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Policy Brief

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Remediating South Sudan's War-induced Petroleum Environmental Damage: Environmental baseline Conditions and Current Impacts

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Summary

This paper reviews the existing literature to determine the adequacy of evidence and extent of the environmental impacts in the oil producing areas in South Sudan. The following is revealed:

- Evidence from previous studies shows that there is a serious environmental and social disaster in the three oil producing areas, even though such evidence does not generate enough consensus for the decision makers.
- Environmental impacts assessments (EIA) conducted before the oil operations reveal that (1) the air in these locations was of good quality and (2) the water was safe for both human and animal consumption, except for the pockets with high concentration of salt in groundwater in the Um Ruwaba geological region.
- Still, many parameters of environmental quality usually recognized by World Health Organization (WHO) have not been tested in both the EIAs and related environmental studies.
- In summary, existing evidence links high concentrations of salt and heavy metals to oil exploration, development and production, which are the cause of the widely reported birth defects, miscarriages, infertility, and cancers in the affected areas.

We recommend a comprehensive, independent environmental and social assessment to determine the extent of environmental and social impacts. Resulting insights could be used to develop remediation measures to restore the environment and address related health and social problems. The assessment should be carried out by a reputable firm or an organization, which would need to be selected by the Ministry of Environment and Forestry through a competitive bidding process. In the long term, results from this assessment could help lay the foundation for sustainable development, provide oil

companies with new social license to operate, avert potential conflict and ecological disasters, and aid in building a lasting peace in the country.

1. Introduction

Oil pollution in the oil producing areas is part of the catastrophic legacy of war between South Sudan and Sudan, also known as the Second Sudanese Civil War 1983 -2005.[1] During the war, the Sudanese government militarized the oil operations (Switzer, 2001, Gagnon and Ryle, 2001). It used oil facilities, military forces, and allied militias to forcefully displace the local communities in the oil producing areas so as to create a room for oil operations (Moro, 2009, Switzer, 2002, Gagnon & Ryle, 2001). The process resulted in land dispossession, blockage of water courses, contamination of surface and groundwater, polluted agriculture and pasture lands, losses of livestock, wildlife species, plant species, and habitat (Moro, 2014, ECOS, 2010). This has caused enormous human suffering, including deaths, illnesses, infertility, premature births, miscarriages, birth defects, and blindness (Rueskamp et al., 2014, Moro, 2009).

This review comes in the context of the signing in September 2018 of the Revitalized Agreement on the Resolution of Conflict in the Republic of South Sudan (R-ARCISS) between the Government of South Sudan and the main opposition groups. While the opportunity brought about by the Comprehensive Peace Agreement (CPA), which ended the 21 years of war in 2005, was not utilized to address the environmental consequences of oil production during the second civil war, the 2018 agreement presents yet another opportunity. Chapter Four of the R-ARCISS lays the ground for a sustainable management of natural resources and the environment. The R-ARCISS requires the implementation of existing laws, creation and enforcement of new policy measures, and the establishment of South Sudan Environmental Authority.

Currently, limited empirical evidence exists on the state of environment in South Sudan's oil-producing areas. There is limited empirical evidence (1) partly because much of the available knowledge on the subject matter is not available in the public domain and to the policymakers and (2) partly because of lack of adequate scientific studies to understand the nature and extent of environmental impacts in the oil producing areas in South Sudan. Therefore, this assessment aims at addressing the former, which is to review and assemble available evidence, evaluate whether such evidence is adequate, and make it available in the public domain for improved policy, with recommendations for remedial action. In addition, little professional attention has been paid to the past EIAs as sources of baseline

[1] This period of the liberation war can appropriately be referred within the context of South Sudan as the Second Phase of South Sudanese Liberation War. The First Phase of South Sudanese Liberation War is what some historians have named the First Sudanese Civil War 1955- 1972.

data in South Sudan and therefore, this review also provides a professional opinion on the quality of EIAs conducted for the oil projects in Melut, Muglad and Sudd Basins. In particular, the assessment attempts to answer three key questions, namely (1) Is there evidence that shows the link between oil operations and environmental impacts in South Sudan? (2) Is there a documented baseline evidence on environment in the country? And (3) is the available evidence enough to inform policy interventions? Evidence of environmental and social impacts is crucial, as it helps in decision making to reverse any possible environmental damage. Environmental baseline information is very crucial in monitoring potential environmental impacts of the oil projects.

The remainder of the paper is structured as follows: Section 2 outlines the methodology used in conducting this study. Section 3 assesses and identifies hazards and impacts, and their links to oil activities. Section 4 discusses the results and concludes with recommendations.

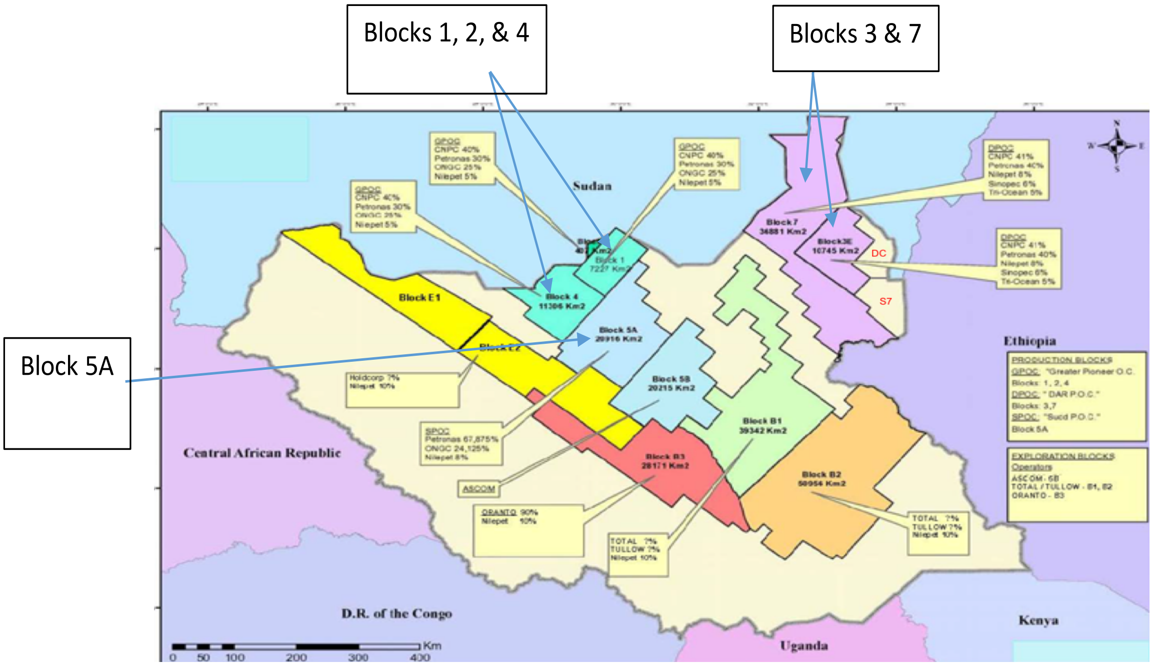
2. Methodology

We reviewed literature and records[2] using, as a reference point, the water and air quality standards set by the World Health Organization (WHO). Our main objective of comparing the documented environmental conditions against WHO's water and air quality standards is to determine whether such tests exceed the guideline values set by the WHO with the view to determining the extent of environmental impacts since the oil operations started. Environmental impacts in the context of this paper refer to negative consequences of oil production on humans, living organisms, and the environment (i.e., air, land and water) caused by toxic substances, resource degradation/depletion, and displacement, among others.

We specifically review the extant literature on water and air quality, as well as environmental monitoring studies conducted following the oil operations as a way to determine the extent of current environmental and social impacts. We reviewed three EIA reports completed before the oil operations in the three oil operation sites in South Sudan, namely Melut (blocks 3 & 7), Muglad (blocks 1,2 & 4) and the Muglad - Sudd Rift Basins (Block 5A) (Figure 1 illustrates the map of the three oil operation sites).

[2] The literature we reviewed includes past reports of impacts which have been compiled but has not been disclosed to the public and responsible policy entities. Evidence from this adds to the body of evidence needed to take action to stop environmental catastrophe in the oil producing areas.

Figure 1: South Sudan's oil concessions map[3]



Source: Ministry of Petroleum with additional illustration by the author

3. Current environmental and social issues and impacts

3.1 Issues and hazards

The first post-war environmental assessment by the UN Environment Program in 2007 reveals produced water pollution, land pollution, and chemical dumping in the petroleum producing areas. Produced water, the most ubiquitous source of pollutants in South Sudan, is a toxic substance containing water separated from crude oil and is supposed to be treated before being released into the environment (Patey, 2012, p. 565, Igunnu & Chen, 2012, UNEP, 2007, p.). It is a combination of water naturally trapped with petroleum deposits and water injected into the wells to facilitate the pumping of oil out of the wells (Igunnu & Chen, 2012)[4]. Produced water contains organic and inorganic compounds that include

[3] The information on this map with regards to who owns the concessions has since changed. However, we present the map to illustrate the locations of the current three oil project sites in Melut (Blocks 3E & 7E), Toma South, Al Nar, and Al Toor Oilfields (Blocks 1, 2 &4) and Tharjath, Mala and Jarayan (Block 5A).

[4] Ebenezer T. Igunnu and George Z. Chen. Produced water treatment technologies. International Journal of Low-Carbon Technologies.

dissolved and dispersed oils, treating chemicals, heavy metals, grease, formation solids[5], radionuclides, salts, dissolved gases[6], waxes, scale products, microorganisms, and dissolved oxygen.[7] These substances are very detrimental to human and environmental health. The volume of produced water increases with the number of years in production (ECOS, 2007, p. 150, Igunnu & Chen, 2012). For example, UNEP estimated in 2007 that Heglig Oil Facility produced about ten cubic meters of such produced water annually (UNEP, 2007, p. 150). In 2007, this volume was estimated to increase at least five times in ten years. More than ten years later, this is now 50 cubic meters annually, which poses more risks than ever before.

A South Sudan's parliamentary fact-finding mission in 2013 found evidence of environmental hazards in three oil producing areas operated by Greater Pioneer Operating Company (GPOC), Dar Petroleum Operating Company (DPOC) and Sudd Petroleum Operating Company (SPOC). Another parliamentary fact-finding mission in 2018 also found the containers of expired chemicals dumped near villages in Blocks 3 and 7 in Melut County, which is a threat to human health and the environment.

A UNDP's study, conducted in 2010, shows evidence of produced water and oil spill contamination, blockage of hydrology, and hazardous waste contamination. A team from CORDAID, a Dutch Catholic organization, through interviews, focused- group discussions and participatory appraisal, reveals widespread produced water, oil spill, drilling muds, and chemicals, which pose serious threats to the environment and people's health. The report discloses that measures to prevent these pollutants are insufficient.

Environmental and social issues are attributed to lack of proper environmental management as the government of Sudan had been focusing on exploiting oil at all cost to win the war against the southern rebels. Available evidence shows that Khartoum government increased attacks on civilians between 2000 and 2001 to depopulate the oil producing areas in oil Blocks in former Unity State, which led to deaths, displacement and environmental degradation (Gagnon and Ryle, 2001). The government of South Sudan inherited this mess following independence in 2011. However, it not has done much to reverse this catastrophe.

[5] Produced solids or solid formation include precipitate solids, bacteria, sand, clays, waxes, carbonates and corrosion and scale products and their impacts include clogging the pipe during oil production.

[6] Dissolved gases include carbon dioxide, oxygen and hydrogen sulphide

3.2 Impacts

Produced water, oil spill, and hazardous wastes, among other hazards, are suspected to be the cause of the infertility, skin diseases, miscarriages, blindness, eye infections, eye pains, fatigue, stomach pains, and appendicitis widely reported in various studies. An investigation committee established by the Minister of Petroleum, Mining and Industry in 2013 found increased incidents of birth defects, premature births, miscarriages, still births, blindness, infertility and reproductive health complications, among others. A 2018 state of environment and outlook report issued by the Ministry of Environment and Forestry in collaboration with UNEP and BRACED Consortium raises concerns about environmental degradation in the oil producing areas. Studies commissioned by European Coalition on Oil in Sudan show land use has considerably been affected (Bol, 2014). For example, a land impact report reveals that 37 villages have been totally lost to oil exploration in Melut. The studies also reveal a high level of mistrust between local communities and oil companies partly due to lack of local benefits and labor related issues (Moro, 2014; Akec, 2014).

A joint investigation team formed by the three ministries of Environment & Forestry, Petroleum, and Health in response to symptoms of a potential disease outbreak in 2016 found high concentrations of heavy metals, which were above the US Environmental Protection Agency's allowable limits. The investigation team collected environmental and biological samples which were analyzed in a South African laboratory. High concentrations of mercury, selenium, manganese and chromium were found. The symptoms shown by the patients were found to be similar to symptoms usually displayed by those exposed to these heavy metals. A recent field study conducted in Paloch in March 2019 by the Sudd Institute found that (1) communities who live next to oil wells, graze their livestock, and grow crops within the oilfields are largely exposed to oil contaminations, (2) widespread complaints of a high prevalence of diseases and birth defects, both of which are highly suspected to be linked to the petroleum pollution, and (3) high level of frustration by communities due to lack of response to their repeated complaints. The Ministry of Health of Ruweng Administrative Area reveals that there has been a rise in the number of premature births. For example, 41 premature births were recorded in 2015, 59 in 2016, and 118 in 2017.

3.3 Links between impacts and oil pollution

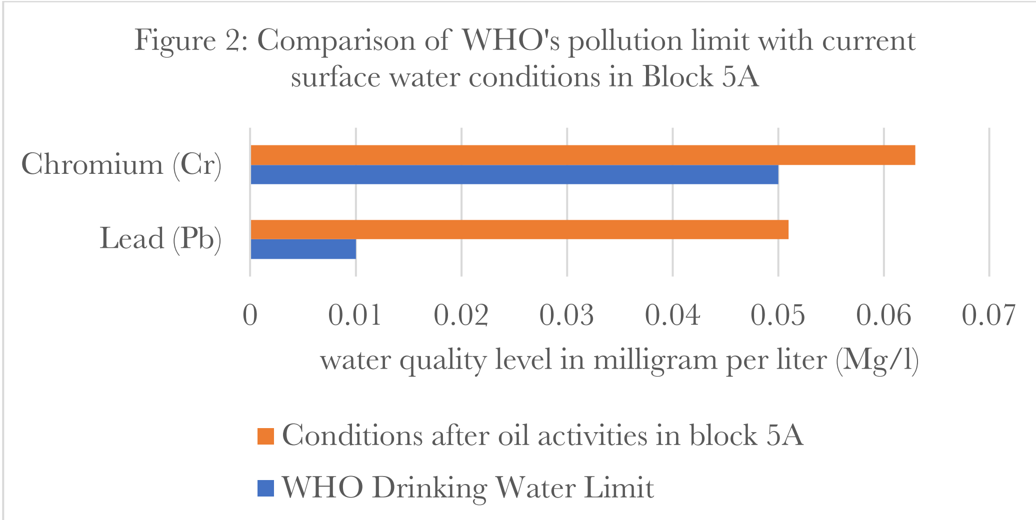
Is there any evidence that shows current impacts have been caused by oil activities? Sign of Hope, a German organization, has linked water pollution to oil production activities based on laboratory tests of water samples in Block 5A (Rueskamp et al., 2014). Some of the contaminants found in these samples include salt and heavy metals. The source of the contamination was produced water, which is stored in ponds and mud pits (Rueskamp et al., 2014). In addition, the chemical components in the oil wells were found to be similar to the ones in the drinking water wells. About 30 shallow drinking water wells have been contaminated beyond the levels allowed by both the US Environmental Protection Agency (EPA) and WHO. For example, Chromium and Lead (Pb) concentrations have been reported to be five times the allowable levels. The Sign of Hope study found concentration of Lead (Pb) to be 12.5 mg/l, cadmium 0.53 mg/l, arsenic 0.08 mg/l, Barium 140 mg/l and chromium 0.45 mg/l. Lead (Pb), cadmium, and arsenic have serious health concerns and could be responsible for widespread birth defects and cancers. Salt concentration was found to be 6,600.50 mg/l, strontium 6.7 mg/l, and nitrate 81.6 mg/l. The allowable levels are 500 gm/l for salt concentration and 10 mg/l for nitrate based on EPA's standards.

A high concentration of heavy metals in the Sign of Hope's study reflects the findings in the 2004 EIA report, which assessed the impacts of previous oil activities, from 1997 and 2003. The EIA 2004 links oil activities between 1997 and 2003 to environmental pollution in Block 5A[8]. The study found concentration of Lead (Pb) in the surface water to be above the WHO's drinking water allowable limits (see table 1b). The allowable limit for Pb is 0.01 milligram per a litter (mg/l) while the test found the concentration of Lead (Pb) in surface water during the 2004 EIA study to be 0.051 mg/l at most. The same EIA study also found, in surface water, the Chromium concentration to be 0.63 mg/l which is above the allowable limit of 0.05 mg/l (See figure 2).

On groundwater, the 2004 EIA in Block 5A found sodium concentration to be above the WHO's allowable limits (See table 1a). This is due to the fact that groundwater in this area is naturally salty due to water stagnation. Second, the rest of the groundwater tests were within the WHO's allowable limit. While the EIA conducted by the Environmental Resources Management Ltd did some physical and chemical tests, it did not cover most of the parameters.

Pragst et al., (2017) found higher concentration of heavy metals of Lead (Pb) and Barium in human hair in areas close to Tharjath oilfields in Block 5A. The level of heavy metal concentration decreases with the increase in the distance between the oilfields and area of residence of those tested. For example, average Lead (Pb) concentration in Rumbek was 2.8mg/g compared to average Lead (Pb) concentration of 18.7mg/g in Koch, which is located next the oilfields. Pragst and his colleagues describe these concentrations to be within "the same range as in highly contaminated mining regions in Kosovo, China or Bolivia." This demonstrates the serious risks oil activities are posing to residents of the oil producing areas in South Sudan.

[8] Block 5A was operated by Lundin and other consortium members from which White Nile Petroleum Operating Company took over in 2003.



However, the oil companies dismiss this evidence, calling it baseless and counterclaiming that they operate on the basis of international best practices. For example, White Nile Petroleum Operating Company (WNPOC), from which SPOC took over Block 5A oilfields, termed Sign of Hope's findings as "baseless" and "unjustified" accusations. It went on to argue that it adheres to "international HSE [Health, Safety and Environment] standard in carrying out its operations and strictly emphasizes on zero pollutant and discharge, in sensitive ecological areas, such as the Sudd Swamps."[9] It further added that the area is naturally salty based on an EIA carried out before the exploration and production started.

The government commissioned a fact-finding assessment in 2011 to confirm or dispute the findings by Sign of Hope. Norconsult, a Norwegian consulting firm, found high concentration of salt, heavy metals, and chemicals but instead attributed the cause of these high concentrations to natural phenomena instead of WNPOC's oil operations. But the consultant failed to state how natural phenomena can cause such a high concentration of heavy metals and toxic substances. The fact is that while the EIA conducted in 2004 found high concentration of salt, it also pointed out that the previous oil activities contributed to salinity. In addition, it attributed the existing heavy metals in the area to previous oil activities. Besides, the evidence shows that while the groundwater of Um Ruwaba geological formation has high salt concentration, the water in various pockets of the aquifer is generally good for human and animal consumption. Therefore, while there are pockets of high concentrations of salt in the groundwater, widespread salt concentration and heavy metals are due to oil exploration and development in the area.

[9]WNPOC. (2009). White Nile Corporation Response to Concerns over Water Contamination. http://www.ecosonline.org/news/2009/WNPOC_response/

Despite claims by the companies of adhering to HSE standards, the Sudd Institute finds that standards set up in the South Sudanese laws (e.g. Petroleum Act, 2012 and related HSE management system and plan regulations) have neither been enforced nor adhered to (Tiitmamer, 2015, 2016). The regulations require petroleum companies to submit environmental management system (EMS) and environmental management plan (EMP) to the Petroleum Ministry 60 days before commencing petroleum activities. They also require the companies to submit to the government the EMS/EMP for existing petroleum activities no later than 90 days from the date the regulations come into existence. None of these requirements have been complied with by the companies. The review of the HSE management system and plan regulations shows no clear degrees of penalties should the companies fail to abide by the requirements.

Table 1a: Comparison of groundwater quality with WHO's drinking water standards in oil Block 5A in Unity State, South Sudan

Parameters	WHO Drinking Water Standards	Water quality level in Block 5A	Remarks
Sodium (Na)	200 mg/l	255 gm/l	Sodium concentration exceeds WHO's limit
Total Chromium (Cr)	0.05 mg/l	0.002mg/l	Total chromium concentration is within WHO's limit
Barium (Ba)	0.3 mg/l	0.165 gm/l	Barium concentration is in line with WHO's limit

Zinc (Zn)	3 mg/l	0.011 gm/l	Concentration is in line with WHO's limit
Chloride (Cl)	250 mg/l	24 gm/l	Concentration of chloride is in line with WHO's limit
Fluoride	1.5 mg/l	0.9 gm/l	Concentration is in line with WHO's limit
Calcium	100 – 200 mg/l	29.9 gm/l	Concentration is in line with WHO's limit
pH	6.5 – 8.5	7.4 gm/l	PH is within WHO's limit

Source: Compiled by the author from past EIA reports and WHO's water quality guidelines

Table 1b: Comparison of surface water quality with WHO Drinking Water Standards in oil block 5a in Unity State, South Sudan

Pollutants	WHO Drinking Water Standards	Conditions after oil activities in block 5a	Remarks
Sodium (Na)	200 mg/l	440 mg/l	Sodium concentration exceeds the WHO's limit
Lead (Pb)	0.01 mg/l	0.020 – 0.051 mg/l	Lead concentration exceeds WHO's

			allowable limit
Chromium (Cr)	0.05 mg/l	0.063 mg/l	Chromium concentration exceeds WHO's allowable threshold
Barium (Ba)	0.3 mg/l	0.147 mg/l	Barium concentration is in line with WHO's limit
Cadmium (Cd)	0.003 mg/l	NI	No information on the current condition
Nickel (Ni)	0.02 mg/l	0.043 mg/l	Nickel concentration exceeds WHO's allowable limit
Manganese (Mn)	0.4 mg/l	0.102 mg/l	Manganese concentration is within WHO's allowable limit
Copper (Cu)	2 mg/l	0.069 mg/l	Concentration of Copper is within WHO's allowable limit

Zinc (Zn)	3 mg/l	0.180 mg/l	Zinc concentration is within WHO's allowable limit
Chloride (Cl)	250 mg/l	80 mg/l	Chloride concentration is within WHO's allowable limit
Fluoride	1.5 mg/l	5.4 mg/l	Fluoride concentration exceeds WHO's allowable threshold
Calcium	200 mg/l	33.0 mg/l	Calcium concentration is within WHO's allowable limit

Source: Compiled by the author from past EIA reports and WHO's water quality guidelines

While there have been no studies to empirically link reproductive issues (such pre-mature births and birth defects) to oil contamination in the oil-producing areas, available evidence elsewhere shows that exposure to lead (Pb) during pregnancy leads to reproductive abnormalities[10] (e.g. still birth, reduced placental functioning, miscarriage, and neonatal death), fetal growth retardation, reduced attention and low IQ (Bellinger, 2005). More than 10 ug/dL blood lead level can lead to some of the above-mentioned problems in pregnant women[11] (Pergament et al., 1995). Specifically, paternal blood lead level between 25 ug/dL

[10] Bellinger, D.C. (2005). Teratogen Update: Lead and Pregnancy. Wiley Interscience. Birth Defects Research (Part A) 73:409–420.

[11] Eugene Pergament, MD, PhD; Amy Schechtman, MS; Carrie Koval. (1995). Lead Exposure in Pregnancy. Illinois Teratogen Information Service.

and 40 ug/dL can reduce fertility and fetal growth, and increase abortion risk (Bellinger, 2005). In addition, lead blood level of 10 ug/dL can cause hypertension, abortion and reduce neuro behavioral development (IBID). Other petroleum pollutants such as benzene and Cd have been empirically associated with various forms of birth defects, which include neural abnormalities. Therefore, even though no empirical studies have been conducted to determine this link in South Sudan, the trends in the number of cases in the oil-producing areas are suggestive of what is documented in similar contexts.

3.4 Evidence of environmental baseline conditions

This part discusses key findings from the EIA and other past studies in the three oil project areas, with a focus on Block 5A, blocks 1, 2, & 4 and blocks 3 & 7.

Block 5A

Block 5A lies within the Muglad - Sudd Rift basin, part of the Um Ruwaba formation, whose aquifers (water bearing rocks) are classified as having a low to high water production capacity (Kut et al., 2018). However, due to water stagnation within the Sudd basin, there are areas with high salt concentration, ranging from "270 to 6,500 mg/1, with average values of 1,500 mg/1 which increase with depth and towards the north" (UN, 1988). The salt types found in the Sudd basin are "mainly of the carbonate and sodium bicarbonate types when the salinity is low or moderate, and of the chloride and sodium Sulphate types in the areas of high concentrations; in some cases, there are heavy concentrations of nitrates" (UN, 1988). Despite containing areas of high salt concentration, "the water of the Umm Ruwaba aquifer is usually fairly soft and is suitable for human and animal consumption" (UN, 1988). Nevertheless, "when the concentration of nitrates exceeds the admissible amount (35 mg/1), the water cannot be used and the wells and boreholes must be condemned" (UN, 1988).

An EIA conducted in 2004 before the White Nile Petroleum Operating Company (WNPOC) took over the Block 5A concession found the water quality outside the project operations to be within the permissible limits of the WHO's quality standard. However, Block 5A concession areas operated by oil companies between 1997 and 2003 by Lundin and partners were found to have been contaminated.[12] Therefore, the EIA conducted in 2004 was in part an audit of the past oil activities and an examination of potential future impacts of the would-be activities. The assessors examined a number of parameters that include water (both surface and groundwater), air, biodiversity and social impacts. They found oil related contaminations near or around existing Lundin's facilities. For example, the EIA found that "there is contamination with much of it involving oil and drillings and,

[12] Block 5A was operated between 1997 and 2003 by a consortium led by Lundin, a Swedish oil company, before WNPOC took over.

in some areas, evidence of that contamination may have been transported to shallow groundwater aquifers that are used as seasonal potable resource in areas of Block 5A." In addition, the assessors found that "such contamination tends to be very localized and generally the soils elsewhere are pristine." Furthermore, evidence also shows that "past seismic activity and vehicle movements in the area have led to fairly extensive surface scouring."

For groundwater, the assessors did not test for lead (Pb), mercury (Hg), manganese (Mn), aluminum (Al), magnesium, potassium (K), copper (Cu), Uranium (U), Nickel (Ni), Cadmium and arsenic, among others. Of the parameters tested, sodium concentration was found to be above the WHO's water quality standards.

For surface water in block 5A, lead (Pb), Chromium (Cr), Nickel (Ni), and fluoride test results were above permissible limits. There is no evidence of surface water tests carried out for Mercury (Hg), Arsenic (As), PH, Uranium (U), and Aluminum (Al) either. Manganese, Copper, Zinc, Chloride, Fluoride, and Calcium test results were within the permissible limits.

Air quality parameters tested in the 2004 EIA for block 5A include Particulate matter (PM10), Nitrogen Dioxide (NO_2), and Sulfur Dioxide (SO2). However, there is no evidence of tests for Particulate Matter (PM2.5) and Ozone (O_3). While no tests seem to have been performed for Ozone (O_3) and Particulate matter (PM2.5), the rest of the air quality parameters mentioned above were within the WHO's air quality permissible limits.

Blocks 1, 2, & 4

No new tests for water quality were performed in Block 1, 2, & 4 during the EIA in 1998. The 1998 EIA report only cites three samples of ground water in the project area, which were taken and analyzed by the Non-Nilotic Water Administration and the Khartoum State Water Corporation. The results show that "the water is of high quality" except one "anomaly" of "high turbidity," which is attributed to the "mode of operation of wells," which is thought to be reduced with "the continued abstraction." The main geological feature is the Um Ruwaba formation, which overlays the Nubian sandstone, and whose water is generally good for human and animal consumption.

The surface water bodies in this region include Kiir River (also known as Bhar al Arab), Bhar al Ghazal, Lake Keilak and a number of smaller water bodies that are both natural and human made. The assessors did not also conduct new water testing on the surface water quality in this area. They used evidence from past studies which shows the surface water was good for human and animal consumption (Talling 1957, Moghaby, 1975, Green et al., 1984). However, the past studies they used did not cover all of the parameters of surface water quality. Hence, baseline evidence from these past studies cannot alone be considered adequate for establishing evidence on surface water in Blocks 1, 2 & 4 areas.

Air quality was also found to be very high as the area had little industrial activities before the oil operations. However, there were some pollutants of natural particulates of soil and pores which were found to be in the air.

Blocks 3 and 7 (Paloch and Adar Oil Project Sites)

The main surface water body in Blocks 3 & 7 is the White Nile and various small seasonal tributaries. Other water bodies include human-made water pools and groundwater. Physical and chemical parameters examined in 2004 as part of the EIA in Blocks 3 & 7 include Ph, Conductivity, Total Dissolved Solids, Total Hardness ($CaCO_3$), Total Alkalinity ($CaCO_3$), Chloride (Cl), Sodium (Na^+), Potassium (K^+), Calcium (Ca^{++}), Magnesium (Mg^{++}), Phosphorus (PO_4-P), Nitrate ($NO_3 - N$), Sulphate (SO_4), Fluoride (F), and Ammonia (NH). Most of the results fall within the permissible limits by the WHO's water quality standards. However, the EIA did not test for many major pollutants: Lead (Pb), Mercury (Hg), Chromium (Cr), Arsenic (As), Barium (Ba), Cadmium (Cd), Nickel (Ni), Manganese (Mn), Copper (Cu), Aluminum (Al) and Uranium (U).

In addition, the EIA report for Blocks 3 & 7 shows that groundwater "bearing layers are mainly the Sudd Basin belonging to the Tertiary sediments of Umm Ruwaba formations" (p. 16). Its water "is generally alkaline, hard with high contents of sodium" (p. 16). The EIA report also reveals to us that "many wells, used by both human beings and animals are designated as chemically unfit for human consumption" (p. 16). This description is largely in line with existing evidence about the past conditions of the project area.

The air quality in Paloch and Adar oil project sites was of good quality prior to the oil production based on the 2004 EIA.

Table 2 summarizes key findings from the three EIA reports for the three oil project sites

Table 2: Summary of environmental impact assessment reports for South Sudan's oil concession blocks

Consultant that conducted the EIA	Concession blocks	Summary of key findings from the 3 EIAs	Areas and project activities covered	date of completion
Institute of Environmental Studies,	Blocks 1, 2 & 4 in former	1. Air was of good	Higlig, Unity, Toma El South, El Nar and El	1998

University of Khartoum, Khartoum, Sudan	Unity State	quality due to prior minimal industrial activities.	Toor oilfields	
Institute of Environmental Studies, University of Khartoum, Khartoum, Sudan	Blocks 3 & 7 in Northern Upper Nile	2. Surface and groundwater were generally good except pockets of high salt concentrations. 3. Many parameters considered by WHO as of significant health concerns were not tested, rendering the studies inadequate.	Paloch FPF, Adar or Agordeed FPF, Jabalyn CPF, Field Surface Facilities, Adar Pipeline, Operation Base Camps and Airport	2004
Environmental Resources Management Ltd	Block 5A in former Unity State	4. EIA conducted in 2004 in Block 5A cannot be considered as a true measure of natural environmental baseline quality of the area	Facilities in Thar Jath, Mala, and Jarayan	2004

4 Conclusion

Most of the studies we have examined provide evidence of serious environmental pollution. They also show this pollution is due to the oil operations. However, one study, which was commissioned by the government and conducted by a consultant from Norway, claims the impacts are not related to oil pollution. In addition, some impacts, such as birth defects, premature births, infertility, cancers, and related environmental health issues, have not adequately been examined to determine whether they are being caused by oil pollution. Oil companies and some government institutions use this gap to dismiss concerns being expressed by researchers and residents of oil producing areas. To have a consensus, there is a need for additional empirical studies. Areas to pay attention to should include links between birth defects, premature births, miscarriages, cancers and other relevant issues to oil pollution.

In conclusion, there are alarming indications of environmental and social impacts based on previous studies, even though the evidence does not generate enough consensus for the decision makers. Therefore, to determine the extent of possible impacts, we recommend to the government a comprehensive, independent environmental and social assessment to understand the extent of environmental and social impacts.[13] The assessment should be carried out by a reputable international firm or organization to be selected by the Ministry of Environment and Forestry through a competitive bidding and its recommendations should be enforced through a Presidential Order or an Act of Parliament. Conducting this assessment can lay the foundation for evidence needed to support sustainable development, including providing oil companies with new social license to operate, averting potential conflict and ecological disaster, and acting as an ingredient into building sustainable peace in the country.

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[13] See Tiitmamer, N. (2019). Confronting a Life-threatening Pollution: A Guide for Credible Environmental and Social Audit of Petroleum Companies' Operations in South Sudan. https://www.suddinstitute.org/publications/show/5dc151f3460e8

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