

# Impacts of crude oil exploration and production on environment and its implications on human health: South Sudan Review

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## Abstract

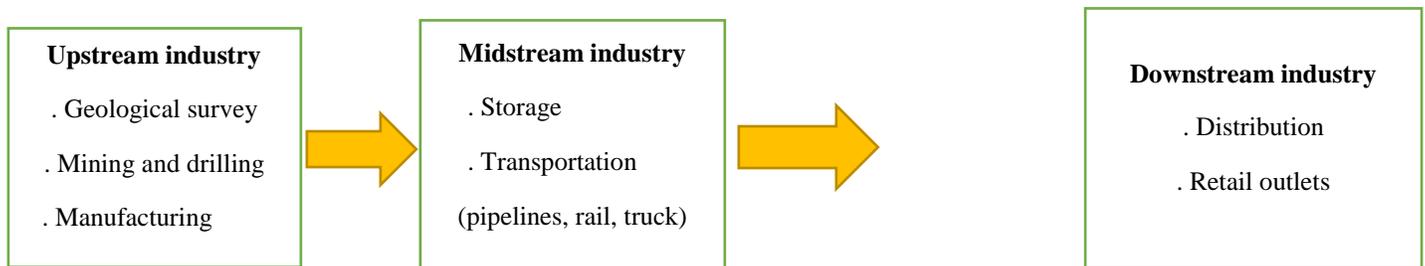
Crude oil contamination of the environment associated with exploration and production operations, is a common feature in oil producing nations around the world, especially in a developing country including South Sudan. Apart from this, the country has been suffered from civil war for long period of time which severely affected the oil production areas and oil facilities such as pipelines ware out hence causing oil linkages and spill, therefore it has resulted to significant contamination of the total environment (air,soil,water,biota) and negatively impacted human health. The contamination occurs during all crude oil production and exploration processes and negatively affect the environment which in turn reflect risks to human health through food chain such as apparition of heavy metals ;Lead, and Barium in hair of some of the South Sudanese people.This review examines some the environmental effects related to crude oil exploration and production in South Sudan and its implications to human health.It has further highlighted some recommendations that may help sustainable practices for the exploration and production of this resource which may yield in less negative impact for both environment and human health.

**Key words: Crude oil, Exploration, Environment, human health , implications**

## 1. Introduction

Oil is the lifeline of the South Sudan economy now and over the medium term.[1].According to the World Bank (2008) South Sudan is one of the newest significant oil producing countries in the World, and the third largest oil producer in Sub-Saharan Africa after Nigeria and Angola. As a result of oil exploitation, the structure of the Sudanese economy has shifted from being being predominantly reliant on agriculture to oil. It accounted for about half of the country's GDP, and most of the country's exports (about 97 %) and government's revenue (about 98 %) in the period 2008-2011[2]. Oil production of360 thousand barrels per day in 2011 resulted in high export earnings, high government revenues and an income per capita level of a lower middle-income country. Natural resources especially hydrocarbons have become one of the most important resources of energy for mankind. However, the process of extraction of these natural resources is very complicated and most of the time the pollutant's products that accompany the process of oil exploration play a vital role to declare an inconsistency in the ecosystem[3]. This means an increase in the probability of environmental risk and as a result a widespread of hazardous material in the aquatic environment. An aquatic environment can be considered as one of the environments that are subjected more to the contamination by crude oil. This seems to be a big issue due to the spillage of some crude oil into the water. This spillage is due to the leakage which accompanies the process of oil exploration and transportation [4]. As a result, the aquatic environment becomes contaminated region. This situation is a big threat for the evolution of macrophyte, and for the life support balance of living organisms in that environment. Air pollution also bear a great concern with crude oil exploration and production and both mentioned reflect serious human health effects with high rate. Therefore, with world's

increasing dependency on the production of crude oil products, crude oil water contamination problem becomes the major factor that can alter the natural consistency of the outstanding life source in a particular environment [5]. Therefore, in order to decrease or remedied these effects, oil companies must adopt proper measure that are helpful to minimize the contamination rate to the normal wedge. This paper reviewed the impacts caused by crude oil exploration and production on environment (water, soil, aquatic plants and animals and its implications to human health. Oil is currently the backbone of South Sudan’s economy. Available data indicate that oil alone accounts for 98 per cent of the government budget and in the recent past, contributed between 60 and 80 per cent to GDP[6] [6]. In 2011, the petroleum sector accounted for 61.3 per cent of GDP, but that proportion declined to 7.4 per cent in 2012 and 14.7 per cent in 2013. The massive decrease in the share of petroleum in GDP in 2012 was due to the shutdown of oil production, which led to a decline in production in that year and a decline of about 47 per cent in GDP [6]. In June 2014, oil prices dipped from \$112 to \$30 per barrel. South Sudan currently produces 130,000 barrels of crude oil per day, down from 350,000 per day before the war [7] In the foreseeable future, oil will remain a strong driver of investments in the economy. However, it is not a renewable resource and already declining crude oil reserves point to an urgent need for government investment in other revenue earning sectors [8]. Crude oil exploration in South Sudan is carried out mainly in the central flood- plains of Jonglei, Lakes and Upper Nile, which are also endowed with rich terrestrial and aquatic natural resources. The oil blocks include part of Block 4, most of Block 5A, Block 5B.). The petroleum industry is traditionally divided into three sectors: upstream, midstream and downstream. In South Sudan, the upstream segment includes exploration activities, field development, and oil and gas production activities. The downstream sector, which became operational in 2012, comprises activities that refine the crude oil, and the marketing, sale and distribution of any ensuing products. The midstream sector links the upstream and downstream segments, and includes activities and facilities that enable processing, storage and transportation of products, such as pipelines and other facilities.



The Ministry of Petroleum oversees this sector in South Sudan. The state oil company is the Nile Petroleum Corporation (Nile pet), established in 2003 and incorporated in June 2009 under the New (South)Sudan Companies Act 2003 by the Ministry of Legal Affairs and Constitutional Development. It has joint ventures with the Nile Delta Petroleum Company Limited (Nile Delta), Diets Mann Nile, East pet Ltd and SIPET[9] . Crude petroleum is produced by joint ventures of state-owned companies from China, India, Malaysia and South Sudan. The government, through Nile pet, holds no less than an 8 per cent share in any of these petroleum joint ventures, [10].

Table 1. STRUCTURE OF THE OIL INDUSTRY IN SOUTH SUDAN, 2013

Commodity	Major operating companies and major equity owners	Location of main facility	Annual capacity [bpd]

Petroleum crude	PETRODAR Operating Company (PDOC) China National Petroleum Corp (CNPC) 41% Petronas Carigali Overseas Shd.Bhd., 40%: Nile Petroleum Corp (Nile pet), 8%: Nile Petroleum Corp., 6%: Tri-Ocean Energy,5%	Blocks and 7 in Upper Nile	91500 First oil production was in 2001 and the average current production is 163 bpd
Petroleum crude	Greater Nile Petroleum Operating Co China National Petroleum Corp (CNPC) 41% Petronas Carigali Overseas Shd.Bhd., 30% ONGC Vides LTD 25 %: Nile Petroleum Corp (Nile pet),5%	Blocks,1,2, and 4 in Unit	32 200
Petroleum crude	White Nile Operating Company Co Petronas Carigali White Nile Petroleum Petronas Co. Petronas Carigali	Block 5A in Unit	4,400

Source:(Yager,2015)

Since April 2016, the petroleum sector regulator is the Ministry of Petroleum. The Ministry is guided by the Petroleum Act 2012 and the Mining Act 2012, as well as the Mineral Title Regulations 2015 and other bills that are currently being drafted to implement its mandate [11]. e. The Ministry is assisted in its duties by three institutions: The National Petroleum and Gas Commission, the National Petroleum and Gas Corporation, and the Petroleum Exploration and Production Authority. The National Petroleum and Gas Commission is the policy-making body for the petroleum sector. It is also in charge of petroleum resources management and coordinates all petroleum stakeholders at national and state levels, from the private sector and including non-governmental organizations. The National Petroleum and Gas Corporation is a commercial company limited by shares established by the government. It is to be the chief policy making and supervisory body in the upstream, midstream and own stream segments of the sector. The National Petroleum and Gas Corporation handles petroleum agreements for the government while the Ministry of Petroleum is responsible for the management of the petroleum sector. The Petroleum Exploration and Production Authority is to oversee day-to-day activities concerning petroleum operations and advise the Ministry.[12]

## 2.Impacts of Crude Oil and Natural Gas Production on the Environment

Environmental impacts that occur during production of crude oil and natural gas would mostly occur from long-term habitat change within the oil and gas field, production activities (including facility component maintenance or replacement), waste management (e.g produced water), noise (e.g from well operations, compressor or pump stations, flare stack, vehicle and equipment), the presence of workers and potential spills [13]. These activities could potentially impact on the resources as explained below:

### 2.1. Noise

The main sources of noise during the production of crude oil and natural gas would include compressor and pumping stations, producing wells (including occasional flaring), and vehicle traffic. Compressor stations produce noise levels between 64 and 86 dBA at the station to between 58 and 75 dBA at about 1 mile (1.6 kilometers) from the station [14]. The primary impacts from noise would be localized disturbance to wildlife, recreationists, and residents. Noise associated with cavitation is a major concern for landowners, livestock, and wildlife [15]

## **2.2. Soil**

Plants germinate, develop and grow in soil medium where water, air and nutrient resources supply plants for healthy growth for productive and profitable agriculture. Frequent crude-oil spillage on agricultural soils, and the consequent fouling effect on all forms of life, render the soil (especially the biologically active surface layer) toxic and unproductive. The oil reduces the soil's fertility such that most of the essential nutrients are no longer available for plant and crop utilization [16]. The enormity of toxicity by oil spillage on crop performance is exemplified in mangrove vegetation, which has been dying off in recent times [17]. Spilled crude-oil which is denser than water, reduces and restricts permeability: organic hydrocarbons which fill the soil pores expel water and air, thus depriving the plant roots the much-needed water and air [18]. Soil properties involved in soil-plant-water relationship are degradable and include texture, infiltration, hydraulic conductivity, moisture content and density, which affect root and leaf development and plant growth and yield [19, 20]. Overall, oil spillage affected crop yield and farm income, and by extension, the social and economic livelihoods of farming communities [20].

## **2.3. Air Quality**

The primary emission sources during the production of crude oil and natural gas would include compressor and pumping station operations, vehicle traffic, production well operations, separation of oil and gas phases, and on-site storage of crude oil. Emissions would include volatile organic compound (VOCs), nitrogen oxides, sulfur dioxide, carbon monoxide, benzene, toluene, ethylbenzene, xylenes, polycyclic aromatic hydrocarbons (PAHs), hydrogen sulfide, particulates, ozone, and methane [21]. Venting or flaring of natural gas (methane) may occur during oil production, well testing, oil and gas processing, cavitation, well leaks, and pipeline maintenance operations. Methane is a major greenhouse gas. Air pollution during oil and gas production may cause health effects and reduce visibility.

## **2.4. Wildlife ecosystem**

The adverse impacts to ecological resources during production of crude oil and natural gas could occur from: disturbance of wildlife from noise and human activity; exposure of biota to contaminants; and mortality of biota from colliding with above ground facilities or vehicles. The presence of production wells, ancillary facilities and access road reduces the habitat quality, disturbs the biota and thus affects ecological resources [22]. The presence of an oil or gas field could also interfere with migratory and other behaviors of some wildlife. Discharge of produced water inappropriately onto soil or into surface water bodies can result in salinity levels too high to sustain plant growth. Wildlife is always prone to contact with petroleum-based products and other contaminants in reserve pits and water management facilities [23]. They can become entrapped in the oil and drown, ingest toxic quantities of oil by preening (birds) or licking their fur (mammals); or succumb to cold stress if the oil damages the insulation provided by feathers or fur. In locations where naturally occurring radioactive material (NORM)-bearing produced water and solid wastes are generated, mismanagement of these wastes can result in radiological contamination of soils or surface water bodies [24]

## **2.5. Plants**

Seed germinations seem to be affected by oil at least in two ways. At high level of crude oil pollution, seed germination is prevented probably by oil soaking through the outer integument of the seeds. At low level of crude oil pollution, seed germination is retarded by the presence of oil [25]. The effect of crude oil on plant is one that is of great concern as it causes damage to different parts of the plant that are vital for its well-being and survival and hence obstructs development and growth.[26] showed that the leaves of plants affected by oil tended to dehydrate and show a general sign of chlorosis, indicating water deficiency. The reduction of leaf area may be due to dehydration. [27]The study agreed with the work of who found that reduction in photosynthetic rate resulted in the decreased rate of growth, which led to the reduction of leaf sizes.[28]observed that the volatile fraction of oil had a high wetting capacity and penetrating power and when in contact with seed, the oil would enter the seed coat and kill the embryo readily, which will in turn, cause reduction in percent germination.[25] found that the significant reduction in final germination percentage of all the species may be due to toxic effects of the crude oil on the seed and poor aeration of the soil. From various experiments, it has been elucidated that crude oil spillage would affect plants in the following ways: Inhibit the germination of plants [29]. Delay germination by inducing stress, which prolongs lag phase[30] [Inhibit the uptake of water and nutrients by the root of the plant, hence causing deficiency to other parts as the leaves.[31] Affects regeneration of stumps [32].Affects anatomical features of leaves[33].Causes cellular and stomatal abnormalities.[34]. Disruption of the plant water balance, which indirectly influences plant metabolism[35].Causes root stress, which reduces leaf growth via stomata conductance[36]. Causes chlorosis 'of leaves [37]. Enlargement of cells in various 'tissues due to oxygen starvation were cells coalesce forming large cells in tissues[38]

## 2.6. Impact on water quality

When oil is explored in water scarce areas the water resources become stressed. Off-shore oil exploration creates risks for the marine life while oil distribution and transportation will generate increasing risk for the ecology in case of leakages or accidents[39]. Accidents, leakages and spills are realities in oil drilling, shale gas exploration, pipeline transportation as well as in oil tanker transportation [40].A serious threat posed by oil-related pollution is the impact on both surface and underground waters. When oil spills occur or when there is an effluent discharge, it seeps into the ground and becomes mixed in the underground water system[41].It has been found that polluted underground water takes many years before it can be remedied. Yet this underground water moves into streams and wells which are the only sources of local water supply in the community which results in the rise of water-borne diseases. This has affected the traditional relationship of the people with water in the oil-bearing enclaves. There is a perceptible fear that rather than being the source of life, these water systems have become sources of misery, disease and death. Oil is always pumped together with water and they must be separated. There are big volumes of produced water stagnant in ponds with apparently inadequate treatment such as skimming which is less effective[42]. On another hand disposed drilled water may contain much quantity of salts and this become serious threat to the environment and aquatic ecosystem when salts concentration exceeds threshold levels. Petroleum pollutants in the African tropical region, consist of complex mixtures of both the aliphatic and aromatic hydrocarbons [43, 44]. The major pollutants in drinking water supplies fall into three general classes: petroleum hydrocarbons, halogenated hydrocarbons, and taste-and-odour compounds (which comprise of algae and bacteria). Petroleum hydrocarbons consist of the most ubiquitous pollutants and apart from polycyclic aromatic hydrocarbons (PAHs) [45] the most prevalent are the volatile organic compounds (VOCs): benzene, toluene, ethylbenzene, and xylenes (BTEX) [46, 47]. It is known that BTEX are often found in water supplies, but certainly not exclusively in groundwaters because of the widespread use of petroleum hydrocarbons and their relatively high-water solubility (130 – 1780 mg l<sup>-1</sup> at 20°C)[46]. According to Ite and Semple [48], polycyclic aromatic hydrocarbons (PAHs) containing from two to five fused aromatic rings are of serious concern because of their persistence in nature due to their lipophilic

character and electrochemical stability. It is known that PAHs are relatively recalcitrant in soils and some PAHs have been identified as carcinogens, mutagens, or teratogens.

The discharge of produced water causes serious environmental risks to both human and the natural environment and the use of technologies such as high efficient halophile oil-degrading microorganisms in biological treatment should be combine with membranes (SBR) biological treatment systems for effective management of produced water since the Dar blend (South Sudan) crude oil is acidic in nature and contain heavy metals[49], The pipelines are causing major problems from leaking leading to massive oil spills along the transportation line to the sea terminal at port Sudan requires proper maintenance and monitoring. Today, most oil producers re-inject produced water or reuse it for onshore wells (98%). However,91% of produced water from offshore wells is discharged into the ocean.[48]

## **2.7. Public health impact resulting from crude oil exploration and production**

The literature indicates that pollutants from the oil extractive industry are likely to have led to emerging health problems, including rising rates of female infertility, increases in the number of miscarriages, birth defects, and eye infections and even blindness and skin problems. Some interviewees mentioned in addition fatigue and stomach pains and an increased incidence of appendicitis [50, 51]. Noxious smells and smoke are also an issue, causing discomfort and distress to people living in or close to production oil fields [50]. Research shows that health workers in Melut and Koch indicate a positive correlation between these health issues and increased pollution from the oil industry [50]. A study in 2014 showed that 88.5 percent of the women in the oil producing areas had delivered babies with birth defects. Studies in the U.S. State of Colorado indicate a correlation with proximity to oil and gas fields; and the occurrence of congenital heart defects and neural tube defects in infants [52].The Mala oilfield shows signs of pipe leakage [53]. Oil spills from leaking pipelines, refineries or corroded or aging equipment and damage from fighting is common and has increased exposure to cancerous petrochemicals in the oil producing areas [54]. Emissions from gas flaring are also a significant environmental issue. During the mining process, gas that is produced along with the oil is flared or re-injected[55] . Although there is a law regulating against this, the emissions from gas flaring are the products of incomplete combustion. In oil field conditions, many particulates and other harmful gases are dispersed into the air. Some of these hazardous hydrocarbons include benzene, styrene, ethynyl benzene, ethynyl-methyl benzenes, toluene, xylenes, acenaphthylene, biphenyl and fluorine. Oil spill around Tharjat oil field, Unity, some of these are well known carcinogens, while others are thought to contribute to complications in foetuses[56] .The high lead and Barium concentrations in hair of the volunteers from Koch, Leer and Nyal indicate a serious exposure by this toxic metal detection of high lead concentrations in local well water samples, suggests that the contaminated water plays an essential role as a source of the lead hair results.

Apart from acidic precipitation and its negative impact, acid rain precursor gases (NO<sub>2</sub> and SO<sub>2</sub>) are part of six (6) common outdoor pollutants [57]. Inhalation of fine particulates that are fallouts from acid precursor gases have been linked to illness and premature death from heart and lung disorders such as asthma and bronchitis [58]. Nitrogen dioxide (NO<sub>2</sub>) poses a health threat itself as well as playing a major role in the formation of the photochemical pollutant ozone. Previous studies have shown that animals exposed to NO<sub>2</sub> have diminished resistance to both bacterial and viral infection [59] while children exposed to high indoor levels of NO<sub>2</sub> may become more susceptible to critical infections of the lower respiratory tract, bronchial tubes and lungs, and may develop bronchitis and chest cough with phlegm [60]. Sulphur dioxide (SO<sub>2</sub>) is a temporary irritant, though research have shown that increased levels of SO<sub>2</sub> in conjunction with particulate matter may trigger small, but measurable, temporary deficits in lung function[60] problems such as skin cancers and lesions may be linked to acid rain. Stomach ulcers could also occur, as consumption of acidic water can alter

the pH of the stomach and leach the mucous membrane of the intestinal walls, this is more so as south Sudanese depends heavily on rain water for drinking, cooking, laundry and other domestic uses.

**Table 2: Health effects of pollutants from oil and gas industry [61]**

Pollutant	Short- and Long-term health effects
benzene	May cause irritation of the skin, eyes and upper respiratory tract, and blisters on the skin. Longer term exposure may cause blood disorders, reproductive and developmental disorders and cancer.
Toluene	May cause nervous system effects, irritation of the skin, eyes, and respiratory tract, dizziness, headaches, difficulty with sleep, birth defects.
Ethylbenzene	Short-term exposure may cause throat and eye irritation, chest constriction, and dizziness. Long-term exposure may cause blood disorders.
Xylenes	Short-term exposure to high levels of mixed xylenes may cause irritation of the nose and throat, nausea, vomiting, gastric irritation, mild transient eye irritation, neurological effects. Long-term exposure to high levels of xylene may impact the nervous system.
n-Hexane	Short-term exposure to hexane can cause dizziness, giddiness, slight nausea, and a headache. Long-term exposure to hexane can cause numbness in extremities, muscular weakness, blurred vision, headaches, and fatigue.

### 3. Conclusion

The crude oil exploration and production result in more severe risks to both human and the natural environment. The Environment Bill 2014 Mining companies in some countries are required to follow environmental and rehabilitation codes, ensuring the area mined is returned to close to its original state. One of the guiding principles of the National Environment Bill 2014 is that the polluters shall be responsible for paying for the pollution that they cause, according to article 20 on the management of mineral resources[62]. Polluters will also pay a pollution tax to the Environment Fund (article 52), that will be used to finance environmental programmes at the local, state and national levels. The Environment Protection and Management Bill 2012 has provisions for Environmental Impact Assessments and Environmental Audits for projects in mining, all aimed at reducing environmental degradation and ensuring pollution control. The National Environment Policy 2012 also aims to control pollution and ensure protection of the environment and water bodies that may arise from mining activities [11]. For instance, it requires that riverbanks be protected from mining activities through the construction of embankments and to avoid sand harvesting too close to the banks and in vegetated areas. It also requires the restoration of landscapes after the conclusion of the various mineral extraction activities. Although South Sudan is endowed with abundant mineral resources and the potential for secondary and tertiary industries, the only modern industrial sector is the oil industry. The limitations to industrial development include the lack of geological exploration.

### 4. Recommendations

To remedy the oil pollution problem in South Sudan, a number of measures, both short terms and long terms, ought to be expeditiously undertaken before the situation spirals out of control. As short-term measures,

(1) The oil companies in conjunction with the government and the local communities who have been impacted by the oil pollution ought to urgently conduct environmental health awareness campaigns in the oil-rich areas to sensitize the local populations on the danger of oil contaminants in the environment. If this is properly done, the locals' exposure to environmental contaminants could be reduced, and the long term impacts of oil pollutants on the health of the people living in the oilfields could be drastically reduced.

(2) Construction of wastewater treatment plant for the produced oil wastewater, which is poorly managed, to undergo series of treatment (primary, secondary and advanced treatment processes) to meet discharge standards before released to the environment

(3) Air pollution control measures such as the use of air bag filters and electrostatic precipitators should be used to trap particulate gas matter from flaring process

(4) All the drilling chemicals that have been left decomposing in the environment need to be removed and destroyed.

(5) All the Produced Water (PW) ponds need to be fenced off so that the locals' livestock won't have access to them. In the long terms, there is a need for a complete Environmental and Social Audit (ESA) in all the South Sudan oilfields ostensibly to know the extent of environmental damage that has been caused by oil exploration dating back to the times when South Sudan and the Sudan were one country.

(6) Environmental and biological samplings need to be undertaken so that the extent of environment pollution and the exposure of the local populations to oil pollutants could be quantified regularly for proper monitoring.

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