine nor bathroom, in addition to, there is no permanent sources of drinking water, but they rely on water which usually brought by oil company in water tankers and there is no electricity in their houses.

Local communities are still living within and around oil wells and near ponds of produced water, they cultivate cereal crops and grazed their domestic animals inside the oil field. The infrastructures are still very poor, no permanent roads net work, no concrete schools and hospital except one in New Paloch. Oil related diseases such as skin itches, respiratory systems, lungs infection, and infections in nervous system where reported by the native.

Interviews:

All native representative interviewed stated that oil production and mining caused negative effect to the area especially drilling chemicals which were brought in huge quantity to Paloch from Juba, mismanagement of drilling chemical caused damages to land use systems especially agriculture, grazing and forest land. In addition to that, there are many diseases appeared in area such as deformedness of many children, eye and respiratory infections, lungs and skin itches, frequent miscarried of pregnant women, swelling of human legs and increased in mortality rates of domestic animals. In addition to that all the trees species within the oil produced water were dried because of chemical and salinity of this water.

There are social problems which related to oil production, these include the influx of people from outside the area with different social and culture activities such as engagement of female in different business which include opening restaurants for selling tea, coffee and food increased the rate of sexual related diseases such as HIV inturn increased the mortality rate especially among the youth.

The results of questionnaires were showed in form of questions followed by answers as follows:

How were conditions of natural forest before petroleum mining and operation?

Fig. 1 show the condition of natural forest before mining and operation, 90% of respondents reported that, the

natural forests was vigorous in the area and extremely covered with *Acacia seyal* stand associated with *Balanites aegyptiaca*, *Acacia senegal* and *Acacia millifera*, but 8.75% of them said that, the natural forests were moderate and 1.25% said don't know.

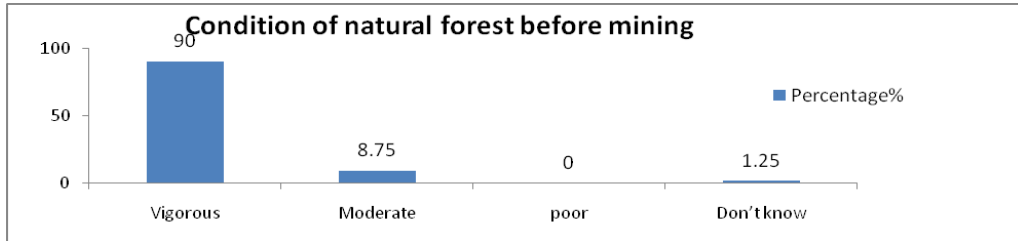


Fig. 1: Conditions of natural forest before petroleum mining and operation:

The main causes of drying up trees in the affected site:

Fig2 explained that 83.75% of the respondents answered that, drying up of trees is caused by produce water, especially in the evaporation pond in which area of 2 x 2km² near Paloch FPF is full with produce water and all trees within this area are dried. 7.5% of them said overcutting while 6.25% said fire and 2.5 % of the respondents said the reason is overgrazing.

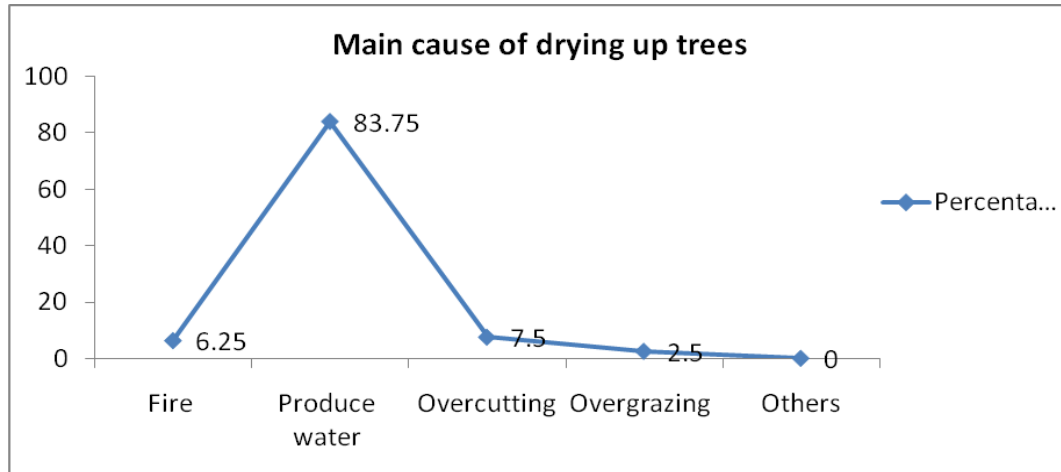


Fig. 2: The main causes of drying up trees in the affected site:

(Note FPF) = Field Processing Facility

The most destructed land use system of economic importance:

Concerning this in fig3, 63.75% of respondent answered that the most destructed land used by petroleum production is cultivated land while 11.25% of them said wildlife and 7.5% said is natural forest, while 6.25% of them said it is the grazing land.

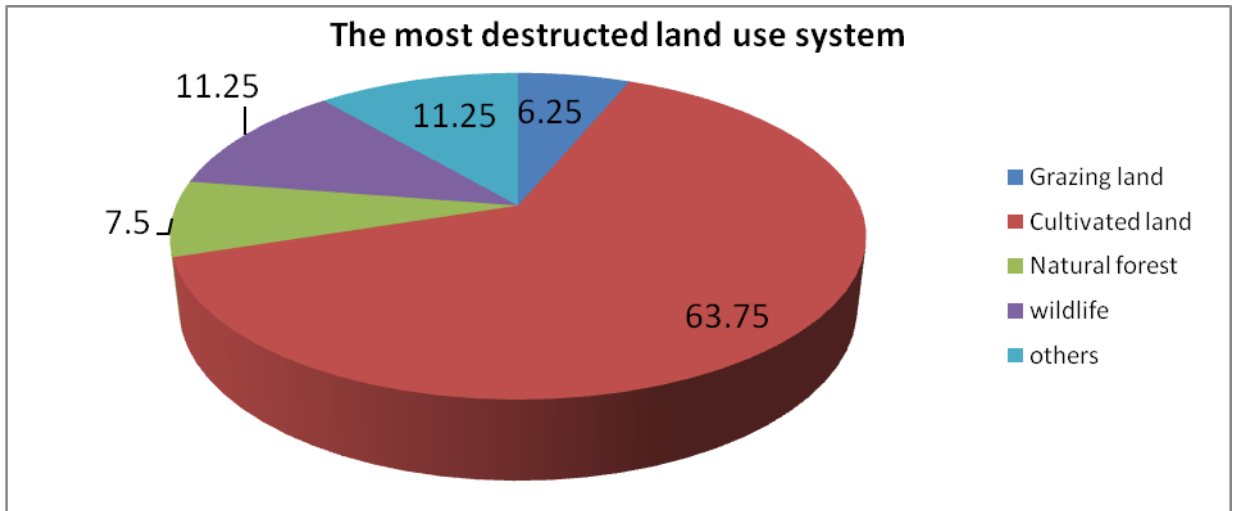


Fig:3 The most destroyed land use system of economic importance.

The type of dominant pollution in the area:

Concerning this in fig:4, 68.75% of respondents answered that the air pollution is the dominant type while 18.75% of them said that the soil pollution is the dominant type 8.75% of respondents said that the water pollution is the dominant type and 1.25% of respondents said that the noise and other pollution is the dominant types of pollution.

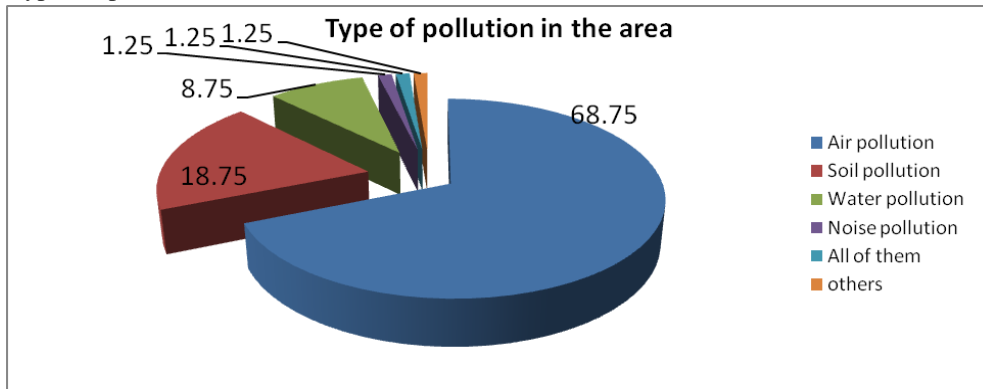


Fig 4: Type of dominant pollution in the area

The effect of produce water on the local population:

Concerning the effect of produce water on the local population within the oilfield in table 2 explained that, 67.5% of respondent answered that, it caused lungs infection to many people in the area (S2 gas), while 20% of them said it caused leg swelling and 12.5% of them said it caused pain and stomach swelling among the native people.

Table No:2 The effect of produce water on the local population:

S/n	The effect of produce water	Frequency	percentages%
1	Lungs infection	54	67.5
2	Leg swelling	16	20
3	Pain and stomach swelling	10	12.5
4	Others	0	0
Total		80	100

The Environmental Impact Assessment conducted before mining activity.

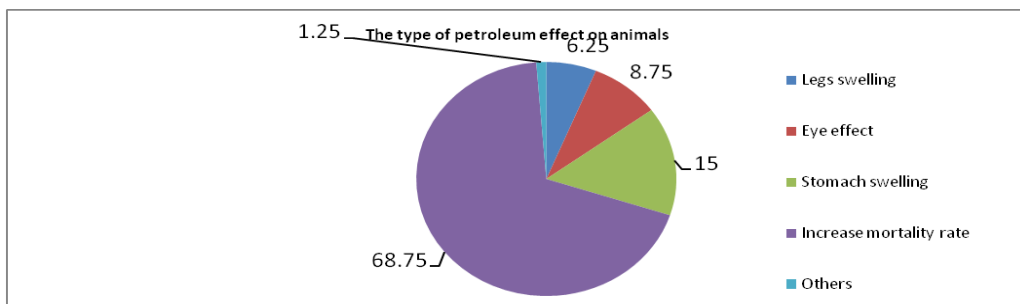
Concerning the environmental impact assessment conducted before mining activity in oilfield areas in table No:3, 81.25% of respondents answer that there is no environmental impact assessment conducted before mining activity while 18.75% of respondents said that there is environmental impact assessment conducted before mining activity in the area.

Table3: Environmental impact assessment conducted before mining activity.

S/No	E. I. A conducted	Frequency	Percentage%
1	No	65	81.25
2	Yes	15	18.75
Total		80	100

The types of effect on the animals:

Concerning this in fig:5, 68.75% answer that there is increase in mortality rate of the animals and 15% of respondents said that the effect is stomach swelling and 8.75% said that effect is eye effect while 6.25% answer that the effect is leg swelling.

**Fig. 5:.. The types of effect on the animals:**

Laboratory analysis of NPK and heavy metals:

Content of NPK elements in water collected from three producing water sites:

Paloch oil field produced 451451bbl/d of oil produced water daily, the percentage is 3.5 bbl per 1 bbl of crude oil, this bulk of water stored in three large ponds (skimming, bioremediation and evaporation ponds) in four sites.

To evaluate the content of NPK and heavy metals elements in oil produce water, the samples of water were collected from four sites and three ponds of produced water after analyses the differences in NPK were found significant in four sites and three ponds. Potassium (K) element was found high in well site (99%) and Evaporation pond while Phosphorus (P) is high in bioremediation ponds. Three heavy metals were analyzed (Pb, Cd and Cu). Lead Pb was not found in all sites, Cadmium (Cd) was found high in oil produced water sites than control and it is less in chemical yard sites and not detected in well sites. Copper is not detected in well sites and the differences were not significant in other three sites. See table 4 and figure No:6

Fig: 6 Content of three heavy metals NPK in water collected from four sites:

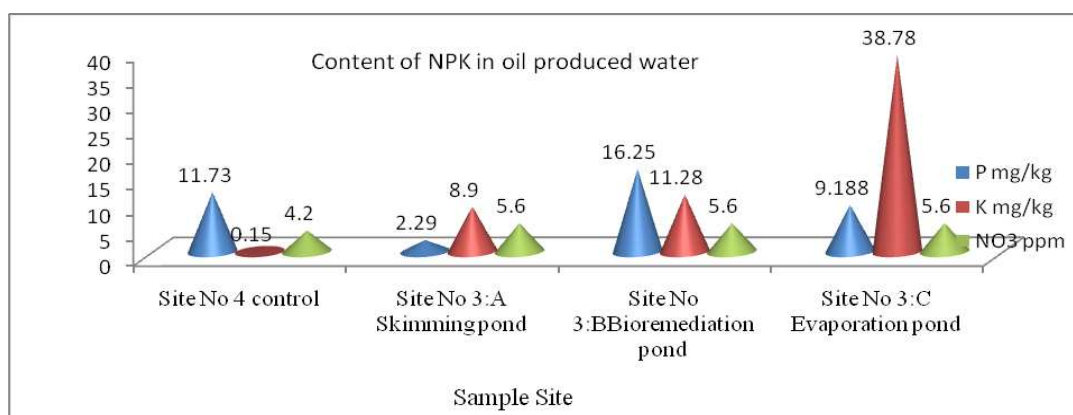


Fig: 6 Content of three heavy metals NPK in water collected from four sites:

Table No. 4: Content of three heavy metals (Pb, Cd, Cu elements) in water collected from four sites:

No	Sample site	Pb mg/L	Cd mg/L	Cu ppb(μg/L)
1	Site No 4 control	ND	8.800	32.200
2	Site No 1 chemical yard	ND	3.100	20.300
3	Site No 2 Wells site	ND	ND	ND
4.	Site No 3 oil produced water	ND	12.07	31.07
	Site No 3:A oil produced water Skimming pond	ND	7.900	28.800
	Site No 3:B oil produced water Bioremediation pond	ND	17.400	28.800
	Site No 3:C oil produced water Evaporation pond	ND	10.900	35.600

ND: Not detected

Daily gross production (BBL/D) (crude, water and gas)

Paloch oil field produced 580644 bbl daily as gross which include crude oil, produced water and gas, these components are separated from each other before it sent refinery. The quantity of produced water was found high than crude and gas. These water not fenced and treated but left exposed to human and animals live within the oil field.

Table No:5 Daily gross production (BBL/D) (crude, water and gas)

<i>Block (FPF)</i>	<i>Gross (BBL/D)</i>	<i>Crude (BBL/D)</i>	<i>Water (BBL/D)</i>	<i>Gas (M³/D)</i>	<i>Water / Crude (BBL/D)</i>
<i>Adar Yale</i>	59571	12448	47123	26918	3.8
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<i>Paloich</i>	39660	84987	311653	283345	3.7
<i>Total</i>	580644	129193	451451	368417	

Source: (Loro,2018) Note: BBL/D = Barrel By Liter/ Day

Daily oil produced water bbl/d:

Daily produced water is increased with increased life span and the gross production of oilfield (old field produced much water than new one) fig7: explained that Paloch oil field which is the old one produced much water than Moleeta, Gumry and Adar Yale. These bulk of water will cover lage area in forest land if it is not treated and reinjected into oil well or used in irrigation of plantations in affected sites.

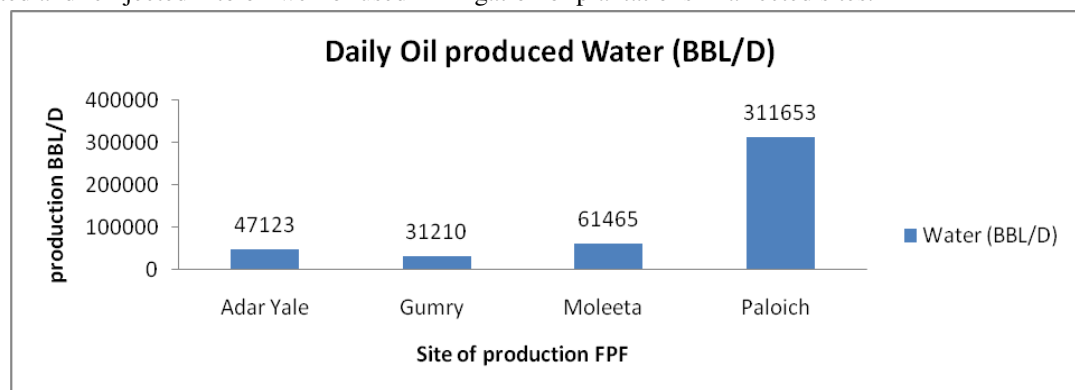


Fig. 7 Daily oil produced water bbl/d: Source: DPOC, paloch 2018

Content of NPK elements in plants foliar (leaves) collected from four sites:

NPK are the elements that required by crops in the largest amounts (10 – 100kg or more per hectare) and are considered as the most important nutrients.

Generally the main function of N and P are that, they constituents of proteins and nucleic acids which are

important components of plants tissues. While K is mainly have importance in the regulation of process in plants such as osmosis and enzymes activities. During the leaves analysis their percentage were found different from site to another site as follows; Nitrogen percentage in form of nitrates was found high (35.4%) in leaves of five tree spieces collected within the site affected by chemical yard and the percentage of phosphorus element was found highb(32%) in leaves of site affected by oil produced water while the percentage of potassium element was found high (33.4%) in site affected by chemical yard that is in compersion with control the site which is no affected by any factor (24.6%, 21.2% and 27%) respectively see table No: 6

Table No: 6 Content of NPK elements in plants leaves collected from four sites:

<i>No</i>	<i>Sample site</i>	<i>N%</i>	<i>%</i>	<i>P mg/kg</i>	<i>%</i>	<i>K mg/kg</i>	<i>%</i>
<i>1</i>	<i>Site No 4 control</i>	<i>0.146</i>	<i>24.6</i>	<i>256.0</i>	<i>21.2</i>	<i>339.7</i>	<i>27</i>
<i>2</i>	<i>Site No 1 chemical yard</i>	<i>0.21</i>	<i>35.4</i>	<i>336.0</i>	<i>27.8</i>	<i>419.9</i>	<i>33.4</i>
<i>3</i>	<i>Site No 2 Wells site</i>	<i>0.112</i>	<i>18.9</i>	<i>220.0</i>	<i>18.2</i>	<i>184.6</i>	<i>14.7</i>
<i>4</i>	<i>Site No 3 oil produced water</i>	<i>0.126</i>	<i>21.2</i>	<i>397.3</i>	<i>32.9</i>	<i>313</i>	<i>24.9</i>
	<i>Total</i>	<i>0.594</i>	<i>100</i>	<i>1209.30</i>	<i>100</i>	<i>1257.2</i>	<i>100</i>

Content of NPK elements in soil collected from four sites:

For the optimal growth of plants, sufficient amount of NPK nutrients should be available in the root zones of plants but due to differences in climatic conditions and some external factors such as the human activities like oil production may alter the available nutrients in the soil therefore soil sample were taken from four different sites in the study area to evaluate the possible changes in availability of NPK in soil of different sites affecting by petroleum mining and operation because too low availabilities will lead to hampered growth and low yield (yellowing of leaves and brown spots on them) while high availabilities of more nutrients lead to disturbed plants growth and adverse effects for yield and quality of products. The soil analaysis reveal that, the percentage of Nitogen informof nitrate was found high (78%) in soil of site affected by oil produced water than cotrrol which is (1.9%), the difference in percentage of phosphorus was not significant and the percentage of potassium was found high in two site well and oil produced water site (45% each) than control which is 7.6% see table No: 7.

Table No: 7 Content of NPK elements in soil collected from four sites:

<i>6</i>	<i>Sample site</i>	<i>N%</i>	<i>%</i>	<i>P mg/kg</i>	<i>%</i>	<i>K mg/kg</i>	<i>%</i>
<i>1</i>	<i>Site No 4 control</i>	<i>0.0139</i>	<i>1.9</i>	<i>2268</i>	<i>29.6</i>	<i>58</i>	<i>7.6</i>
<i>2</i>	<i>Site No 1 chemical yard</i>	<i>0.07</i>	<i>9.8</i>	<i>1910</i>	<i>24.9</i>	<i>18</i>	<i>2.3</i>
<i>3</i>	<i>Site No 2 Wells site</i>	<i>0.07</i>	<i>9.8</i>	<i>2026.6</i>	<i>26.4</i>	<i>346</i>	<i>45</i>

4	<i>Site No 3 oil produced water</i>	<i>0.56</i>	<i>78</i>	<i>1468</i>	<i>19.1</i>	<i>346</i>	<i>45</i>
	<i>Total</i>	<i>0.7139</i>	<i>100</i>	<i>7672.6</i>	<i>100</i>	<i>768</i>	<i>100</i>

4. Conclusions:

The mass destruction of petroleum exploitation and production to environment is expected to worsen rapidly and the hazard caused by environmental impact not restricted within the affected site like paloch but it cross and goes beyond the geographical borders between the states and countries. The oil produced water which discharge randomly and not manage, fenced and controls will affect all inhabitants relying on River Nile as sources of water, because the residual of untreated mining and drilling chemical in addition to remains of crude oil after spillage will mix with surface running off during raining season. The lack of awareness and ignorance of the native people will worsen the situation because some of them misused the chemical containers, destroyed the fence set to protect the chemical yard, well and oil produced water sites, this act increased the risk to all living organism inhabitants within and around the oilfield especially the younger's children, domestic and wild animals. To overcome all these impacts oil produced water should be treated and reinjection in wells, the affected sites should be rehabilitated and planted with tolerance species by using treated oil produced water in irrigation, incorporating community based program in oil production that include compensation and reallocation in safe site, close the remain natural forest as a reserved forest, lastly conducting Environmental Impact Assessment (EIA), more researches of hazards on environment should be done and the results should be integrated in oil production program .

5. References:

- Bliss Matthew, (2014) Oil production in South Sudan : making it a benefit for all, Cordaid:
 ECOS. (2006) Oil development, A preliminary investigation by the European Coalition on Oil in Sudan.
 Hesperian (2018). Health Guide, illnesses from dust, A Community Guide to Environmental Health pages 476 to 480.
 kharakas. (2005). The American Association of Petroleum Geologists /Division of Environmental Geosciences.
 Laurance William F. (2010), Habitat destruction: death by a thousand cuts Oxford University Press.
 Loro Emmanuel L. (2018), International Journal of Scientific and Research Publications, Volume 8, Issue 10, October (2018), 206 ISSN 2250-3153
 Matthew Bliss. (2014) Oil production in South Sudan, making it a benefit for all. Baseline assessment of the impact of oil production on communities in Upper Nile State.
 Patey Luke A.. (2012) Lurking beneath the surface: Oil, environmental degradation, and armed conflict in Sudan, Danish Institute for International Studies. Online publication date: June 2012.
 Pelz Daniel, (2017) NGO blames water pollution in S. Sudan on oil company
 Ruland Greg (2017) The Harmful Effects of Petrochemicals on the Environment,
 Sudan population and housing Census (2008)', in Statistical Yearbook for Southern Sudan 2010, Southern Sudan Centre for Census, statistics and Evaluation, p 12
 Thawes Trevor Hawes. (2017) Modern oil industry born in 1859 at Pennsylvania well thawes@mrt.com, Midland Reporter-Telegram
 UNEP (2007): Environmental Issues. Post conflict Environmental Assessment. Internet,