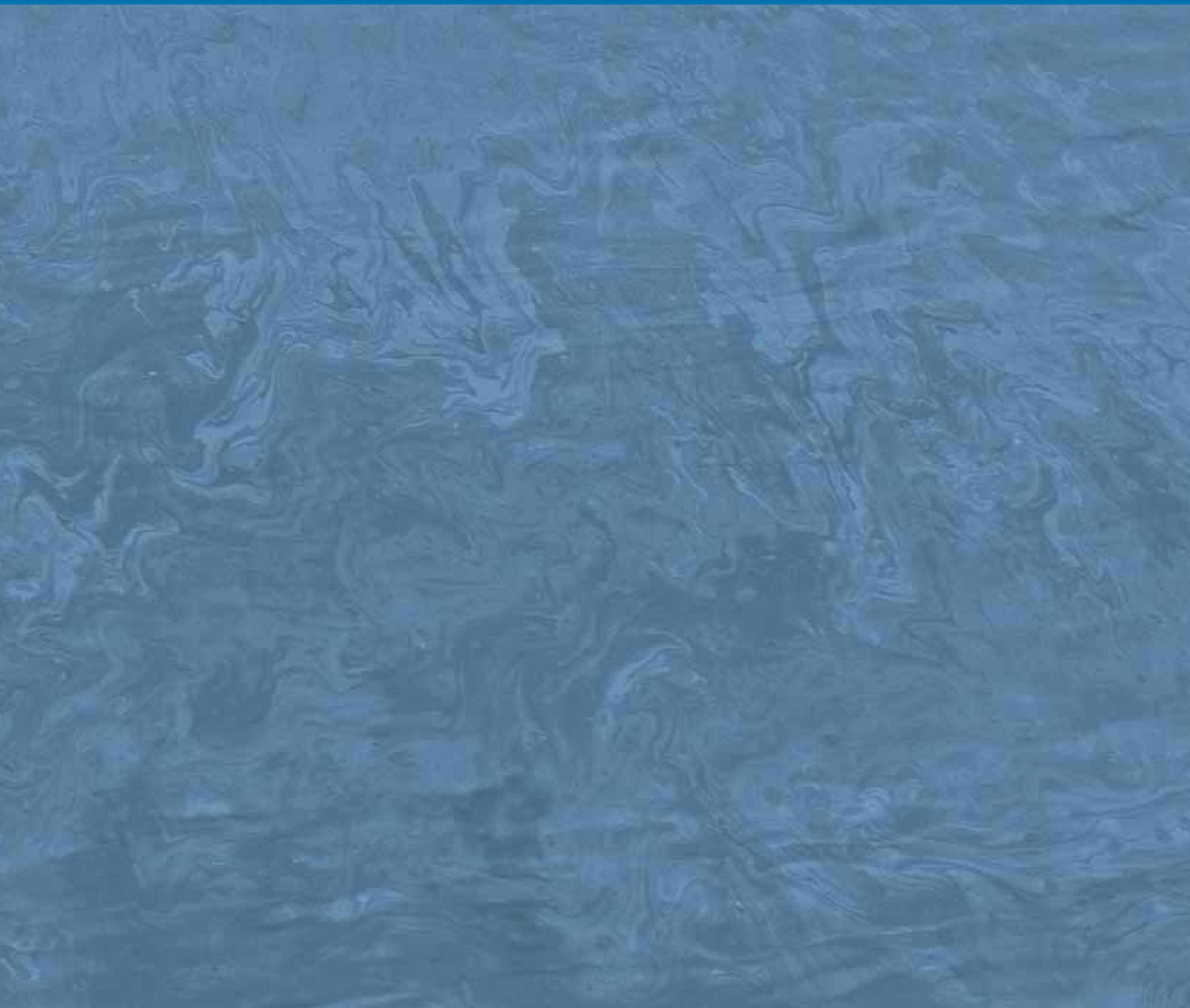
UNEP

Environmental Assessment of Ogoniland



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Foreword

The history of oil exploration and production in Ogoniland is a long, complex and often painful one that to date has become seemingly intractable in terms of its resolution and future direction.

It is also a history that has put people and politics and the oil industry at loggerheads rendering a landscape characterized by a lack of trust, paralysis and blame, set against a worsening situation for the communities concerned.

The reality is that decades of negotiations, initiatives and protests have ultimately failed to deliver a solution that meets the expectations and responsibilities of all sides.

In an attempt to navigate from stalemate to action, the Government of Nigeria, in consultation with many of the relevant actors, invited UNEP to consider undertaking an assessment of oil pollution in Ogoniland.

UNEP has acquired an international reputation for assembling expert teams, coordinating demanding assessments and bringing scientific and empirical evidence to policymakers.

UNEP initially consulted with a wide range stakeholders and the United Nations Country Team in Nigeria in order to consider the scope and indeed the feasibility of the assessment.

We were confronted with a unique challenge: lack of trust between actors; political tensions between communities; regional and national government; gaining access to Ogoniland; security considerations and technical and logistical challenges.

Despite imperfect conditions, UNEP in the end agreed to undertake the study as it represented the only tangible option for possibly breaking the decades of deadlock while providing the government and stakeholders with a potential foundation upon which trust might be built and action undertaken to remedy the multiple health, environmental and sustainable development issues facing millions of people in Ogoniland and beyond.

In order to ensure the independence of the study and provide the logistics necessary, a framework for cooperation was negotiated in which all parties were involved and a recognized team of national and international experts then recruited for the two year assessment.

This report details how that team carried out their work, where samples were taken and the findings that they have made. Over a 14-month period, the UNEP team examined more than 200 locations, surveyed 122 kms of pipeline rights of way, reviewed more than 5,000 medical records and engaged over 23,000 people at local community meetings. Detailed soil contamination investigations were conducted at 69 sites. Altogether more than 4,000 samples were analyzed, including water taken from 142 groundwater monitoring wells drilled specifically for the study and soil extracted from 780 boreholes.

The findings in the report underline that there are, in a significant number of locations, serious threats to human health from contaminated drinking water to concerns over the viability and productivity of ecosystems. In addition that pollution has perhaps gone further and penetrated deeper than many may have previously supposed.

This report represents the best available understanding as to what has happened to the environment of Ogoniland – and the corresponding implications for affected populations – over many years of oil industry operations. It provides the government, stakeholders and the international community with invaluable, baseline information on the scale of the challenge and priorities for action in terms of clean-up and remediation.

It does not address all scenarios and answer all questions which have arisen over the years, particularly in respect to legal questions which were beyond the terms of reference of the undertaking.

But UNEP believes it can provide a firm foundation upon which all the stakeholders concerned can, if they so wish, draw up a response to the findings presented here.

Before and during the assessment, the consensus that has allowed this work to proceed in the first place was at times fluid and sometimes fractious and fragile. Many questions were raised, not least surrounding how the study was financed and by whom. The report and its long list of annexes needs to speak for itself.

But it is important to point out that from the outset UNEP deemed it right and appropriate that key actors in the petroleum sector should bear the financial costs for this assessment and this was spelt out in the project document which is publicly available.

To date all parties have honoured those commitments and the rigor, independence and impartiality of the study and its conclusions has been maintained which we hereby acknowledge.

This study would not have been possible without the local knowledge and cooperation of the Ogoni people and the support of many other stakeholders in Nigeria. We wish to sincerely thank the members of the Presidential Implementation Committee, under the Chairmanship of The Most Reverend Matthew Kukah, Bishop for the Diocese of Sokoto; the former Federal Minister for the Environment, The Hononourable John Odey; the traditional rulers of Ogoniland, in particular the Paramount Ruler, His Majesty King Godwin N.K. Gininwa; the Executive Governor of Rivers State, the Right Honourable Rotimi Chibuike Amaechi, along with the faculty and students at the Rivers State University of Science and Technology led by Vice Chancellor Professor Barineme Beke Fakae.

We also appreciate the assistance of our colleagues at the UN Nigeria Country Team, in particular the UN Resident Coordinator, Mr Daouda Touré, the Country Director of the United Nations Development Programme, Ms Ade Mamonyane Lekoetje, and the Resident Representative and Resident Security Coordinator in Port Harcourt, Mr Larry Boms.

I would also like to thank the national and international members of the assessment team including UNEP staff members.

For the first time, there is systematic and scientific evidence available in the public arena on the nature, extent and impacts of oil contamination in Ogoniland. The report also provides clear operational guidelines as to how that legacy can be addressed.

The oil industry has been a key sector of the Nigerian economy for over 50 years. But many Nigerians have paid a high price, as this assessment underlines. It is UNEP's hope that the findings can catalyze not only significant environmental and social improvements in the region but a strategic policy on how the oil industry there will function in a way that truly benefits the lives and livelihoods of these communities now and in the future.

Achim Steiner
United Nations Under-Secretary-General
Executive Director
of the United Nations Environment Programme

Executive Summary

Introduction

Covering around 1,000 km^2 in Rivers State, southern Nigeria, Ogoniland has been the site of oil industry operations since the late 1950s. Ogoniland has a tragic history of pollution from oil spills and oil well fires, although no systematic scientific information has been available about the ensuing contamination.

With this independent study, conducted at the request of the Federal Government of Nigeria, the United Nations Environment Programme (UNEP) reveals the nature and extent of oil contamination in Ogoniland.

The *Environmental Assessment of Ogoniland* covers contaminated land, groundwater, surface water, sediment, vegetation, air pollution, public health, industry practices and institutional issues.

This report represents the best available understanding of what has happened to the environment of Ogoniland – and the corresponding implications for affected populations – and provides clear operational guidance as to how that legacy can be addressed.

Assessment process

Involving desk review, fieldwork and laboratory analysis, the two year study of the environmental and public health impacts of oil contamination in Ogoniland is one of the most complex on-the-ground assessments ever undertaken by UNEP.

UNEP recruited a team of international experts in disciplines such as contaminated land, water, forestry and public health, who worked under the guidance of senior UNEP managers. This team worked side-by-side with local experts, academics and support teams comprised of logistics, community liaison and security staff.

The UNEP project team surveyed 122 kms of pipeline rights of way and visited all oil spill sites, oil wells and other oil-related facilities in Ogoniland, including decommissioned and abandoned facilities, that were known and accessible to UNEP during the fieldwork period, based on information provided by the Government regulators, Shell Petroleum Development Company (Nigeria) Ltd (SPDC) and community members in and around Ogoniland.

Public meetings staged throughout Ogoniland during each phase of the study helped to build understanding of UNEP's project and to foster community participation

During aerial reconnaissance missions, UNEP experts observed oil pollution which was not readily visible from the ground, including artisanal refining sites. Information provided by Ogoniland residents about oil contamination in their communities supplemented official oil spill data supplied by the Nigerian Government and SPDC.

Following its initial investigations, UNEP identified 69 sites for detailed soil and groundwater investigations. In addition, samples of community drinking water, sediments from creeks, surface water, rainwater, fish and air were collected throughout Ogoniland and in several neighbouring areas. Altogether more than 4,000 samples were analyzed, including water drawn from 142 groundwater monitoring wells drilled specifically for the study, and soil extracted from 780 boreholes. The UNEP project team also examined more than 5,000 medical records and staged 264 formal community meetings in Ogoniland attended by over 23,000 people.

The samples were collected following internationally-accepted sample management procedures and dispatched for analysis to accredited (ISO 17025) laboratories in Europe. The analytes examined in the study included certain groups of hydrocarbons that are known to have adverse impacts and which are therefore dealt with selectively in oil-spill assessment and clean-up work. The most important of these are BTEX (benzene, toluene, ethylbenzene and xylenes) and PAHs (polycyclic aromatic hydrocarbons). Volatile organic compounds (VOCs) were the main target of UNEP's air quality investigations.

Extensive remote sensing analyses complemented the fieldwork. Reviews of legislation, institutions, oil industry practices and available remediation technologies were also undertaken by international experts to complete the study.

A selection of the study's key findings and recommendations are summarized below. Given the vast amount of data generated during the assessment, the following content should not be considered in isolation.

Summary of findings

UNEP's field observations and scientific investigations found that oil contamination in Ogoniland is widespread and severely impacting many components of the environment. Even though the oil industry is no longer active in Ogoniland, oil spills continue to occur with alarming regularity. The Ogoni people live with this pollution every day.

As Ogoniland has high rainfall, any delay in cleaning up an oil spill leads to oil being washed away, traversing farmland and almost always ending up in the creeks. When oil reaches the root zone, crops and other plants begin to experience stress and can die, and this is a routine observation in Ogoniland. At one site, Ejama-Ebubu in Eleme local government area (LGA), the study found heavy contamination present 40 years after an oil spill occurred, despite repeated clean-up attempts.

The assessment found that overlapping authorities and responsibilities between ministries and a lack of resources within key agencies has serious implications for environmental management on-the-ground, including enforcement.

Remote sensing revealed the rapid proliferation in the past two years of artisanal refining, whereby crude oil is distilled in makeshift facilities. The study found that this illegal activity is endangering lives and causing pockets of environmental devastation in Ogoniland and neighbouring areas.

Contaminated soil and groundwater

- The report concludes that pollution of soil by petroleum hydrocarbons in Ogoniland is extensive in land areas, sediments and swampland. Most of the contamination is from crude oil although contamination by refined product was found at three locations.
- The assessment found there is no continuous clay layer across Ogoniland, exposing the groundwater in Ogoniland (and beyond) to hydrocarbons spilled on the surface. In 49 cases, UNEP observed hydrocarbons in soil at depths of at least 5 m. This finding has major implications for the type of remediation required.
- At two-thirds of the contaminated land sites close to oil industry facilities which were assessed in detail, the soil contamination exceeds Nigerian national standards, as set out in the Environmental Guidelines and

Standards for the Petroleum Industries in Nigeria (EGASPIN).

- At 41 sites, the hydrocarbon pollution has reached the groundwater at levels in excess of the Nigerian standards as per the EGASPIN legislation.

- The most serious case of groundwater contamination is at Nisisioken Ogale, in Eleme LGA, close to a Nigerian National Petroleum Company product pipeline where an 8 cm layer of refined oil was observed floating on the groundwater which serves the community wells.

Vegetation

- Oil pollution in many intertidal creeks has left mangroves denuded of leaves and stems, leaving roots coated in a bitumen-like substance sometimes 1 cm or more thick. Mangroves are spawning areas for fish and nurseries for juvenile fish and the extensive pollution of these areas is impacting the fish life-cycle.

- Any crops in areas directly impacted by oil spills will be damaged, and root crops, such as cassava, will become unusable. When farming recommences, plants generally show signs of stress and yields are reportedly lower than in non-impacted areas.

- When an oil spill occurs on land, fires often break out, killing vegetation and creating a crust over the land, making remediation or revegetation difficult.

- Channels that have been widened and the resulting dredged material are clearly evident in satellite images, decades after the dredging operation. Without proper rehabilitation, former mangrove areas which have been converted to bare ground are being colonized by invasive species such as nipa palm (which appears to be more resistant to heavy hydrocarbon pollution than native vegetation).

- In Bodo West, in Bonny LGA, an increase in artisanal refining between 2007 and 2011 has been accompanied by a 10% loss of healthy mangrove cover, or 307,381 m^2. If left unchecked, this may lead to irreversible loss of mangrove habitat in this area.

Aquatic

- The UNEP investigation found that the surface water throughout the creeks contains hydrocarbons. Floating layers of oil vary from thick black oil to thin sheens. The highest reading of dissolved hydrocarbon in the water column, of 7,420 μg/l, was detected at Ataba-Otokroma, bordering the Gokana and Andoni LGAs.

- Fish tend to leave polluted areas in search of cleaner water, and fishermen must therefore also move to less contaminated areas in search of fish. When encountered in known polluted areas, fishermen reported that they were going to fishing grounds further upstream or downstream.

- Despite community concerns about the quality of fish, the results show that the accumulation of hydrocarbons in fish is not a serious health issue in Ogoniland but that the fisheries sector is suffering due to the destruction of fish habitat in the mangroves and highly persistent contamination of many of the creeks, making them unsuitable for fishing.

- Where a number of entrepreneurs had set up fish farms in or close to the creeks, their businesses have been ruined by an ever-present layer of floating oil.

- The wetlands around Ogoniland are highly degraded and facing disintegration. The study concludes that while it is technically feasible to restore effective ecosystem functioning of the wetlands, this will only be possible if technical and political initiatives are undertaken.

Public health

- The Ogoni community is exposed to petroleum hydrocarbons in outdoor air and drinking water, sometimes at elevated concentrations. They are also exposed through dermal contacts from contaminated soil, sediments and surface water.

- Since average life expectancy in Nigeria is less than 50 years, it is a fair assumption that most members of the current Ogoniland community have lived with chronic oil pollution throughout their lives.

Contaminated river at Sugi Bodo, Gokana LGA. The report provides baseline information on the scale of the challenge for Ogoniland and priorities for action in terms of clean-up and remediation

- Of most immediate concern, community members at Nisisioken Ogale are drinking water from wells that is contaminated with benzene, a known carcinogen, at levels over 900 times above the World Health Organization (WHO) guideline. The report states that this contamination warrants emergency action ahead of all other remediation efforts.

- Hydrocarbon contamination was found in water taken from 28 wells at 10 communities adjacent to contaminated sites. At seven wells the samples are at least 1,000 times higher than the Nigerian drinking water standard of 3 µg/l. Local communities are aware of the pollution and its dangers but state that they continue to use the water for drinking, bathing, washing and cooking as they have no alternative.

- Benzene was detected in all air samples at concentrations ranging from 0.155 to 48.2 µg/m^3. Approximately 10 per cent of detected benzene concentrations in Ogoniland were higher than the concentrations WHO and the United States Environmental Protection Agency (USEPA) report as corresponding to a 1 in 10,000 cancer risk. Many of the benzene concentrations detected in Ogoniland were similar to those measured elsewhere in the world, given the prevalence of fuel use and other sources of benzene. However, the findings show that some benzene concentrations in Ogoniland were higher than those being measured in more economically developed regions where benzene concentrations are declining because of efforts to reduce benzene exposure.

Institutional issues

- First issued in 1992, the EGASPIN form the operational basis for environmental regulation of the oil industry in Nigeria. However, this key legislation is internally inconsistent with regard to one of the most important criteria for oil spill and contaminated site management – specifically the criteria which trigger remediation or indicate its closure (called the 'intervention' and 'target' values respectively).

- The study found that the Department of Petroleum Resources (DPR) and the National Oil Spill Detection and Response Agency (NOSDRA) have differing interpretations of EGASPIN. This is enabling the oil industry to close down the remediation process well before contamination has been eliminated and soil quality has been restored to achieve functionality for human, animal and plant life.

- The Nigerian Government agencies concerned lack qualified technical experts and resources. In the five years since NOSDRA was established, so few resources have been allocated that the agency has no proactive capacity for oil-spill detection. In planning their inspection visits to some oil spill sites, the regulatory authority is wholly reliant on the oil industry for logistical support.

- The oilfield in Ogoniland is interwoven with the Ogoni community. The fact that communities have set up houses and farms along rights of way is one indicator of the loss of control on the part of the pipeline operator and the government regulator.

- The UNEP project team observed hundreds of industrial packing bags containing 1,000-1,500 m^3 of waste, believed to be cuttings from oil drilling operations, dumped at a former sand mine in Oken Oyaa in Eleme LGA. The open disposal of such waste in an unlined pit demonstrates that the chain of custody in the region between the waste generator, transporter and disposal facility is not being followed.

Oil industry practices

- The study concludes that the control, maintenance and decommissioning of oilfield infrastructure in Ogoniland are inadequate. Industry best practices and SPDC's own procedures have not been applied, creating public safety issues.

- Remediation by enhanced natural attenuation (RENA) – so far the only remediation method observed by UNEP in Ogoniland – has not proven to be effective. Currently, SPDC applies this technique on the land surface layer only, based on the assumption that given the nature of the oil, temperature and an underlying layer of clay, hydrocarbons will not move deeper. However, this basic premise is not sustainable as observations made by UNEP show that contamination can often penetrate deeper than 5 m and has reached the groundwater in many locations.

- Ten out of the 15 investigated sites which SPDC records show as having completed remediation, still have pollution exceeding the SPDC (and government) remediation closure values. The study found that the contamination at eight of these sites has migrated to the groundwater.

- In January 2010, a new Remediation Management System was adopted by all Shell Exploration and Production Companies in Nigeria. The study found that while the new changes are an improvement, they still do not meet the local regulatory requirements or international best practices.

Summary of recommendations

The study concludes that the environmental restoration of Ogoniland is possible but may take 25 to 30 years. The report contains numerous recommendations that, once implemented, will have an immediate and positive impact on Ogoniland. Further recommendations have longer timelines that will bring lasting improvements for Ogoniland and Nigeria as a whole.

The hydraulic connection between contaminated land and creeks has important implications for the sequence of remediation to be carried out. Until the land-based contamination has been dealt with, it will be futile to begin a clean-up of the creeks.

Due to the wide extent of contamination in Ogoniland and nearby areas, and the varying degrees of degradation, there will not be one single clean-up technique appropriate for the entire area. A combination of approaches will therefore need to be considered, ranging from active intervention for cleaning the top soil and replanting mangrove to passive monitoring of natural regeneration. Practical action at the regulatory, operational and monitoring levels is also proposed.

It is recommended that the restoration of mangroves be viewed as a large-scale pilot project in which multiple approaches to clean-up and restoration, once proven, can be replicated elsewhere as needed in the Niger Delta.

Emergency measures

The report identifies eight emergency measures which, from a duty of care point of view, warrant immediate action.

Emergency Measures

1. Ensure that all drinking water wells where hydrocarbons were detected are marked and that people are informed of the danger
2. Provide adequate sources of drinking water to those households whose drinking water supply is impacted
3. People in Nsisioken Ogale who have been consuming water with benzene over 900 times the WHO guideline are recorded on a medical registry and their health status assessed and followed up
4. Initiate a survey of all drinking water wells around those wells where hydrocarbons were observed and arrange measures (1-3) as appropriate based on the results
5. Post signs around all the sites identified as having contamination exceeding intervention values warning the community not to walk through or engage in any other activities at these sites
6. Post signs in areas where hydrocarbons were observed on surface water warning people not to fish, swim or bathe in these areas
7. Inform all families whose rainwater samples tested positive for hydrocarbons and advise them not to consume the water, and
8. Mount a public awareness campaign to warn the individuals who are undertaking artisanal refining that such activities are damaging their health.

- To begin prioritizing specific locations to be cleaned up, restored or rehabilitated, the report suggests the following framework:
  - **Priority 1.** All instances where the Ogoni community is known to be at risk
  - **Priority 2.** Instances where contamination could potentially affect the community (e.g. where groundwater, fishing grounds or agricultural land are impacted)
  - **Priority 3.** Instances where a community's livelihood support base is impacted, and
  - **Priority 4.** Instances where there is no immediate risk to people but where there is non-compliance with the law.

Operational recommendations

- Immediate steps must be taken to prevent existing contaminated sites from being secondary sources of ongoing contamination while further risk assessments and investigations are undertaken for detailed planning of the clean-up of Ogoniland during a recommended Transition Phase.

- All sources of ongoing contamination, including the artisanal refining which is currently ongoing in the creeks, must be brought to a swift end before the clean-up of the creeks, sediments and mangroves can begin.

- A campaign in Ogoniland to end illegal oil-related activities should be jointly conducted by the government, oil companies and local authorities. It should include an awareness component highlighting the disproportionate environmental footprint of artisanal refining (borne by all sections of the community) and spell out training, employment and livelihood incentives that will encourage people away from participating in this illegal activity.

Technical recommendations for environmental restoration

- **Surface water**. Clean-up activities of the mangroves and soil should not be initiated before all possible measures are taken to stop ongoing pollution from reaching the creeks.

- **Restoration of swamplands.** The most extensive area in terms of treatment of contamination will be the topsoil from the swamplands. The two main options are manual cleaning of contaminated topsoil and low-pressure water jetting. A portable facility which can be fixed on a barge, move through the bigger creeks and act as a base for decontamination crews, should be considered.

- A proposed **Integrated Contaminated Soil Management Centre** will be a modern industrial enterprise in Ogoniland employing hundreds of people. On-site 'mini treatment centres' for bioremediation and excavation water will also act as staging areas feeding the main soil treatment centre.

- **Treatment of contaminated sediments.** Decisions on intervention for sediment treatment are more complicated than simply basing them on an intervention value. Issues of erosion, vegetation damage and impact on local aquatic ecosystems as well as potential for natural recovery all need to be part of the decision-making process. In some cases, contaminated sediments will have to be dredged as part of the clean-up or they will act as reservoirs of pollution after the ongoing pollution has been eliminated.

- **Decontamination of groundwater.** The issue of hydrocarbon contamination needs to be addressed in a comprehensive manner, but clean-up actions must be site-specific. In making decisions about the clean-up of groundwater, additional factors such as proximity to the community, absorption characteristics of the soil and all possible pathways must be considered, and this will require additional data to be gathered as part of the detailed clean-up planning process.

- **Mangrove restoration.** Local nurseries should be established so that healthy, indigenous plants will be available to regenerate heavily impacted mangrove stands. Rehabilitation will focus on red mangroves along the waterfront and on white mangroves inland – which have been most severely impacted – and also on containing the spread of invasive species.

Recommendations for public health

- Everyone who has consumed water from contaminated sources should be requested to undertake a comprehensive medical examination by physicians knowledgeable about the possible adverse health effects of the hydrocarbons detected.

- A focussed medical study should be initiated to track the health of the Ogoni community over their lifetimes to ensure any possible health impacts are identified early enough and acted upon.

During and following clean-up operations in Ogoniland, a monitoring programme should be put in place which includes monthly monitoring of surface water and quarterly monitoring of sediments

Table E1. Summary of UNEP's recommendations for monitoring

Monitoring sector	Monitoring approach	Frequency
Preventive surveillance	Aerial scouting	Weekly
	Surveillance from boats	Weekly
	Surveillance of facilities and incident sites	Weekly
Groundwater	Household visits in impacted communities	One-off
	Wells around impacted sites and facilities	Monthly
Water bodies	Surface water	Monthly
	Sediments	Quarterly
	Fish	Quarterly
	Benthic organisms	Quarterly
Vegetation	Transects in creeks and oilfield sites	Once a year
	Mangrove fauna	Once a year
	Analysis of satellite imagery	Once a year
Air quality	Particulate measurements, hydrocarbons	Monthly
Public health	Cohort registry of highly exposed communities	Yearly
	Public health registry of entire Ogoniland community	Yearly

Recommendations on monitoring

- During and following clean-up operations in Ogoniland, a monitoring programme should be put in place in consultation with the national institutions mandated to deal with specific environmental issues. All monitoring activities should be communicated to the community and all results should be publicly available.

- Comprehensive air quality monitoring across Ogoniland should be initiated to detect ongoing pollution, to help establish guidelines for protecting public health and to track improvements at sites where clean-up activities are under way.

- A public health registry should be established for the entire Ogoniland population in order to determine health trends and take proactive action individually or collectively where impacts related to long-term exposure to hydrocarbon pollution are evident.

Recommendations for changes to regulatory framework

- Transfer oversight of the EGASPIN legislation from DPR to the Federal Ministry of Environment, with the concurrent transfer of staff or by recruiting and training new staff.

- Comprehensively review existing Nigerian legislation on contaminated site clean-up considering recent international developments in regulation and incorporating community consultation to determine remediation closure levels so that decisions on new legislation are seen as both transparent and inclusive.

Recommendations for Government

- The report recommends that the Government of Nigeria establishes an **Ogoniland Environmental Restoration Authority** to oversee implementation of this study's recommendations. With a fixed initial lifespan of 10 years, the Authority will have a separate budget which will accrue from an Ogoniland Environmental Restoration Fund and its staff will largely be seconded from relevant national and state institutions.

- The overall cost of the clean-up should not be an obstacle to its implementation. Therefore, an **Environmental Restoration Fund for Ogoniland** should be set up with an initial capital injection of USD 1 billion contributed by the oil industry and the Government.

It is UNEP's hope that the findings can catalyze significant environmental and social improvements in the region

To be managed by the Authority, the Fund should be used only for activities concerning the environmental restoration of Ogoniland, including capacity building, skills transfer and conflict resolution.

- A **Centre of Excellence for Environmental Restoration** should be established in Ogoniland to promote learning in other areas impacted by oil contamination, in the Niger Delta and elsewhere in the world. Offering a range of activities and services, the Centre could run training courses in environmental monitoring and restoration and ultimately become a model for environmental restoration, attracting international attention.

- Build the capacity of government agencies to enable them to fulfil their mandates, through such actions as increasing human resources and equipment, and improving the technical skills of staff.

- A public awareness campaign should be mounted to improve the community's understanding of the environmental and health impacts arising from hydrocarbon contamination in Ogoniland. This should include a formal education component in the academic curricula in the Niger Delta.

Recommendations for oil industry operators

- SPDC procedures for oil spill clean-up and remediation need to be fully reviewed and overhauled so as to achieve the desired level of environmental restoration. In addition to procedures and clean-up methods, contracting and supervision also need to be improved.

- SPDC should conduct a comprehensive review of its assets in Ogoniland and develop an 'Asset Integrity Management Plan for Ogoniland' and a decommissioning plan. These plans should be communicated to the Ogoni people.

- It is recommended that SPDC works with the Nigerian regulators to clarify the paradox of remedial intervention and target values being the same. The parties should also agree on a consultative approach to setting site-specific clean-up values.

- In the event that a decision is made to restart oil exploration and production activities in Ogoniland, the region should be treated as a green-field site of high environmental and social sensitivity. This would mean applying the latest technologies and environmental guidelines, such as re-evaluating pipeline routes to minimise environmental damage and allocating a percentage of all project costs for environmental and sustainable development initiatives in Ogoniland.

Recommendations for the Ogoniland community

- The Ogoni community should take full advantage of the employment, skills development and other opportunities that will be created by the clean-up operation which is aimed at improving their living conditions and livelihoods.

- Community members should avoid protracted negotiations over access by oil spill response teams as this means that responses to spills are delayed, resulting in a far greater environmental impact.

- The community should take a proactive stand against individuals or groups who engage in illegal activities such as bunkering and artisanal refining.

The way forward

Restoring the livelihoods and well being of future Ogoni generations is within reach but timing is crucial. Given the dynamic nature of oil pollution and the extent of contamination revealed in UNEP's study, failure to begin addressing urgent public health concerns and commencing a clean-up will only exacerbate and unnecessarily prolong the Ogoni people's suffering.

A Transition Phase is recommended to maintain momentum and begin detailed planning in the intervening period between the release of UNEP's environmental assessment and the commencement of a clean-up operation guided by an Ogoniland Environmental Restoration Authority.

While fishing was once a prime activity in Ogoniland, it was evident from community feedback and field observations that it has essentially ceased in areas polluted by oil

Introduction

Ogoniland is a kingdom
situated in the Niger Delta –
the largest river delta in Africa
and the third largest in the world

Introduction

This report presents the results of an environmental assessment undertaken by the United Nations Environment Programme (UNEP) in Ogoniland, Nigeria. The study covers thematic issues of contaminated land, groundwater, surface water and sediments, vegetation, air pollution and public health.

Ogoniland has witnessed recurrent social unrest during the past several decades over concerns related to oil industry operations, its revenue and petroleum-related contamination. Although oil industry operations were suspended in Ogoniland in 1993, widespread environmental contamination remains. Upon a request from the Federal Government of Nigeria, UNEP undertook an independent study to determine the extent of the environmental impacts arising from oil industry operations in Ogoniland. This report sets out the background and context to the present-day conditions in Ogoniland, provides a synthesis of UNEP's findings, and gives a set of overarching recommendations to deal with the multi-faceted environmental challenges currently facing the Ogoni people.

1.1 Nigeria and the Niger Delta

Nigeria, one of Africa's largest countries and its most populous, is situated in West Africa. The country covers an area of 923,768 km^2, with an estimated 4,049 km of land boundaries, shared with Cameroon in the east, the Republic of Niger in the north, Chad in the north-east and Benin in the west. In the south, Nigeria's 853-km long coastline opens onto the Atlantic Ocean.

The southern lowlands merge into the central hills and plateaus, with mountains in the south-east and plains in the north. The country's largest river is the Niger, which joins with the Benue River to form a confluence at Lokoja. The Niger Delta, located in the southernmost part of Nigeria and covering an area of some 70,000 km^2, is the largest river delta in Africa and the third largest in the world (Map 1). From a coastal belt of swamps, stretching northwards the land becomes a continuous rainforest which gradually merges with woodland and savanna grasslands in central Nigeria. The swamp, forest and woodland areas occupy about 12 per cent of the delta's land surface.

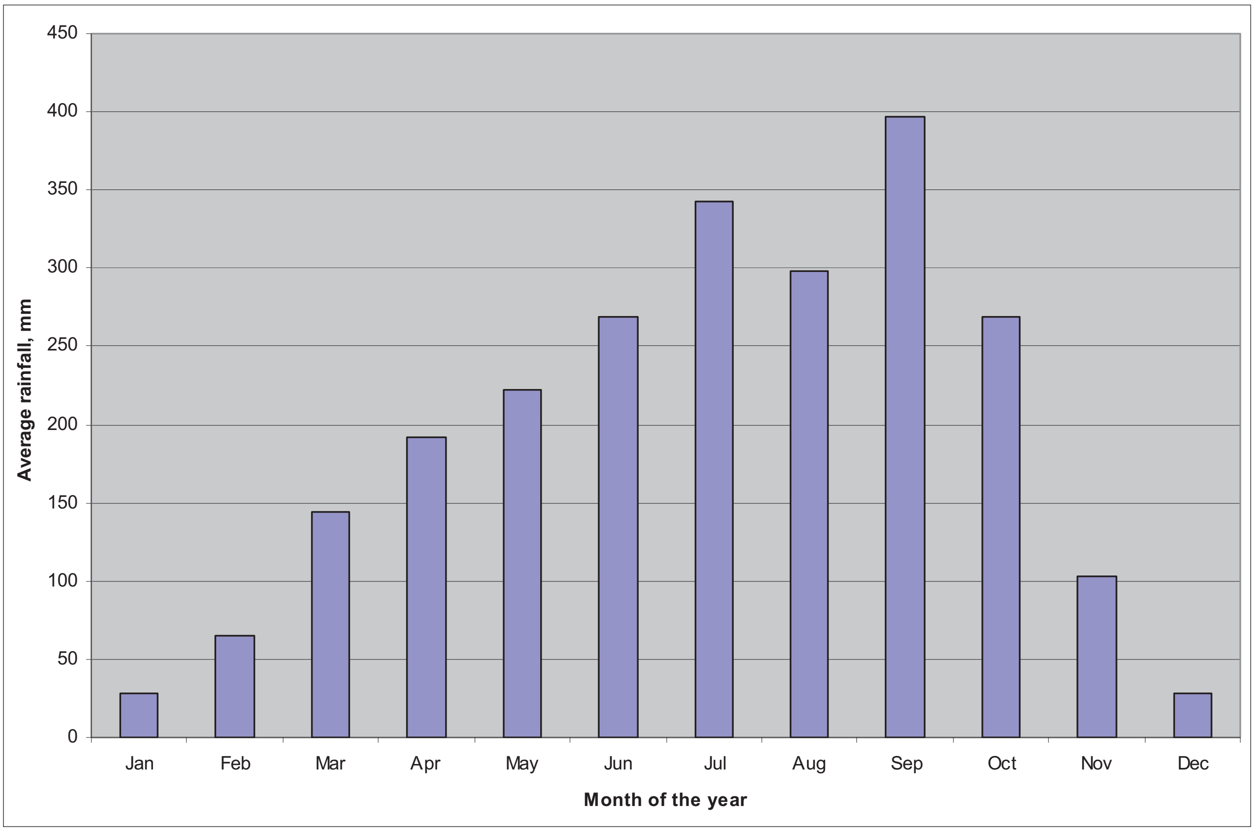
Nigeria gained independence from the United Kingdom in 1960. With a population in excess of 158 million people, Nigeria is a multi-ethnic federation divided into 36 states and the Federal Capital Territory, within which lies the capital city of Abuja. More than 250 ethnolinguistic groups are scattered across the country, but the three dominant groups are the Hausas living in the north, the Ibos in the south-east and the Yoruba mainly in the south-west [1].

Nigeria is rich in natural resources, including natural gas, petroleum, tin, iron ore, coal, limestone, niobium, lead, zinc, timber and extensive arable land. Prior to the discovery of oil in the 1950s, agriculture was the mainstay of the economy, with agricultural produce exported to the more industrialized regions of the world. By 1971 there had been a shift from agriculture to petroleum production, such that between 1973 and 1981 the value of agricultural exports fell from more than USD 1.5 billion to about USD 0.3 billion [2]. Currently, oil provides 80 per cent of budget revenues and 95 per cent of foreign exchange earnings.

A farmer tends her maize crop in Horo, Tai LGA. Prior to the discovery of oil in the 1950s, agriculture was the mainstay of Nigeria's economy

Map 1. The Niger Delta, showing Ogoniland

Figure 1. Mean monthly rainfall in Port Harcourt



Rivers State

Rivers State – in which Ogoniland, the study area for this report, is located – is situated in the coastal plain of the eastern Niger Delta. Its topography is mainly characterized by rivers, lakes, creeks, lagoons and swamps of varying dimensions. The land surface can be grouped into three main divisions from north to south: the freshwater zone, mangrove swamps and the coastal sand ridge zone.

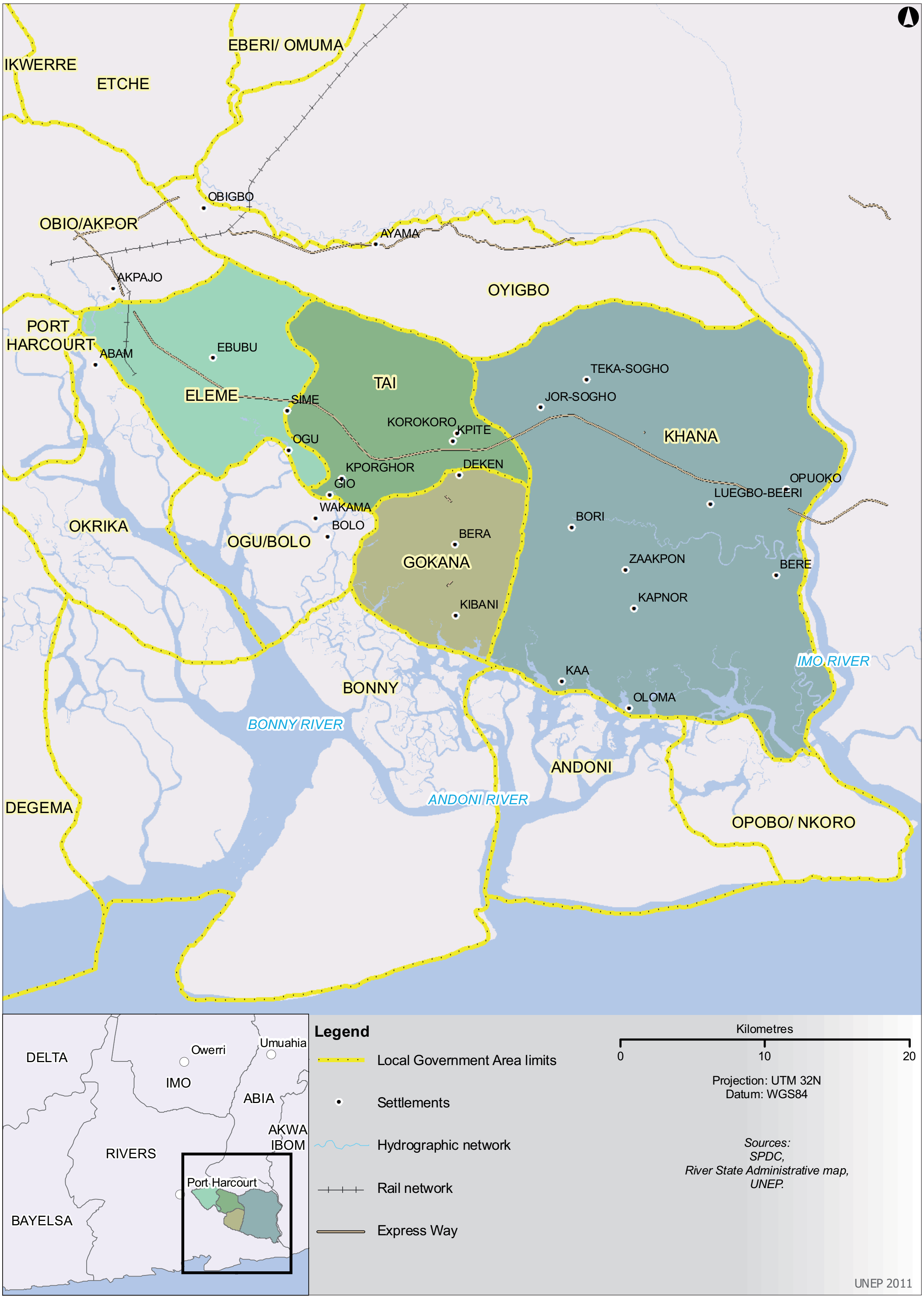
The riverine area, with a land surface between 2 and 5 metres above sea level, covers about 40 per cent of the state, while drier uplands occupy the remainder. Most water channels in the freshwater zone are bordered by natural levees that provide the basis for settlements and agriculture. The upland area varies in height from 10 to 45 metres above mean sea level (msl), but the majority is below 30 metres asl. Its surface is interspersed by small ridges and shallow swamp basins, as well as by gently sloping terraces intersected by deep valleys that carry water intermittently. The southern part is subject to tidal influences and is highly susceptible to recurrent inundation by riverine flooding. These flow patterns are responsible for the deposition of fine-grained sediments in the delta.

Rainfall, which is variable but heavy across much of the country, occurs throughout the year, decreasing from around 4,700 mm/year in the south to around 1,700 mm/year in the north of the state. The rainy season, which in coastal and south-eastern parts of Nigeria begins in February or March, lasts about 330 days, with 250 mm or more of rain per day at times. The state's capital, Port Harcourt, has about 180 rainy days per year (Figure 1). Temperatures range from 28°C to 33°C. The hottest months are February to May, with high relative humidity throughout the year, decreasing slightly in the dry season.

Ogoniland

Ogoniland is a region covering some 1,000 km^2 in the south-east of the Niger Delta basin (Map 2). It has a population of close to 832,000, according to the 2006 National Census, consisting mainly of the Ogoni people. The region is divided administratively into four local government areas:

Map 2. Ogoniland, showing the four Local Government Areas



His Majesty King Godwin N.K. Gininwa, Ogoniland's Paramount Ruler

Eleme, Gokana, Khana, and Tai. Traditionally the area is formed by six kingdoms (Babbe, Eleme, Gokana, Ken-Khana, Nyo-Khana and Tai) with His Majesty King Godwin N.K. Gininwa as the area's Paramount Ruler. While to the outside world the communities of Ogoniland may appear similar, they have distinctive differences, including traditional institutional structures, languages and cultural features.

1.2 Impacts of oil exploration and production

Oil exploration in Ogoniland commenced in the 1950s and extensive production facilities were established during the following three decades (Table 1). These operations were handled by Shell Petroleum Development Company (Nigeria) Ltd (SPDC), a joint venture between the Nigerian National Petroleum Company (NNPC), Shell International, Elf and Agip.

Table 1. Oilfield facilities in Ogoniland at the cessation of oil production, 1993

SPDC facility	Number
Oilfields	12
Wells drilled	116
Wells completed	89
Flow stations	5
Flow station capacity (barrels per day)	185,000

Oil exploration and production projects may have impacts on the natural environment long before any oil is actually produced. These are complex, multi-faceted projects, with many different phases, including: land survey, land clearance for seismic lines, establishment of seismic and drilling camps, site preparation, infrastructure construction, drilling for oil (even when the effort is unsuccessful) and development of transportation infrastructure. Once a facility begins operating other issues have to be dealt with, such as spills caused during oil production and the disposal of water (often salty and known as 'produced water') and flaring of gas ('produced gas') generated alongside the oil. All of these activities and their effects leave an environmental footprint.

The oil industry's environmental awareness and standards in the 1960s were very different and lower compared to those of the present day. This impact was exacerbated by the Nigerian Civil War (known widely as the Biafran War) in the late 1960s, during which oil industry infrastructure was targeted and a number of facilities were damaged, with consequent spillage of oil and widespread pollution.

1.3 The Ogoni struggle and the cessation of oil exploration and production

While oil exploration and the associated social and environmental consequences in Ogoniland began prior to Nigeria's independence, the situation did not improve when the country gained independence in 1960. Environmental incidents, such as spills and uncontrolled flares, continued to occur in the area and responses were slow and inadequate.

Partly in response to the environmental consequences of oil production, the Movement for the Survival of the Ogoni People (MOSOP) was founded under the leadership of the Nigerian author Ken Saro-Wiwa. A staunch defender of the rights of the Ogoni people, Saro-Wiwa criticized oil companies and the government's oil policy and brought international attention to the Ogoni cause.

In 1990, MOSOP presented the Ogoni Bill of Rights to the Federal Government of Nigeria [3]. The Bill included a number of references to environmental issues. In 1993, Saro-Wiwa joined 300,000 Ogoni on a march to demand a share in oil revenues and greater political autonomy [4]. The conflict within the region, however, was not resolved in a peaceful manner. As a consequence of the ensuing violence, oil exploration and production activities in Ogoniland ceased in 1993.

In November 1995, following a trial by a military tribunal, Saro-Wiwa and eight other Ogoni leaders were hanged in Port Harcourt. Continued social upheaval in the area further alienated the Ogoni community from SPDC, and MOSOP has since been campaigning for the total expulsion of Shell from Ogoniland.

While no oil production has taken place in Ogoniland since 1993, the facilities themselves have never been decommissioned. Some oil pipelines carrying oil produced in other parts of Nigeria still pass through Ogoniland but these are not being maintained adequately. Consequently, the infrastructure has gradually deteriorated, through exposure to natural processes, but also as a result of criminal damage, causing further pollution and exacerbating the environmental footprint.

A UNEP project team member at a wellhead at Ebubu Ejama, Eleme LGA, typical of the oil infrastructure progressively installed in Ogoniland since the late 1950s

1.4 Reconciliation process

In 1999, democracy was re-established in Nigeria and legislation to increase revenue sharing within oil-producing regions soon followed. However, as the Ogoniland oilfield lay dormant, the Ogoni people were unable to benefit from these reforms. The country's political leadership therefore decided to establish a mechanism whereby the oil industry operator could enter a process of reconciliation with the Ogoni community, enabling oil production to recommence and the community to benefit from the new revenue-sharing legislation.

In 2005, His Excellency Olusegun Obasanjo, President of the Federal Republic of Nigeria, appointed Reverend Father Matthew Hassan Kukah as mediator between the Ogoni and Shell. As part of the reconciliation process, an impartial, international agency would be appointed to undertake an environmental assessment and supervise the clean-up of the areas damaged by the effects of oil operations in Ogoniland.

Accordingly, in July 2006, UNEP received an official request from the Federal Government of Nigeria to conduct a comprehensive assessment of the environmental and public health impacts of oil contamination in Ogoniland, Rivers State, together with options for remediation. In response, the Executive Director of UNEP deployed a high-level mission to Nigeria in order to gain a fuller understanding of the background to the request and the expectations of the Nigerian Government. Extensive discussions took place with various stakeholders, including the President of Nigeria, local government officials and SPDC management. The UNEP team also conducted field visits to Ogoniland and met with the key Ogoni stakeholders. A series of pre-arranged, well-publicized and well-attended public meetings helped the mission to understand local community perspectives and expectations.

Following these preparatory consultations, UNEP presented a proposal (including workplans and budgets) to the Nigerian Government in January 2007 for a two-phase project:

A typical market in Ogoniland

A community meeting in Ogoniland, 2006. UNEP representatives consulted the community prior to commencing the environmental assessment

1. A comprehensive Environmental Assessment of Ogoniland, and
2. An environmental clean-up to follow, based on the assessment and subsequent planning and decisions.

The President agreed with UNEP's proposals and made two suggestions:

- A Presidential Implementation Committee, under the chairmanship of Bishop Kukah should be formed to oversee the work, and would consist of HM King Gininwa, the Paramount King of Ogoniland, and representatives of the Federal Environment Ministry, the Rivers State Ministry of Environment, the National Oil Spill Detection and Response Agency (NOSDRA), SPDC and MOSOP, and
- All expenses relating to the environmental assessment should be borne by SPDC under the 'polluter pays' principle.

These suggestions were agreed to by all parties. UNEP also made it clear that the assessment would be completely independent, and this too was accepted by all parties.

While the project was approved in 2007, administrative delays meant that fieldwork could not start until late 2009. Fieldwork and laboratory analysis were completed in January 2011. The study resulted in tens of thousands of analyses and photographs, all illustrative of the environmental situation in Ogoniland. The many separate reviews and findings have been synthesized in this final report – the main output of the Environmental Assessment of Ogoniland component of UNEP's work – to present the information in a relevant and useful manner. Before discussing the scientific findings, a series of field observations are described. The data on which this report is based are being made available online (www.unep.org/nigeria) to enable those who wish to undertake more in-depth analyses to do so.

Background to Environmental Degradation in Ogoniland

An Ogoni woman draws water from an open well. With a rich and diverse culture, the Ogoni have lived in the Niger Delta for hundreds of years
© UNEP

Background to Environmental Degradation in Ogoniland

Ogoniland is characterized by typically deltaic features: uneven terrain, numerous creeks, shallow brackish water bodies and a variety of vegetation types including swamp forest. The following section describes in detail Ogoniland's environmental setting and oil industry operations.

2.1 Environmental setting in Ogoniland and the Niger Delta

Geology

The Niger Delta is the product of both fluvial and marine sediment build-up since the upper Cretaceous period, some 50 million years ago. Over time, up to 12,000 metres of shallow marine sediments and deltaic sediments have accumulated, contributed mainly by the Niger River and its tributaries. The main upper geological layers consist of Benin Formation, Agbada Formation and Akata Formation. The Benin Formation is comprised of multiple layers of clay, sand, conglomerate, peat and/or lignite, all of variable thickness and texture and covered by overburden soil. Clay beds are discontinuous and groundwater is therefore present both as localized aquifers or in hydraulically interconnected aquifers. The ground characteristics are consistent with deltaic environments, where erosion and deposition of sediments constantly shift the course of channels, tributaries and creeks.

Groundwater

Ogoniland's aquifers are a crucial resource upon which the region's entire population depends for drinking water. The protection of these aquifers is therefore vital. These aquifers are very shallow, with the top-most groundwater levels occuring anywhere between close to the surface and a depth of 10 metres. To tap the aquifers, Ogoni communities typically construct open, hand-dug wells about 60 cm in diameter and water is abstracted either manually or with pumps. In some areas affected by localized pollution of water closer to the surface, wells can be up to 50 metres deep. In such cases, immersible pumps are used to draw water. Water levels in these aquifers are highly seasonal.

An Ogoni fisherman

Map 3. Ogoniland is marked by numerous deltaic creeks

Fresh groundwater can also be found in the shallow, sandy and unconfined aquifers of the coastal beach ridges, river bars and islands in the mangrove belt, as well as at varying depths in confined aquifers. A large number of wells drilled in the coastal area produce brackish (salty) water which is not fit for drinking. In some areas, brackish groundwater can be found at depths greater than 200 metres below ground level.

Surface water

The Rivers State region is drained by the Bonny and New Calabar river systems and numerous associated creeks and streams. Ogoniland itself is bounded to the east by the Imo River and to the west by a series of creeks (Map 3). The Imo receives freshwater inflow during the rainy season but is also influenced by tidal variations. The width and velocity of freshwater creeks increase downstream to form meandering or braided channels in the delta.

Tidal systems are confined to the southern part of the UNEP study area and comprise saline and brackish mangrove swamps with meandering tidal creeks.

Vegetation

The coastal area comprises three vegetation zones: (i) beach ridge zone, (ii) saltwater zone and (iii) freshwater zone. The beach ridge zone is vegetated by mangroves on the tidal flats and by swamp trees, palms and shrubs on the sandy ridges. The saltwater zone is mainly vegetated by red mangrove (*Rhizophora mangle*). The coastal plain and freshwater zone is vegetated by forest tree species and oil palm. The Niger River floodplains are covered by rainforest trees, oil palm, raffia palms, shrubs, lianas, ferns and floating grasses and reeds.

Mangroves have traditionally provided a variety of ecosystem services and products to the community, including fishing grounds, timber for housing, and fuelwood. Tree and shrub cover remains important in uncultivated areas. Other non-timber forest products which are important, especially for poorer households, include grass cutters, bamboo for staking of yam (edible perennial herbaceous vines), medicinal plants, vegetables, fruits and snails.

An agriculture-based economy and an increasing population have meant that most of the rainforest that once covered Ogoniland has been cleared for farming. In many places the practice of integrating farming and forestry remains, covering large areas of land and consisting mainly of oil palm and rubber plantations. The farm animal population too has increased with population density, with the animals also involved in nutrient recycling [5].

In Ogoniland, only small-sized sacred forests (shrines) of usually less than 1 ha remain in a relatively undisturbed state, while most of the remaining vegetation is highly degraded. Original vegetation consists mainly of mangroves.

Local communities

The Ogoni are a distinct people who have lived in the Niger Delta for hundreds of years. They live in close-knit rural communities, their livelihoods based on agriculture and fishing. The total population of the four local government areas (LGAs) – Eleme, Gokana, Khana and Tai – according to the 2006 National Census was approximately 832,000 (Table 2).

Within Ogoniland, four main languages are spoken, which although related are mutually exclusive: Eleme, Gokana, Khana and Tai. Linguistic experts classify Eleme, Gokana and Khana as a distinct group within the Beneu-Congo branch of African languages or, more specifically, as a branch in the New Benue-Congo family.

Table 2. Number of inhabitants by local government area (LGA), 2006 [6]

LGA	Inhabitants
Eleme	190,884
Gokana	228,828
Khana	294,217
Tai	117,797
Total	**831,726**

Ogoni women carrying wood and produce

Ogoniland is home to an estimated 832,000 people

The creeks in Ogoniland also form important transportation routes

Eleme LGA occupies the western end of Ogoniland. It has 10 clans within two administrative political blocs or units: the Nchia bloc with six clans (Akpajo, Aleto, Alesa, Alode, Ogale and Agbonchia) and the Odido bloc with four clans (Onne, Ebubu, Eteo and Ekporo). Each clan has numerous sub-communities; the Ebubu clan for example includes the Ejamah, Ochani, Obollo, Egbalor and Agbeta communities.

The oilfields in Eleme LGA, which encompass locations in Ebubu (Ejamah, Agbeta, Obollo, Egbalor), Ogale (Ajioepuori, Nsisioken, Obajeaken, Nsisioken) and Onne (Ekara), were discovered in October 1956. Oil from operations in Eleme was included in the first shipment of 22,000 barrels of crude oil exported from Nigeria to Europe in 1958.

The communities of Eleme host several major national and international establishments.

Eleme's main river is the Imu Ngololo, along which the Nigerian Naval College is based.

Gokana LGA was created out of the former Gokana Tai Eleme LGA and came into being on 23 September 1991. It comprises 17 autonomous communities. The Gokana people are mostly fishermen and farmers. Gokana is located within the South East Senatorial Zone and has both riverine and upland communities. It was also one of the major oil-producing areas in Rivers State. It shares boundaries with Tai in the north, Khana in the east, Ogu/Bolo in the west and Bonny in the south. The LGA is situated about 50 km south of Port Harcourt and 30 km from Onne industrial area.

Khana LGA is the largest of the four LGAs in Ogoniland, with a total of 106 communities and a population of 294,217 (as at the 2006 census). The people are also predominantly farmers and fishermen. The LGA has four districts: Babbe, Ken-Khana, Nyorkhana and Bori Urban. The Yorla oilfield lies in Khana LGA.

Tai LGA was created out of the former Tai-Eleme LGA in 1997, which in turn was a successor in 1991 to Gokana Tai Eleme LGA. Its administrative headquarters are at Saakpenwa. It is one of the major oil-producing LGAs in Rivers State and is composed of 27 communities and villages inhabited predominantly by farmers and fishermen. The LGA has three districts – Tua-Tua District, Nonwa Area and Kira Central District (Tai Central) – and is bounded by Oyigbo to the north, Gokana to the south, Khana to the east and Eleme to the west. Korokoro Tai, in Tua-Tua district, is one of the Tai LGA's major oil-producing communities, with one flow station and nine oil wells. It was discovered by SPDC in 1968.

Ogoni interaction with neighbouring regions

Metaphorically and practically speaking, Ogoniland is not an island. This has two implications. The first is that pollution from Ogoniland has the potential to reach and cross its boundaries, as well as entering Ogoniland from external sources. The second is that the problems of Ogoniland cannot be solved in isolation.

These issues are particularly significant with regard to pollution in creeks. Oil pollution, once it reaches the creeks, can move back and forth with the tides. Consequently, an oil spill, even around Bonny Island at the southern edge of Rivers State, can reach the coast and waters of Ogoniland. Similarly, pollution from Ogoniland can reach downstream villages such as Andoni, and eventually as far as the sea.

Cross-border environmental impacts are also relevant for oil industry infrastructure. While oil production no longer occurs in Ogoniland, crude and refined oil products transit the region via pipelines. The main SPDC oil pipeline, or trunk line, from upstream production areas runs to the export terminal at Bonny, while the pipelines from Bonny terminal to Port Harcourt refinery and from Port Harcourt refinery to Umu Nwa Nwa also pass through Ogoniland.

Pipelines in neighbouring Okirika LGA. The environmental impacts of oil operations are a shared legacy

Institutional framework

The institutional set-up and legislation related to environmental management of the oil and gas industry in Nigeria have evolved over the past 50 years and are very complex.

The Department of Petroleum Resources (DPR) under the Federal Ministry of Petroleum Resources plays a key role in regulating and enforcing environmental law in Nigeria. The DPR regulation 'Environmental Guidelines and Standards for Petroleum Industry in Nigeria' (EGASPIN) [7], first issued in 1992 and reissued in 2002, forms the basis for most environmental regulation of the oil industry.

In 1999, the Federal Ministry of Environment was formed, followed in 2006 by the establishment of the National Oil Spill Detection and Response Agency (NOSDRA). Both of these institutions base their operations on the DPR Environmental Guidelines and Standards.

There are also ministries at the state level; the Rivers State Ministries of Environment and Water Resources both have the management of environmental issues in Ogoniland within their mandates. Local government bodies do not have an official role in either environmental management or regulation of the oil industry, but have *de facto* involvement with both issues because of their physical presence 'on the ground'.

The long history of environmental problems caused by oil spills also gives the Nigerian judicial system a prominent role as it deals with penalties and punishments for environmental and oil-related offences and crimes, as well as with compensation claims for victims.

2.2 Petroleum hydrocarbons: origin and environmental consequences

Origin and use

'Petroleum' originates from two Latin words: 'petra' meaning rock, and 'elaion' meaning oil. Hydrocarbons refer to chemical substances formed exclusively from carbon and hydrogen. Petroleum hydrocarbons are thus naturally occurring hydrocarbon substances and, depending on the length of the carbon chain, can occur in gas, liquid or solid form. Hydrocarbons are formed by the decay of organic substances trapped within sedimentary rocks. High temperatures and pressure convert the trapped matter into hydrocarbons. Liquid hydrocarbon found in nature is also referred to as crude oil [8].

Visible hydrocarbon pollution on surface water in Ogoniland

Crude oil consists of a complex mixture of hydrocarbons of various molecular weights. In addition nitrogen, oxygen and sulphur occurs in small quantities. The hydrocarbons consist of alkanes (paraffins) and cycloalkanes (naphtalenes) that are saturated hydrocarbons with strait or branched chains of hydrocarbon molecules. Alkanes and cycloalkanes which normally constitute the dominating part of the oil, about 80%, have similar properties but cycloalkanes have higher boiling points. The remaining hydrocarbons are aromatic, meaning the molecules are unsaturated made up of benzene-rings. To this group of molecules belongs the polycyclic aromatic hydrocarbons (PAHs – also known as polyaromatic hydrocarbons or polynuclear aromatic hydrocarbons), some of which are know for their carcinogenic properties. One additional group of hydrocarbons that occur in varying amounts up to 10% in crude oil is the asphaltenes, which are molecules with relatively high weight. Oils consisting of a relatively high proportion of asphaltenes tend to be thick almost like asphalt.

The use of crude oil has created at least four major industrial groups:

1. The exploration and production industry, which searches for, finds and then produces crude oil
2. The oil and gas tanker industry, which transports crude oil and refined products around the world
3. The refining sector, which breaks down crude oil into a number of products, including diesel, petrol and specialty oils
4. The petrochemical industry, which takes crude oil-derived hydrocarbons as feedstock and converts them into a range of everyday products used in modern living

Environmental consequences of hydrocarbons

While the economic significance of hydrocarbons as the primary source of fuel and its versatile application in downstream industries are obvious, the product may also have major environmental consequences [9].

Oil exploration, production and processing represent prime sources of exposure to petroleum hydrocarbons. But there are other possible sources, such as vehicle and generator emissions, burning of vegetation and trash (including domestic waste), food processing and use of cooking fuels. All these activities are commonplace in Ogoniland.

In looking at the environmental consequences of hydrocarbons, it is important to remember that 'hydrocarbons' is an umbrella term used for hundreds of different organic compounds. Secondly, hydrocarbons can cause environmental consequences due to their chemical properties (e.g. toxicity) or physical properties (e.g. smothering). And lastly, owing to the very large number of hydrocarbons present in crude oil, the environmental and health impacts of all the constituent parts have not yet been fully studied or understood.

Impacts on soil

Hydrocarbon pollution of soil can occur in several ways, from natural seepage of hydrocarbons in areas where petroleum is found in shallow reservoirs, to accidental spillage of crude oil on the ground. Regardless of the source of contamination, once hydrocarbons come into contact with the soil, they alter its physical and chemical properties. The degree of alteration depends on the soil type, the specific composition of the hydrocarbon spilled and the quantity spilled. In the least damaging scenario, such as a small spill of a volatile hydrocarbon onto dry sand, the hydrocarbons evaporate fast, causing no chemical or physical damage to the soil. In other situations, for example a spill of heavy crude oil onto clay soil, the chemicals can remain within the soil for decades, altering its permeability, causing toxicity and lowering or destroying the quality of the soil. In such circumstances, the soil itself will become a source of pollution.

Contaminated soil can affect the health of organisms through direct contact or via ingestion or inhalation of soil contaminants which have been vaporized. Soil also acts as a reservoir of residual pollution, releasing contaminants into groundwater or air over extended periods of time, often after the original source of pollution has been removed [13].

Impacts on water

Hydrocarbons can enter water through direct spills or from a spill originally occurring on land

UNEP expert examining vegetation

and subsequently reaching water bodies through the effects of wind, rain, surface or sub-surface flow. Regardless of the means of entry, there will be adverse impacts though the nature and severity of such impacts is dependent on the specific chemical composition and physical characteristics of the hydrocarbon involved and the degree of concentration/dilution. Hydrocarbons can cause both physical and chemical effects in water; even very small quantities of hydrocarbon can prevent oxygen transfer in the water column, thus affecting aquatic life-support systems. The presence of mere traces of a highly toxic hydrocarbon, such as benzene, may render water unfit for human consumption [10].

Impacts on vegetation

Hydrocarbons can come into direct contact with vegetation in many ways: through spillage onto roots, stems or leaves; through spillage onto soil; through dissolved hydrocarbons in the groundwater in the root zone of the vegetation; or via air surrounding the vegetation [11]. Impacts on vegetation depend on a range of factors, from the type and quantity of the chemical(s) involved, to the life-cycle development stage of the plants concerned, and the means through which the plants came into contact with the hydrocarbon. Different vegetation types also have varying sensitivity to hydrocarbons.

In the case of Nigeria, where spillages are not immediately attended to, oil spills often lead to fires, causing total or partial destruction of vegetation. While such fires tend to be localized, more extensive fires, especially in forested regions, have the capacity to change species diversity over significant areas.

Impacts on aquatic and terrestrial wildlife

Oil spills can affect wildlife, both aquatic and terrestrial, in many ways. The severity of damage will depend on the type(s) of hydrocarbon involved, the quantity spilled, the temperature at the time of the incident, and the season. Dissolved or emulsified oil in the water column can contaminate plankton, algae, fish eggs and invertebrate larvae [12].

Intertidal benthic invertebrates located in sediments subjected to tidal variations are particularly at risk, due more to the smothering effects of thick, weathered oil reaching the coastline. Sediments often become reservoirs of hydrocarbon contamination. Meanwhile, fish can be affected via their gills or by ingesting oil or oil-contaminated prey. Fish larvae are equally at risk, particularly when oil enters nursery areas such as mangroves or other wetlands.

Physical contact with oil destroys the insulation properties of fur and feathers, causing various effects in birds and fur-bearing mammals. Heavily oiled birds can also lose their ability to fly, as well as their buoyancy, causing drowning. In efforts to clean themselves, birds often ingest oil, which may have lethal or sub-lethal impacts through, for example, liver and kidney damage.

For a more comprehensive discussion of the biological impacts of oil pollution, refer to the Guidelines on Biological Impacts of Oil Pollution prepared by the International Petroleum Industry Environmental Conservation Association (IPIECA) [13].

An Ogoni farmer harvesting plantain

Impacts on people

Petroleum hydrocarbons can enter people's bodies when they breathe air, bathe, eat fish, drink water or accidentally eat or touch soil or sediment that is contaminated with oil (Figure 2).

Crude oil contains many compounds, primarily volatile and semi-volatile organic compounds (VOCs and SVOCs), including some PAHs, as well as some other sulphur- and nitrogen-containing compounds and metals. When oil is burned, additional PAHs can be formed as combustion by-products along with inhalable fraction PM_{10} (particles measuring less than 10 microns), and respirable fraction $PM_{2.5}$ (particles measuring less than 2.5 microns). Petroleum hydrocarbons differ with respect to their behaviour in the environment and it is this behaviour that defines whether they are more likely to be in air, water, soil, sediment, food or other media that people might come in contact with.

Petroleum products can contain hundreds or even thousands of individual compounds that differ with respect to their potential impacts on people with regard to both exposure and degree of toxicity. The dose and duration of exposure has a direct influence on the effects that may follow. Some petroleum hydrocarbons are soluble in water, while others might be present in water as a separate phase of oil. People of all ages might be exposed to petroleum-contaminated surface water or groundwater when used for bathing, washing, cooking and drinking. People of all ages can also be exposed to petroleum that evaporates into the air. Members of fishing communities risk exposure to petroleum if they drink, bathe or collect shellfish in contaminated water, or if they come into contact with or accidentally ingest contaminated sediment while engaged in any of these activities.

Petroleum hydrocarbons are not efficiently taken up by plants or animals, and finfish – unlike shellfish – metabolize PAHs, preventing accumulation in edible tissue. While most foods are therefore unlikely to be important sources of exposure to petroleum hydrocarbons, farmers can suffer direct exposure from contaminated soil during their day-to-day work.

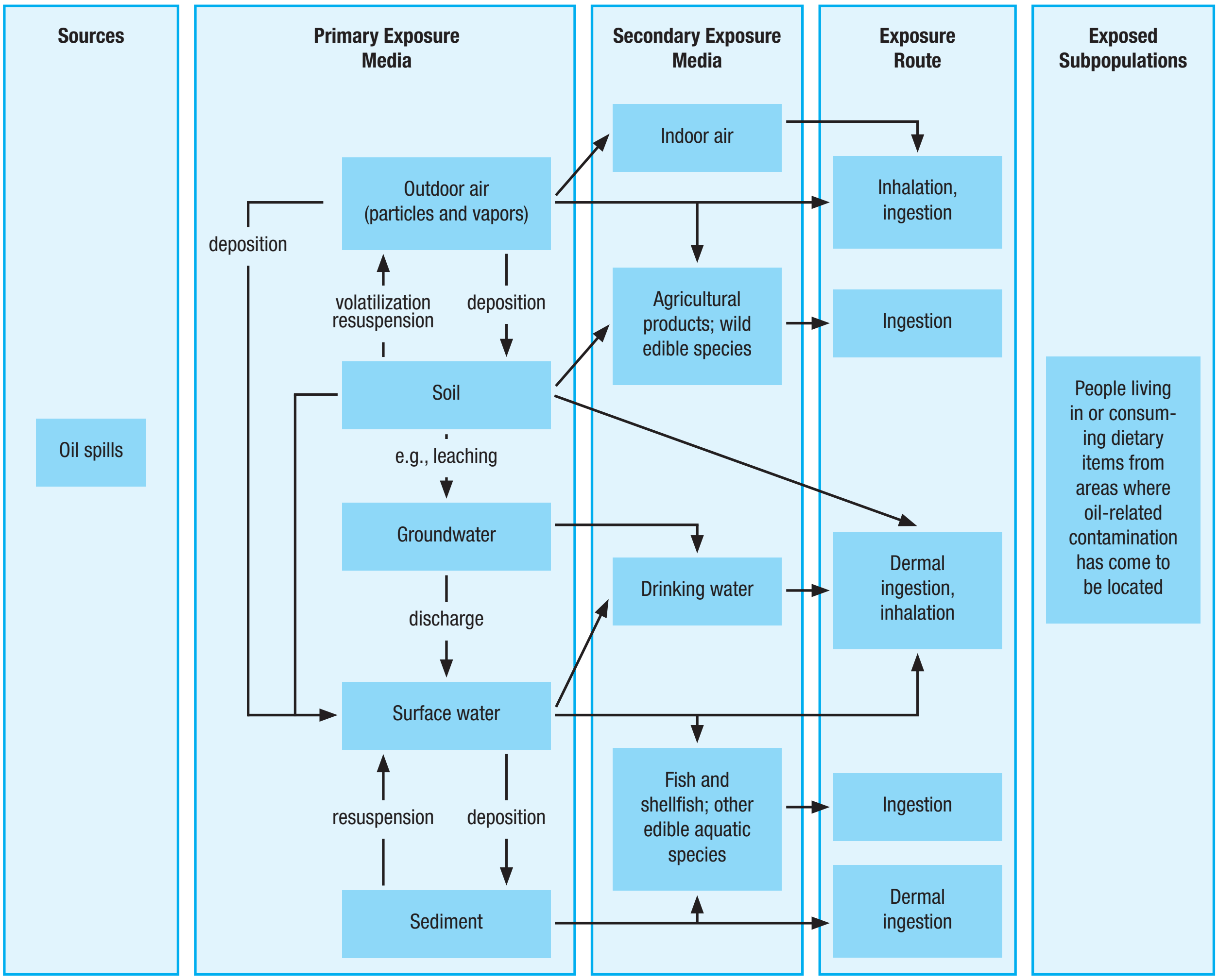
The types of chemical present in crude and refined oils and released during its combustion may lead to short-term respiratory problems and skin and eye irritation if concentrations are sufficiently high. Acute health effects of exposure to petroleum are reasonably well understood: dermal exposure can lead to skin redness, oedema, dermatitis, rashes and blisters; inhalation exposure can lead to red, watery and itchy eyes, coughing, throat irritation, shortness of breath, headache and confusion; and ingestion of hydrocarbons can lead to nausea and diarrhoea [14, 15, 16]. In addition, environmental contamination associated with oil spills and its effect on livelihoods and general quality of life could reasonably be expected to cause stress among members of affected communities, and stress alone can adversely affect health [17, 18].

Chronic effects from comparatively low-level exposure are not so well understood and might include cancer and neurotoxicity [19]. Aguilera *et al.* (2010) reviewed human health evaluations associated with oil spills around the world and found that most provided evidence of a relationship between exposure to spilled oils and acute physical and psychological effects, as well as possible genotoxic and endocrine effects [17]. Effects of oil exposure on the developing foetus are also not well understood, although adverse effects have been observed in studies involving individual petroleum hydrocarbons, including benzene and some PAHs [19, 20].

Impacts of specific hydrocarbons on environment and health

Given that there are many hundreds of different hydrocarbons, which may occur individually or in combination, their impacts on the natural

Figure 2. Conceptual model of human exposure to oil spills



environment and health of organisms are not fully understood. However, there are certain groups of hydrocarbons that are known to have adverse impacts and which are therefore dealt with selectively in oil-spill assessment and clean-up work. The most important of these groups are BTEX (benzene, toluene, ethylbenzene and xylenes) and PAHs. There are many published documents worldwide that provide comprehensive information on these groups. The following gives a brief overview.

BTEX compounds contain one aromatic carbon (benzene) ring. They have low molecular weight, high volatility and are comparatively highly soluble in groundwater. BTEX is naturally present in crude oil, often in small quantities. The concentration of these substances is increased during petroleum cracking (the breaking down of high-molecular weight hydrocarbons into low-molecular weight compounds) [21, 22].

BTEX substances are highly mobile and able to find their way into human beings through air or water relatively quickly. In addition, their toxicity also makes them more potent. Benzene, for example, is a known carcinogen, in addition to having numerous other short-term effects.

PAHs are potent pollutants that occur in crude oil, as well as in wood or coal. They are also produced as by-products of fuel burning particularly at low temperatures leading to incomplete combustion (whether fossil fuel or biomass). As pollutants, they are of concern because some compounds have been identified as causing cancer, changing genetic structures and affecting embryos and foetuses [23, 24, 25].

Non-hydrocarbon environmental issues related to the oil industry

In addition to chemical pollution by hydrocarbons, there are other environmental concerns linked with oil industry operations. These range from clearance of land for oilfield facilities, hydrological changes due to construction of roads and pipelines, and contamination from chemicals other than hydrocarbons (three of which are discussed below). Table 3 summarizes the typical impacts of oil industry operations on the environment.

Barium

Barium is a heavy metal and excessive uptake of water-soluble barium may cause a person to experience vomiting, abdominal cramps, diarrhea, difficulties in breathing, increased or decreased blood pressure, numbness around the face, and muscle weakness [26]. Barium chemicals are used by the oil industry in drilling mud, which is then often left in the mud pits around wellheads or dumped offshore [27]. In the past, no particular effort was made either to transport the mud away from the drilling location or to handle it in an environmentally appropriate manner. Consequently, it is not uncommon to find high concentrations of barium in the drilling pits.

Naturally occurring radioactive materials

Naturally occurring radioactive material (NORM) includes all radioactive elements or isotopes found naturally in the environment. Long-lived radioactive elements, such as uranium, thorium and any of their decay products, including radium and radon but also the radioisotope potassium-40, are examples of NORM. These elements have always been present in the Earth's crust and within the tissues of all organisms.

NORM encountered in oil and gas exploration, development and production operations originates in subsurface formations. It can be brought to the surface by the oil or gas itself, or by formation water, which is the by-product of the formation of oil and gas in the ground.

NORM concentrations in crude oil and natural gas are known to be low and therefore do not pose a radiological problem. Oil and gas production and processing operations sometimes cause NORM to accumulate at elevated concentrations in by-product waste streams [28] . An accumulation of NORM, such as in pigging wastes, can be problematic and must be avoided, something that the oil industry is now well aware of. As an example, radium isotopes have a tendency to co-precipitate from water phases through temperature and pressure changes in the presence of other elements such as barium. Precipitates can then be found on the surface of equipment and in sludge and ashes. The decay product of radium is radon gas which, if inhaled may pose radiological problems. NORM generally occurs as radon gas in the natural gas stream.

Workers employed in the area of cutting and reaming oilfield pipes, removing solids from tanks and pits, and refurbishing gas processing equipment may be exposed to NORM, hence posing health risks if inhaled or ingested.

Hydrogen sulphide

Since hydrocarbons are formed by anaerobic decomposition of organic matter, hydrocarbon deposits (of both crude oil and natural gas) are often found in association with hydrogen sulphide gases[29] . Hydrogen sulphide is a foul-smelling gas that can cause odour nuisance even at very small concentrations. At higher concentrations it is lethal.

Produced water

Water is often produced along with hydrocarbons [30]. More often than not it is salty, the salt concentration often exceeding that of sea water. Disposal of produced water, even after removal of hydrocarbons, onto either land or water can cause adverse environmental impacts due to its high salinity.

Table 3. Summary of the environmental impacts of oil exploration and production

Exploration and production activity	Physical activity	Impacts
Seismic activity		
	Setting up base camps	Land clearance Access creation Abstraction of groundwater Hydrological changes Sewage Solid wastes Light and noise pollution Introduction of alien and invasive species
	Cutting lines	Removal of vegetation Access Creation
	Seismic operation	Vibration Noise
Drilling operations		
	Setting up base camps	Land clearance Access creation Abstraction of water Hydrological changes Sewage Solid wastes Light and noise pollution Introduction of alien and invasive species
	Setting up drilling pads	Land clearance Access creation Hydrological changes
	Drilling operations	Noise Drill cuttings and drilling wastes Spills and leaks Light and noise pollution Nuisance odours
Production operations		
	Facility installation	Land clearance Access creation Abstraction of water Hydrological changes Introduction of alien and invasive species
	Pipeline installation	Land clearance Access Creation Hydrological changes Spillages and leaks Fires Nuisance odours Pigging wastes
	Facility operation	Noise Discharge of water Waste, e.g. from tank bottoms Spillages and leaks Fires Nuisance odours

2.3 Oil industry-related infrastructure in Ogoniland

As previously mentioned, oil industry operations in Ogoniland have been going on for more than half a century. Activities involve both upstream (exploration, production) and downstream (processing and distribution) operations. As in oil operations worldwide, these processes are managed by different entities. The two key companies with operational facilities in Ogoniland are the Shell Petroleum Development Corporation (Nigeria), which manages the upstream activities, and the Nigerian National Petroleum Company, which deals with the downstream activities.

SPDC facilities in Ogoniland

Oil production in Ogoniland ran from 1958 until 1993 when it was shut down in the face of a massive campaign of public protest against the company's operations in Ogoniland. SPDC has not produced oil in Ogoniland since.

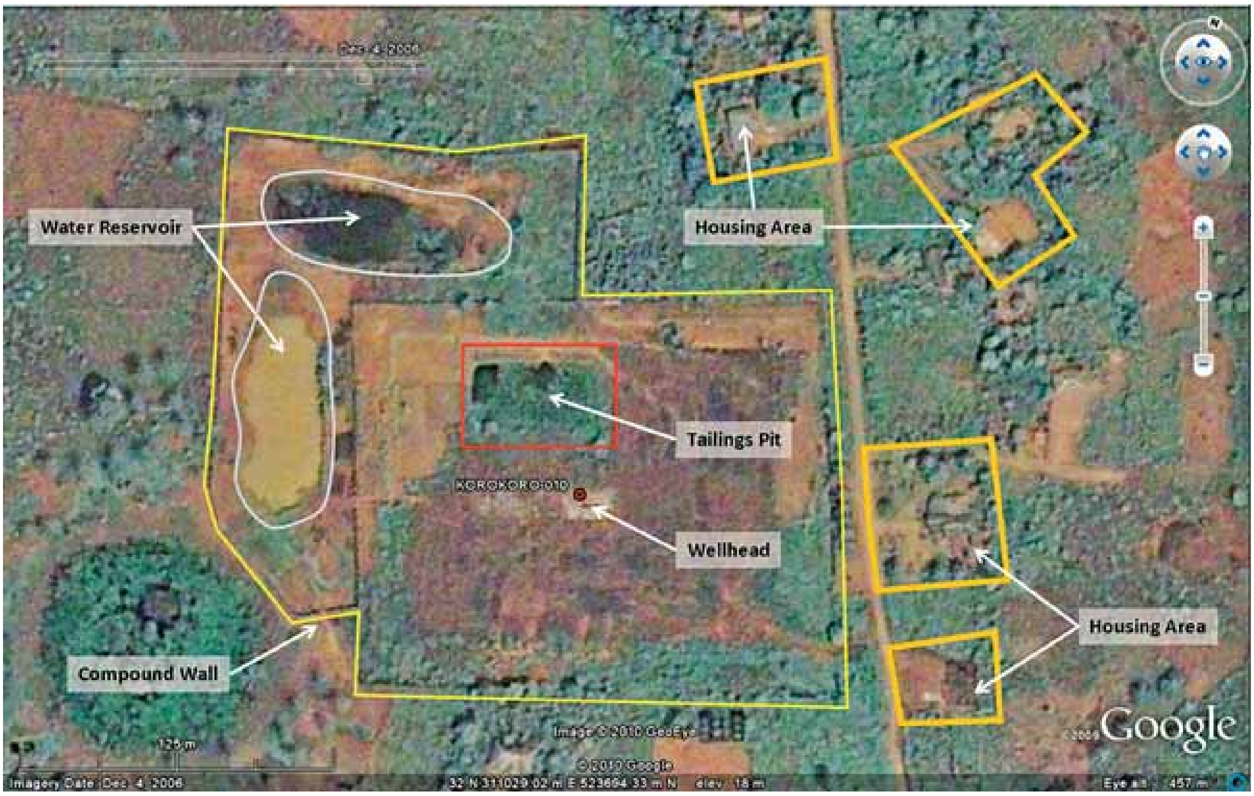
The company's technical installations in Ogoniland comprise oil wells, flow lines, flow stations, manifolds (junctions of pipes) and a number of trunk lines that pass through the region. According to SPDC the oil wells are capped and currently not producing. As a consequence, flow lines, flow stations and some of the manifolds are also not operational. Map 4 shows the extent of oil industry infrastructure in Ogoniland.

The study area for UNEP's environmental assessment contained 116 oil wells which were constructed between 1955 and 1992, as well as five flow stations and 12 manifolds. Potential sources of contamination remain, such as disused technical installations and infrastructure that was damaged or completely destroyed during the Biafran War.

Oil wells

Waste streams potentially generated by well drilling operations are drilling fluids, cuttings/tailings, formation waters and sanitary waste. Drill tailings were stored in pits which can still be identified in the wellhead areas.

Typical infrastructure of a well drilling site in Ogoniland as it appears today is shown in the image below; the tailings pit and water reservoirs are still visible. At other sites, water reservoirs were



Typical well Infrastructure (009-002 Well Korokoro 10, Tai LGA)

Map 4. Oil industry infrastructure in Ogoniland

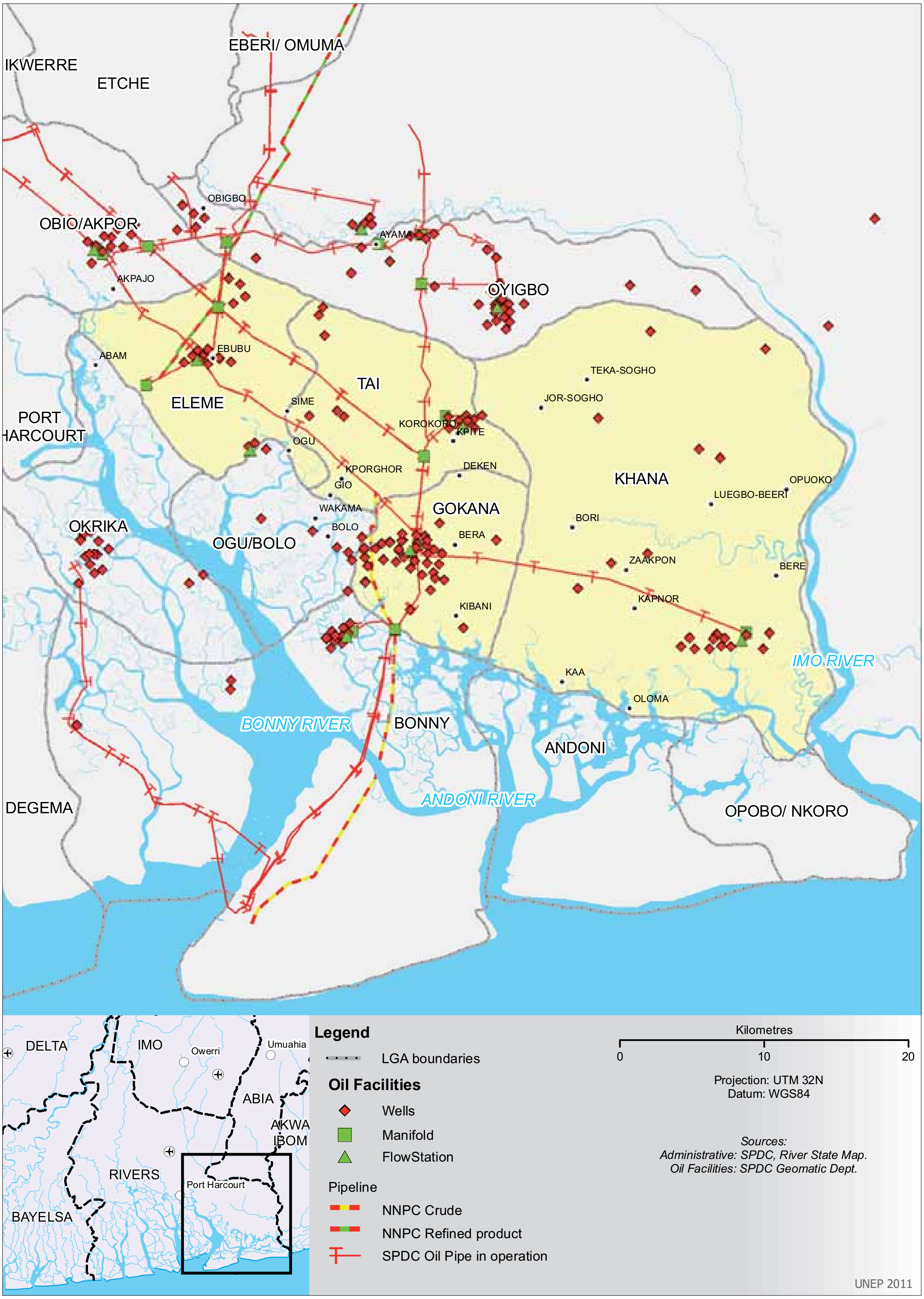


Table 4. Flow stations constructed in Ogoniland by commissioning year

Flow station	Commissioning year	Remarks
Bomu (K-Dere) -1	1958	Legacy infrastructure
Bomu (K-Dere) -2	Not available	Destroyed during Biafran War
Ebubu	1959	Legacy infrastructure
Bodo West	1963	Decommissioned
Korokoro	1965	Legacy infrastructure; 5 spills reported by SPDC
Yorla	1973	Legacy infrastructure; 3 spills reported by SPDC
Onne	Not available	Decommissioned

not present and one or more tailings pits were only visible as shallow rectangular depressions in the ground close to the wellhead.

Flow stations

Wellheads produce a mixture of crude oil, produced water and produced gas, all of which are transported to a flow station via so-called 'flow lines'. In the flow station, oil, gas and water are separated in order to produce crude oil which is then transported towards a manifold.

The gases consist largely of methane and ethane, other gases including carbon dioxide and hydrogen sulphide, along with organosulphur compounds known as mercaptans. Whereas methane, ethane and similar gases have a commercial value and can be used for energy generation, carbon dioxide and hydrogen sulphide can act as asphyxiants, potentially putting oilfield workers at risk. In addition, hydrogen sulphide and mercaptans have a certain corrosive potential which may reduce the lifespan of pipelines, pumps, etc. if not removed from the system. Since produced water is often saline, it is necessary to separate it from crude oil at the earliest possible stage to reduce its corrosive potential.

According to information supplied by SPDC, the flow stations in Ogoniland were constructed between 1958 and 1973 (Table 4).[1]

Apart from oil and gas separators, the only water treatment facilities observed by the UNEP team were simple gravimetric oil separators which were used to skim oil from the surface and discharge wastewater into neighbouring trenches, wetlands or borrow pits. The gas was reportedly flared during operation of the flow stations.

Manifolds

Manifolds collect oil streams from flow stations and transmit the flow into one or more pipelines. They consist mainly of inflowing and outflowing bundles of pipelines, as well as pumps, shutters, valves and generators. Given the large amounts of oil that are pumped through these systems, if there is a rupture, the potential for contamination is high.

Ten manifolds were located in the UNEP study area (Table 5). Of these, six were operational and four had been decommissioned. No information was available about commissioning or decommissioning dates.

1 GIS layers on SPDC-operated infrastructure and rights of way, supplied in 2009.

Typical flow station and associated infrastructure (Ebubu Ejama, Eleme LGA)

Table 5. Operational status of manifolds in the study area (UNEP, 2010)

Manifold	Status	Remarks
Alesa	Operational	Not accessible (in refinery)
Bomu	Operational	Partially operational; seven spills reported by SPDC
Bodo West/Patrick Waterside	Operational	None
Ebubu	Operational	One spill reported by SPDC
New Ebubu I	Operational	One spill reported by SPDC
Elelenwa/New Elelenwa	Operational	None
Bodo West	Decommissioned	None
Botem	Decommissioned	Two spills reported by SPDC
Horo	Decommissioned	None
Yorla	Decommissioned	None

Non-SPDC oil industry facilities in Ogoniland

The **Nigerian National Petroleum Company (NNPC)**, fully owned by the Federal Government of Nigeria, has interests across Nigeria's entire oil industry. In 1988, NNPC was commercialized into 12 strategic business units covering the full spectrum of oil operations: exploration and production, gas development, refining, distribution, petrochemicals, engineering and commercial investments.

The **Port Harcourt Refining Company (PHRC)**, a subsidiary of NNPC, is composed of two refineries: one commissioned in 1965 with a current capacity of 65,000 barrels per stream day[2] and the second

2 The maximum number of barrels of input that a distillation facility can process within a 24-hour period when running at full capacity under optimal conditions.

commissioned in 1989 with a capacity of 150,000 barrels per stream day. The latter has a crude distillation unit (CDU), a vacuum distillation unit (VDU), a fluid catalytic cracking unit (FCCU) and a liquefied petroleum gas (LPG) unit. The refinery has a captive power plant with an installed capacity of 14 MW and four boilers each capable of generating 120 tons of steam per hour [31].

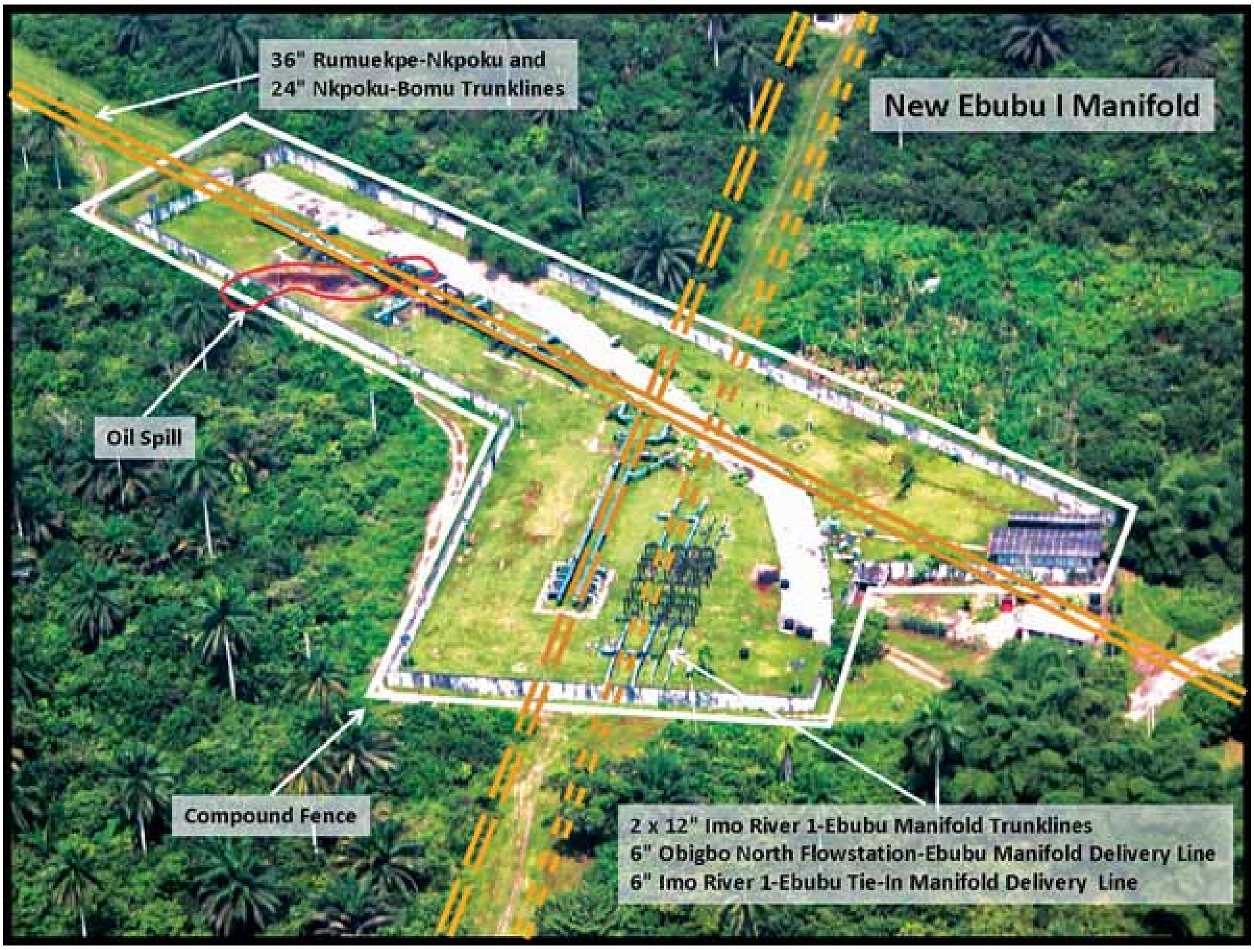
PHRC produces the following products:

- LPG
- Premium motor spirit
- Kerosene (aviation and domestic)
- Automotive gas oil (diesel)
- Low pour point fuel oil
- High pour point fuel oil
- Unleaded gasoline

Pipelines and Products Marketing Company (PPMC), is also a subsidiary of NNPC. Until Nigeria established its own refinery in 1965, all the petroleum products used in the country were imported. PPMC was created in 1988, during the reorganization of NNPC, to manage the distribution of refined products to all parts of Nigeria and to ensure they are sold at uniform prices.

Eleme Petrochemicals Company is a polyolefin producer located in Eleme, Ogoniland. Established in 1988, the company was a 100 per cent subsidiary of NNPC until, in 2006 as part of a privatization drive, the Indorama Group of Indonesia was declared core investor by the Nigerian Government-sponsored National Council on Privatization [32].

The Eleme complex is designed to produce 240,000 metric tons per year of polyethylene and 95,000 metric tons per year of polypropylene. To produce these resins, natural gas liquids are cracked in an olefin plant. In addition, the complex has the capacity to produce 22,000 metric tons of Butene-1 (a colourless, flammable,



Manifold at the intersection of pipelines (Ebubu Ejama, Eleme LGA)

Oil-related infrastructure in Ogoniland

liquefied gas) per annum, used as a comonomer in the production of linear low-density polyethylene. Currently occupying 400 ha of land, Indorama is planning to expand the complex to make it the petrochemical hub of Africa.

For the purposes of this report, the key agencies of interest are the Port Harcourt Refining Company, which operates the refinery in Ogoniland, and the Pipeline and Products Marketing Company, which has product pipelines running through Ogoniland.

Oil industry infrastructure was progressively installed in Ogoniland between the 1950s and 1990s, when oil production in the kingdom was shut down in 1993

Objectives, Scope and Methodologies

A multidisciplinary team of international and Nigerian experts conducted fieldwork for the UNEP assessment over a 14-month period
© Mazen Saggar


UNEP

Objectives, Scope and Methodologies

3.1 Objectives

Based on the initial request from the Government of Nigeria and the background work undertaken by UNEP, the following objectives were formulated for the assessment:

1. Undertake a comprehensive assessment of all environmental issues associated with the oilfield related activities in Ogoniland, including the quantification of impacts
2. Provide useful guidance data to undertake remediation of contaminated soil and groundwater in Ogoniland
3. Provide specific recommendations regarding the scope, modalities and means of remediation of soil and groundwater contamination
4. Technical evaluation of alternative technologies which could be employed to undertake such remediation
5. Provide recommendations for responding to future environmental contamination from oilfield operations
6. Provide recommendations for sustainable environmental management of Ogoniland
7. Enhance local capacity for better environmental management and promote awareness of sound environmental management and sustainable development
8. Be part of the peace dividend and promote ongoing peace building efforts.

The full project document approved by the PIC is available online.

3.2 Scope of the investigation

Geographical scope

The geographical scope of the investigation concerned the areas in and around Ogoniland, with a specific focus on the four Ogoniland local government areas (Eleme, Gokana, Khana and Tai). However, the precise location of the boundaries between these LGAs and neighbouring LGAs was not always evident on the ground. Nor did official information necessarily correspond to local community understanding. Consequently, some of the assessment and sampling work straddled the officially mapped boundaries of the four LGAs.

UNEP technical assistant obtaining fish at a local market

Bodo West is an area within the extensive network of deltaic creeks. Though uninhabited it includes a number of oil wells. The wells themselves are submerged, while the associated production station (now decommissioned) is on land. Bodo West is officially mapped as belonging to Ogu/Bolo LGA but since there are no local settlements, it has been regarded by both SPDC and the Ogoni people as part of the Ogoniland oil facilities. Bodo West was therefore included in the scope of UNEP's work.

UNEP's investigations of surface water, sediments and aquatic biota focused on two major water systems, namely the Imo River in the east of Ogoniland and the numerous creeks that extend towards Ogoniland from the Bonny River.

In order to demonstrate that the environmental problems affecting Ogoniland are being felt in neighbouring areas, limited investigations were also carried out in the adjoining Andoni LGA.

Technical scope of the assessment

The investigation into **soil and groundwater contamination** focused on the areas impacted by oilfield operations in Ogoniland. These included the locations of all oil spills reported by SPDC or the local community, all oilfield infrastructure (whether still in operation or abandoned) and all the land area contaminated by floating oil in creeks. In a number of these locations SPDC had reportedly initiated or completed clean-up operations.

Investigations into **aquatic pollution** were carried out along the Imo River and the creeks, focusing on surface water quality, sediment contamination and contamination of fish. Since not all the fish consumed by Ogoni communities come from local water bodies, fish sold at local markets were also examined to establish whether contaminated food is reaching Ogoniland from external sources.

Surveys of **vegetation contaminants** were also made of vegetation around spill sites and mangroves impacted by oil pollution.

The impact of **pollutants on public health** was assessed in three ways: by taking air quality measurements in communities around spill sites, by measuring drinking water quality around spill sites and by a review of public health data obtained from medical centres in Ogoniland. To gain a better understanding of the data, a preliminary social survey of local communities was undertaken.

In reviewing the **institutional and legal structures** related to the environment and the petroleum industry in the Niger Delta, UNEP looked at the governmental institutions directly involved: the Federal Ministry of Environment, NOSDRA and the DPR – an agency under the Ministry of Petroleum Resources which has a statutory role in environmental management.

SPDC has internal procedures dealing with a range of issues that have environmental consequences. UNEP's review of **SPDC practices and performance** included company documentation on responses to oil spills, clean-up of contaminated sites and abandonment of sites. In addition, the assessment also examined whether clean-up of oil spills and contaminated sites in Ogoniland was implemented in accordance with SPDC's internal procedures. The assessment also checked whether environmental clean-up operations accorded with Nigerian national standards.

Lastly, the assessment considered the impact of **illegal operations**. In addition to the licensed operators undertaking legitimate oil production, transport and refining activities in Ogoniland, a number of groups and individuals carry out unlicensed, and therefore illegal, oil-related activities which also have serious environmental consequences.

3.3 Structure of the study team

A major scientific study of this complexity, with extensive geographical and thematic scope, can only be executed using a large team equipped with diverse skills and expertise. The task required scientific teams to work side by side with support teams composed of community, logistics and security personnel. This demanded a high level of coordination and oversight. At the peak of its work, the Ogoniland assessment team numbered over 100 people, with daily convoys into the field requiring up to 15 vehicles. The study team was organized as follows.

Project management

The study team was managed by an international UNEP project coordinator in Port Harcourt. The project was overseen by UNEP's Post-Conflict and Disaster Management Branch, based in Geneva, in conjunction with the UNEP headquarters in Nairobi.

Technical teams

Fieldwork was conducted simultaneously by technical teams covering four thematic areas: **contaminated land, water, vegetation** and **public health**. Each team was composed of international experts supported by national experts, employed by UNEP as project staff, and by senior academics and technicians primarily from Rivers State University of Science and Technology (RSUST).

As the assessment of contaminated land was the most critical part of the assessment, the **Contaminated Land Team** contained the largest number of international experts, primarily contaminated site assessment professionals with extensive experience.

Early morning field trip by members of the aquatic team, Khana LGA, August 2010

Professor Roselyn Konya, Bishop Matthew Kukah, Chairman of the Presidential Implementation Committee, and HM King Gininwa attending a project briefing at State House, Abuja, August 2010

The Aquatic Team dealt with issues of surface water, sediments and aquatic biota, and was led by experts from the World Maritime University in Sweden.

The **Vegetation Team** was led by an international expert from Bern University in Switzerland and the team's studies covered agriculture, forestry and mangroves, all important aspects of the interface between environment and livelihoods.

The **Public Health Team** looked primarily at air quality as well as public health impacts associated with environmental conditions in Ogoniland. The team was led by an international expert from Boston University, USA and supported by an expert team of Nigerian nationals.

Cross-cutting teams

Working in parallel with the thematic teams were a number of smaller teams whose role was to provide data on cross-cutting issues. These involved **remote sensing** (analysis of satellite imagery and provision of aerial photography); **legal and institutional reviews**; and **community surveys** undertaken by RSUST to establish the level of local environmental knowledge and to understand local concerns and perceptions of issues related to the oil sector. In addition, a team of Nigerian nationals, led by an international laboratory expert, ensured that all **samples of water, soil, sediments and fish tissue** collected by the thematic teams reached the correct laboratories for analysis within the shortest possible time, together with appropriate documentation and in compliance with relevant international protocols.

Support teams

A series of support teams provided specific services to the thematic teams, helping to ensure timely completion of project assignments. These teams covered:

- **Well-drilling**. Assessment of contaminated water, soil and sediment, as well as understanding the shallow geology of the Niger Delta, required a large number of groundwater monitoring wells to be drilled throughout the study area. Following an international bidding exercise, this work was assigned to Fugro International (Nigeria).

Members of the UNEP project team with Rivers State University of Science and Technology academic staff and students

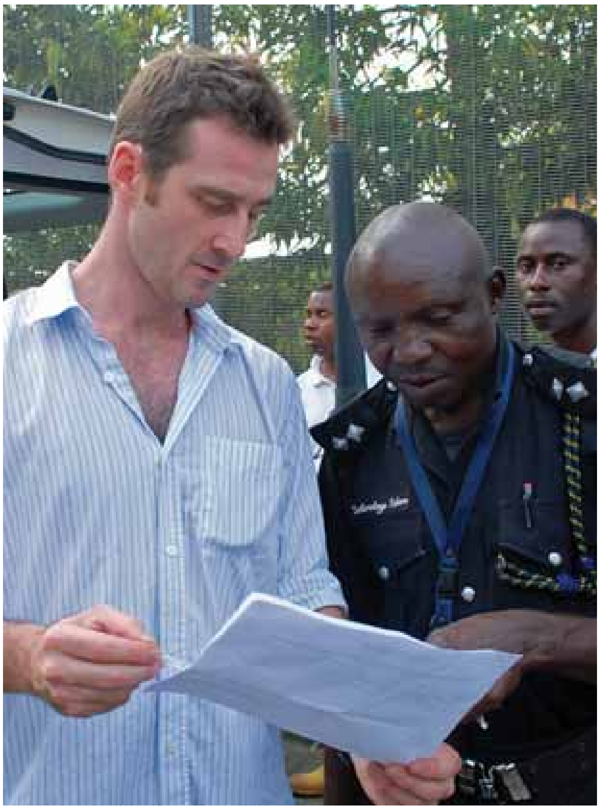

UNEP team preparing to depart into the field

- **Topographical surveys**. In order to obtain information about groundwater flow directions and quantitative information on subsurface contamination, an accurate topographic survey of selected locations throughout the study area was necessary. This work was undertaken by Universal Survey Services (Nigeria).

- **Data management**. The survey generated large quantities of scientific data in various formats, varying from completed site checklists in paper format to video records of aerial surveys. A team of national and international data experts ensured that all data collected in the field were backed up as quickly as possible on a local server at Port Harcourt, with a secondary back-up in Geneva. The Data Management Team also verified the completeness of information provided on field data sheets and cross checked the accuracy of the sample identification codes with corresponding GPS data.

- **Health, safety and logistics**. The work undertaken by the study teams was carried out in an area with serious challenges to public health, road safety and personal security, with personnel arriving and departing via the international airport in nearby Port Harcourt. A project office comprising over 30 national staff was established to assist the dozens of experts, national and international, who were constantly moving around the study area, visiting multiple sites each day. A team of safety and logistics experts was on hand throughout the fieldwork period. At the peak of the project, up to 15 vehicles were in use for fieldwork, airport pick-ups and office runs.

- **Security**. UN Department of Safety and Security (UNDSS) guidelines were followed throughout the project and operational safety was provided by the Nigerian Government. Through the cooperation of the Governor of Rivers State, a contingent of 16 Nigerian Mobile Police (MOPOL) officers provided security cover during all field deployments, as well as travel to and from the project office, accommodation and the international airport.



A project team safety and logistics expert and MOPOL superintendent discussing field trip plans

- **Land access.** Facilitating access to specific sites where UNEP specialists needed to collect data was a major exercise and one that needed to be handled delicately as ownership was not always clear, with attendant potential for local conflict. Multiple negotiations were often required, involving traditional rulers, local youth organizations and individual landowners or occupiers. A Land Access Team, provided by RSUST, working in conjunction with UNEP's Communications Team, managed these challenging issues, explaining precisely what the UNEP team would be undertaking, where and at what times.

- **Community liaison and communication**. The environmental assessment of Ogoniland was constantly in the public eye, such that there was continual demand for information. A dedicated Communications Team consisted of UNEP communications staff and community liaison staff who were familiar with the local languages. The team was responsible for explaining the purpose of the project and the specific activities to be carried out and for

UNEP distributed project information as part of its ongoing outreach to local communities ensuring that entry of the scientific teams into any community had the necessary approval from all sections of the local population (LGAs, traditional rulers, youth, police, etc.). The team provided regular project updates, for example online at the project's dedicated website and via a monthly newsletter, and also sought ongoing community input.

- **Administration**. The Administrative Team included staff from UNEP and the United Nations Development Programme (UNDP) and was based in three geographical locations: a project office in Port Harcourt, with support teams in Abuja and Geneva, which between them covered critical functions such as finance, travel, human resources and procurement.

- **Presidential Implementation Committee (PIC).** The PIC met periodically, typically once every quarter, and was briefed by the project coordinator on progress, challenges and impediments, and future work programmes.

Use of local resources

It was decided during the project planning phase that the team of international experts leading the assessment would work closely with local institutions. In addition to helping to secure the success of the project, this would enhance local capacity building and resource-sharing opportunities. The participation of local institutions was achieved in several ways. Firstly, 30 national staff were engaged in various capacities (technical, logistics, security, liaison, administrative) as part of the UNEP project team in Port Harcourt. Secondly, UNEP formed partnerships with the four LGA secretariats,

The UNEP-Rivers State University of Science and Technology Project Collaboration Coordinator, Mrs Iyenemi Ibimina Kakulu, and the university's Vice Chancellor, Professor Barineme Beke Fakae

UNEP experts during a reconnaissance exercise at Ebubu Ejama, Tai LGA, in January 2010 through their respective chairmen, which enabled access to local community leaders and gave UNEP a presence in each LGA, where its community liaison staff were allocated office space. Thirdly, each of the international thematic teams was paired with local experts and academics provided by RSUST, giving the teams ready access to local knowledge and sites, while RSUST students were brought in as technical assistants both in the field and in the project office. In addition, support teams were recruited locally wherever possible to undertake specific assessments.

Laboratories

Another decision taken early in the planning stage was that all analyses of samples collected during the study would be carried out, wherever technically feasible, by international laboratories with appropriate accreditation, in order to ensure quality and independence. Two separate laboratories were contracted: Al Control Geochem, United Kingdom, an ISO/IEC 17025:2005-accredited laboratory; and ALS Scandinavia AG, Sweden, a specialist in fish tissue analysis. NORM analyses were done at the Spiez Laboratory in Switzerland, which is also accredited to ISO 17025.

3.4 Assessment methodologies

The wide scope of the environmental assessment of Ogoniland, both geographically and thematically, is evident from Chapter 2 and sections 3.1 to 3.3 above. To overcome the challenges this presented and to achieve satisfactory outcomes for all parties involved, it was clear from the outset that a combination of standard approaches as well as innovative methodologies would be needed.

A training session at Port Harcourt, October 2009, was part of UNEP's commitment to capacity building

More than 4,000 people attended a town hall meeting at Bori, Khana LGA, in November 2009, at which the UNEP assessment project was launched. Pictured (from left to right) at the event are Senior Special Adviser to the President, Magnus Kpakol; MOSOP President, Ledum Mitee; HM King Gininwa; and HM King Barnabas B. Paago Bagia, Gbenemene Gokana

The different disciplines conducted investigations within their individual specialisms, backed by well-resourced support teams. While everything possible was done to enable interdisciplinary learning in terms of both approach and substance, the various strands had to work in parallel to complete the assessment within a reasonable time frame. Completion of the project was achieved in three phases:

1. **Scouting/reconnaissance exercises**. A team of experts conducted a series of scouting missions to the region, with two aims: (i) to become familiar with the area and (ii) to obtain community acceptance for the assessment. This was followed by structured reconnaissance of the areas where information about an oilfield facility or an oil spill incident already existed. The information documented from questionnaires and photographs allowed prioritization of a number of sites for follow-up assessment.

2. **Intensive fieldwork**. Individual thematic teams (covering soil and groundwater, water/aquatic life, vegetation, and public health), backed by cross-cutting issues teams and support teams, were deployed for the months of intensive field and office work.

3. **Analysis and writing of the report**. The teams were brought together to assess progress and review the initial analytical results. Based on this review, a final round of data gathering and analyses was carried out, after which the thematic experts prepared the individual contributions that form the basis for this synthesis report.

Phases 1 and 2 are described below in more detail. Phase 3 results are presented in chapters 4 and 5.

UNEP opened its project office in Port Harcourt in October 2009. In November 2009, senior UNEP staff met with key stakeholders in town hall meetings in the four local government areas (Eleme, Gokana, Khana and Tai). The final sampling visit was completed in January 2011. The period of most intensive fieldwork ran from April 2010 to December 2010.

Community engagement

In terms of stakeholder interest, the environmental assessment of Ogoniland was unlike any other environmental assessment previously undertaken by UNEP. In particular, it warranted community involvement and updates at all stages. This almost continuous engagement gave UNEP access to vital local knowledge concerning areas contaminated by oil, as well as consent for access to land and waterways for study purposes.

Public meetings staged throughout Ogoniland during each phase of the study helped to build understanding and acceptance of the project and to foster community participation. Between November 2009 and January 2011, more than 23,000 people participated in 264 formal community meetings (Table 6). Initially town hall meetings were held in each LGA with over 15,000 people participating. These meetings were then followed up with a series of sensitization sessions, or secondary meetings, in villages and community centres.

To provide an additional forum for open discussion of issues surrounding the study, UNEP formed a Community Consultation Committee composed of representatives from a wide cross section of project stakeholders. The committee met on average once every two months.

Table 6. Public meetings held to engage communities in Ogoniland

LGA	Number of meetings held	Number of people present
Eleme	52	3,323
Gokana	87	5,552
Khana	55	9,107
Tai	70	5,289

UNEP project team members meeting with community women leaders, November 2009

UNEP community liaison assistant addressing a public meeting, Gokana LGA, April 2010

Eight schools in Ogoniland took part in the pilot phase of a schools programme called 'Green Frontiers', initiated by UNEP to raise environmental awareness among Ogoni children and youth and to inspire practical action for conserving their environment.

Great care had to be exercised in areas where internal frictions surrounding the UNEP assessment were apt to arise. In many cases this meant that even though permission was granted initially, the project team had to withdraw as tempers became frayed. UNEP's community liaison staff were key intermediaries between the project team, local leaders and interest groups, helping to broker agreement. While team members were never at serious risk of physical attack, UNEP had to remain vigilant that a project aimed at peace-building should not engender division or violence.

3.5 Phase 1: Scouting exercises, desktop reviews and reconnaissance

The initial part of the project involved visits to the study area by experts with a view to understanding the key issues, geographical scope and practical constraints – fundamental to designing the appropriate methodology for the assessment. Scoping exercises were done in two stages: an aerial survey of the study area (Map 5), including SPDC facilities, followed by ground visits to look at oilfield infrastructure, contaminated sites and pollution-affected creeks. Where available, anecdotal information about environmental damage in Ogoniland informed this work.

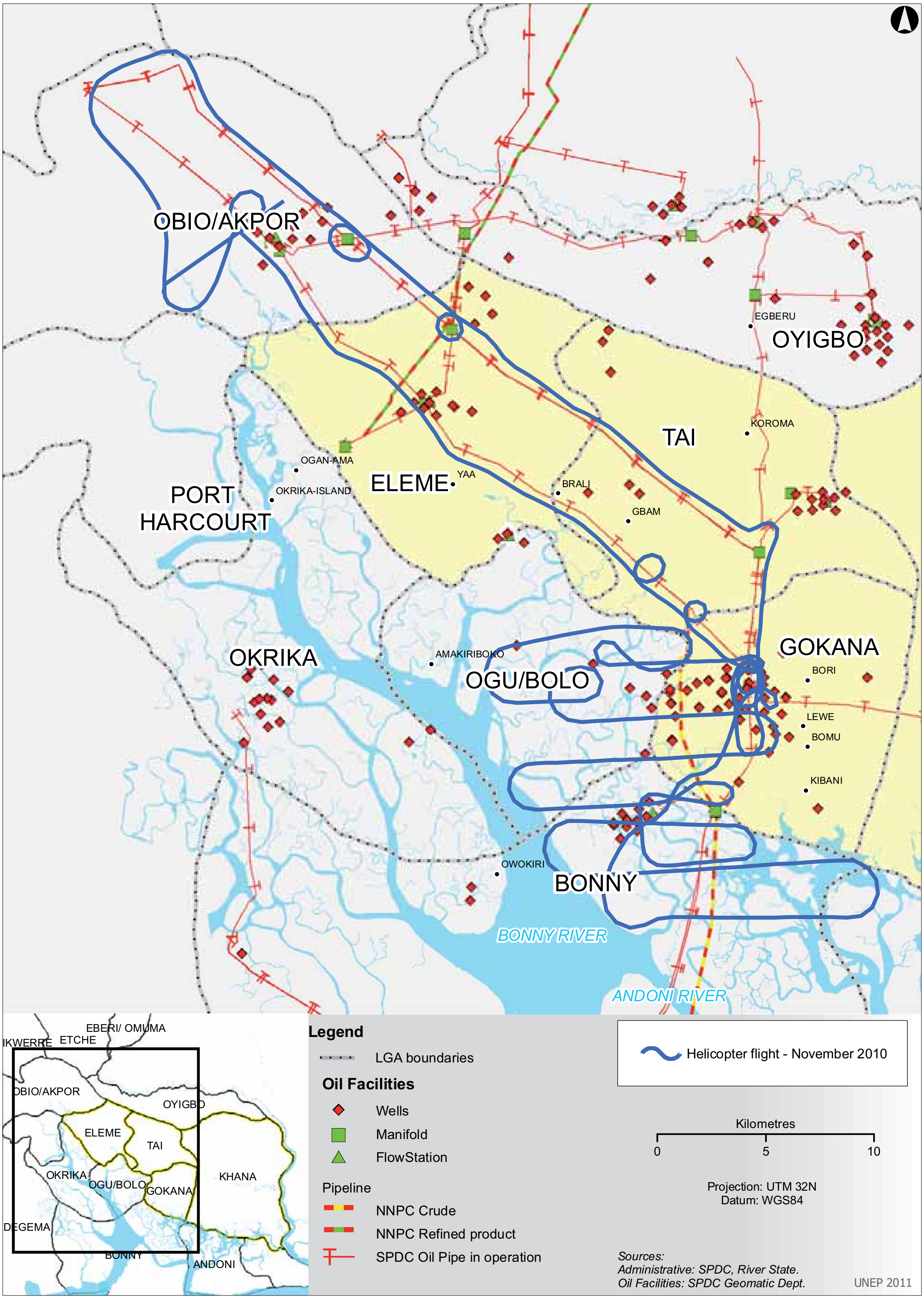
Once the scouting survey was completed, a desktop review was conducted of all available information on oilfield infrastructure in Ogoniland and known associated environmental contamination. Information on oil spills came from the SPDC oil spill database, air and ground observations by the UNEP team, information provided by local communities and information gathered from satellite images. All accessible oil wells and pipelines were visited, even if there were no reported spills at these locations.

With all the initial information assimilated, a three-step reconnaissance phase began:

1. Town hall meetings with community leaders (kings, chiefs, representatives of community elders, women and youth leaders) at which UNEP community liaison staff gave background information about the study, the tasks to be performed and the approach to be taken by the UNEP assessment teams

A UNEP technical team examines infrastructure during the reconnaissance phase

Map 5. Typical helicopter routing for aerial observation



2. Verification of landowners by land access staff who negotiated access to property and scheduled site visits

3. Location of reported spill points identified by an advance party comprised of national UNEP technical staff

With the preparatory work done, UNEP technical teams started to visit sites, equipped with standard questionnaires, GPS and GPS cameras. The basic information collected about each site included GPS coordinates, photographs, proximity to oilfield facilities, proximity to communities, any other significant environmental features, and matters of importance from a logistics and security point of view. In all, 202 locations were visited and 122 km of pipeline rights of way were surveyed.

3.6 Phase 2: Intensive fieldwork

Once the data from the reconnaissance phase had been consolidated, a prioritized list of sites for follow-up assessment was drawn up, based on the observed contamination, potential receptors and size of the impacted area. A total of 69 contaminated land sites were shortlisted for further investigation (Map 6 and see also section 4.4). Of these 67 sites were situated close to oil industry facilities. Subsequent site visits to these locations were carried out after further negotiations with, and permissions from, the appropriate communities.

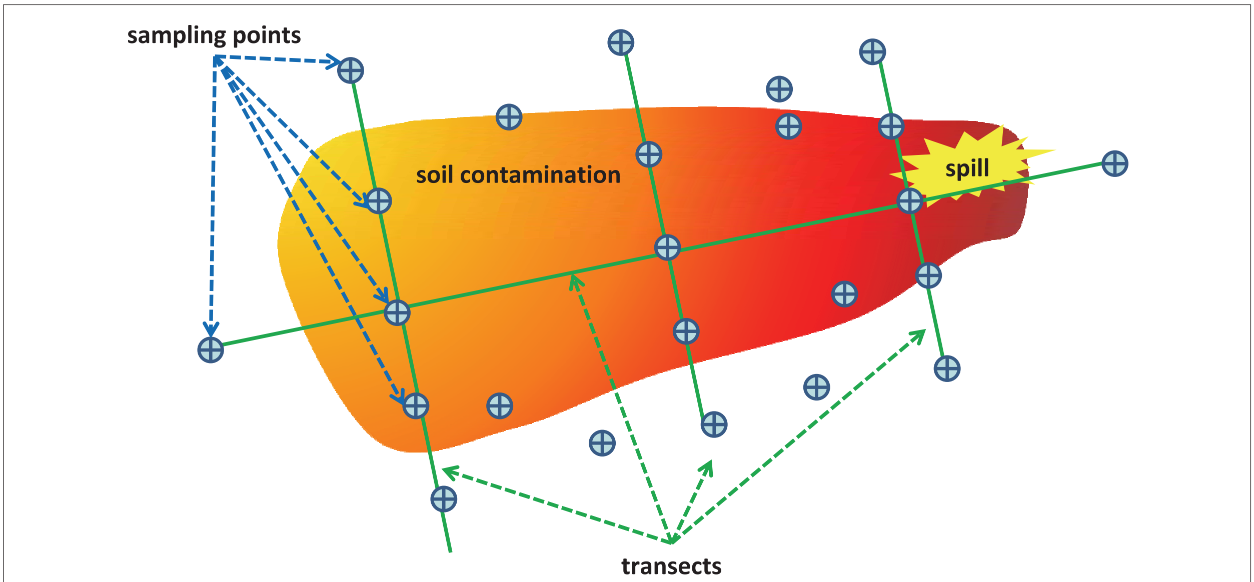
During the course of the second visit, locations for groundwater monitoring wells were delineated and the landowners involved were consulted about the planned works.

Inevitably, additional information gathered from on-site observations and field testing made it necessary to modify the work programmes at different sites, making site access and site characterization an iterative process. To achieve this, the teams on site were required to have expertise in analytical chemistry, geology, geochemistry, hydrogeology and risk analysis.

Assessment of soil contamination

The objective of site-specific sampling was to identify: (i) whether a site was contaminated and (ii) if so, whether the contamination had migrated laterally and vertically. In many instances the pollution was found to have spilled over into nearby creeks and, in the case of older spills, vegetation had started growing again. Thus it was not always easy to identify the geographical extent of a spill. Given the security conditions, access restrictions and the large number of sites to be investigated, the UNEP team could only stay at a specific site for a limited duration, often just one day. Consequently, an adaptive sampling strategy was the norm for the sites assessed, the priority being to identify the epicentres of pollution and the depth of penetration. A combination of deep sampling and surface

Figure 3. A conceptual description of typical positioning of soil sample boreholes



Map 6. Contaminated land sites investigated by UNEP

sampling was undertaken. The approach was always to identify the primary direction of spill migration and carry out cross-sectional transects covering the polluted area (Figure 3). However, this strategy often had to be modified to adapt to the prevailing ground situation and time constraints. Where the ground situation had unusual features, such as a waste pit or swamp, samples (often of sediment) were taken from the most accessible part of the area.

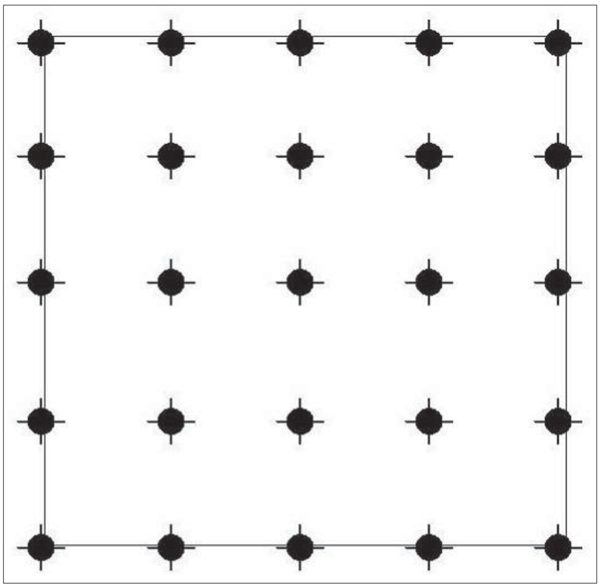
Using hand augers operated by two trained assistants, soil samples were taken out of the boreholes and spread onto a polythene sheet. The soil was segregated typically into intervals of 60 cm and samples were collected from each interval for analysis. In the first round of investigations, sampling was only carried out to a depth of 2 metres. However, after review of early results, the sampling depth was increased to 5 metres. Where monitoring wells were drilled, deeper soil samples were also collected.

In situations where extensive surface contamination was observed, composite soil samples were collected for analysis (Figure 4). In this situation, special grass plot sampling equipment was used to gather samples from a number of points. The individual samples were then amalgamated to form a composite sample. These samples are also referred to as grass plot samples.

All soil samples were analysed for hydrocarbons and non-hydrocarbon parameters.

A soil sample is spread onto a polythene sheet

Figure 4. Grid of soil samples for a composite sample



Assessment of groundwater contamination

On larger and more heavily contaminated sites, groundwater monitoring wells were installed by Fugro. This process was based on an adaptive sampling strategy. The primary intent was to verify if there was indeed groundwater contamination and if yes identify the farthest reach of the pollutant plume (Figure 5). The wells drilled by a contractor using hand-augering systems followed standard monitoring well construction practices. Wellheads were secured with lockable covers.

Subsequent to the initial phase of the assessment, 25 per cent of the wells were found to have been vandalized, making samples from such wells unreliable for inclusion in the final report. A decision was therefore taken during the later phase of the analyses to take water samples from boreholes on the same day that the boreholes were drilled. No wells were installed in these locations.

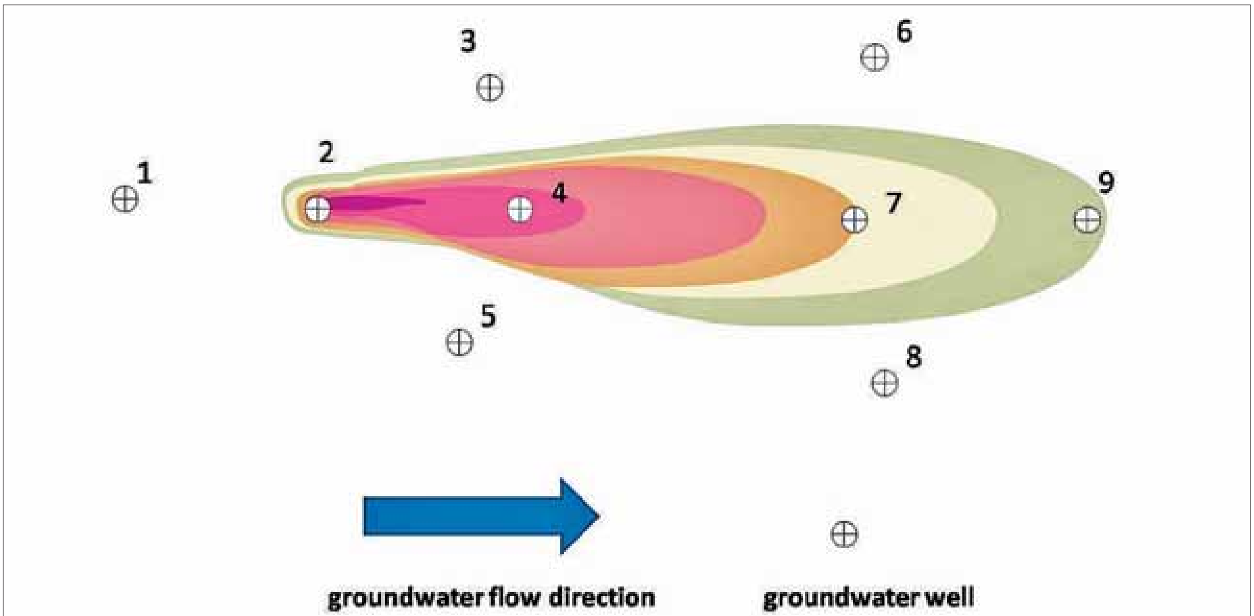
Fugro staff installing a groundwater monitoring well, April 2010

To widen the monitoring of groundwater, a number of existing community wells (both dug wells and boreholes) were included in the sampling. To ensure proper quality control, each groundwater well was given a unique identifier, marked inside the well cover. During sampling, the well identifiers were noted in the sampling protocol. An interface meter was used to measure the depth to groundwater in the wells and to verify the presence and thickness of any floating hydrocarbon product in the groundwater. Groundwater sampling was carried out with bailers. Conductivity, pH, temperature and oxygen were all documented, along with the depth to the groundwater table. When a floating free product was observed, the groundwater underneath the floating layer was not collected.

The equipment used to measure water levels was properly decontaminated between samples to avoid cross-contamination. For the same reason, disposable bailers were used for each well. Where used, the foot valve pump and hose were left securely inside the well for return visits.

All water samples were analysed for a series of hydrocarbon and non-hydrocarbon pollutants. As with the soil and sediment samples collected, each sample was assigned a unique identification number and the exact location was registered.

Figure 5. Contaminant plume and groundwater monitoring well configuration



Assessment of naturally occurring radioactive materials

An assessment of naturally occurring radioactive materials (NORM) in the study area was carried out by an expert accredited under ISO/IEC 17025:2005 between late November and mid December 2010. Wellheads, pumping stations and fresh and old spill sites were sampled. Dose-rate measurements, including surface contamination measurements, were performed at each location. In addition, freshly spilled crude oil at one site, old crude oil from a closed pumping station at another site and crude oil-contaminated soil from an old spill site were also collected [33]. For analytical purposes, a zero-reference soil sample (an old termite mound) was taken from a clearly uncontaminated location in the assessment area.

Assessment of surface water and sediment contamination

The study area was bounded on two sides by open water bodies, the Imo River on one side and a network of creeks on the other. The creeks wrapped around the study area but also extended via small side arms into inland areas. Neither the river nor the creeks were confined to the study area; the Imo originating beyond Ogoniland and flowing past it before reaching the sea and the creeks extending through and interconnecting with numerous other branches in other areas of Ogoniland.

Surface water contamination was assessed by: (i) aerial observations over the creeks, (ii) observation of water bodies from boats, (iii) observation of water bodies from land, (iv) water quality monitoring and (v) monitoring of sediments. The first three approaches were primarily based on visual observations and documented by photography. Water quality monitoring was conducted using a combination of field kits and laboratory analysis of samples taken. The monitoring of sediments was done entirely by laboratory analysis of samples.

In terms of visual observation, the focus was on identifying the presence of hydrocarbons on the surface of water bodies and, where possible, identifying the possible source of the contamination. Hydrocarbons can form very thin layers in water bodies and are therefore distinct enough to be noticed even at very low concentrations. Hydrocarbon layers were photographed using a GPS camera, which automatically fixed the coordinates.

In terms of field monitoring, a portable multi-parameter analyser was used to collect information on pH, temperature and conductivity, and the coordinates of sampling locations were logged.

Surface water sampling

In order to determine contamination of surface water samples were taken from estuaries, rivers, streams and ponds (Map 7). Samples were collected as near to the middle of the water body as could be reached using wading gear and a 2-metre extendable metal grab. Samples were collected against the flow of the water, where any flow was discernible. The sampling bottles were submerged to a depth of 10-20 cm under the surface and rinsed once with the water at that depth before the water sample was taken. If a boat was used, samples were collected at 50 cm depth by a Limnos water collector.

UNEP technical assistant collecting surface water sample

Map 7. Location of surface water, sediment and fish sampling

Sediment sampling

Areas of calm water where sedimentation occurs may accumulate pollutants which are later released through re-suspension due to tidal mixing or flooding after heavy rains or as a result of biological processes. Suitable areas for the collection of accumulated pollutants in the bottom sediment are therefore sites which consist of fine organogenic mud, sand and silt.

Sediment samples were collected at 37 locations (Map 7). At each location, five sub-samples were collected in a plastic bucket and mixed before being transferred to a glass sampling jar. In most cases a piston sampler with a diameter of 6 cm was used for sampling. Only the top 10 cm of the sediment core were used for the samples and care was taken to avoid flushing away the surface floc on top of the more solid sediment. In some locations deeper cores were taken to examine whether pollution had penetrated further down. The samples were stored frozen until the analyses were performed.

Assessment of fish contamination

In order to determine the concentrations of pollutants in the tissues of fish and shellfish, samples were collected for analysis of petroleum hydrocarbons, including PAHs.

Fish and shellfish were collected from 28 sites (Map 7), usually where sampling of water and sediment were carried out. In most cases, fish were purchased directly from local fishermen either in the process of fishing or transporting fish they had just caught. A number of fish samples from unknown origins were also purchased from local markets; although these samples could not be used to determine pollution at specific sites, their value lay in demonstrating health risks to the community where fish were found to be contaminated.

For analytical purposes, tissue samples from four to six different fish were pooled to form a composite sample. Fish tissues were obtained by cutting the dorsal muscle from the fish with a

Sediment samples were collected at 37 locations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A snapper (genus Lutjanus) is dissected for analysis. Fish and shellfish were collected from 28 sites

scalpel and transferring it to a glass jar. In most cases about 50 g of tissue was collected for each sample. All the samples were frozen and shipped to the laboratory following standard quality-control procedures.

Each sample was analysed for metals, extractable hydrocarbons, PAHs and pesticides, following internationally recognized analytical methods. The samples were homogenized prior to analysis. Preparation of samples (homogenization, extraction and clean-up) was carried out in a laboratory room used exclusively for biotic samples. Specially pre-cleaned glassware was used for organic analyses, and specially pre-cleaned Teflon beakers were used for analysis of metal samples. All preparation and analysis were carried out in a clean room environment.

PAHs and chlorinated pesticides were analysed by a process of chemical extraction, evaporation and measurement through gas chromatograph equiped with a mass spectroscopy (GC-MS). Petroleum hydrocarbons were also solvent extracted and analysed using a similar process, through a gas chromatograph-flame ionization detector (GC-FID). Samples were analysed for metals using high-resolution inductively coupled plasma mass spectroscopy (ICP-MS).

Assessment of impact of oil contaminants on vegetation

Two types of impact can be distinguished: (i) impacts related to physical disturbance, such as the cutting of seismic lines and seismographic survey, development of access infrastructure (roads, dredging of channels in wetlands) and drilling; and (ii) impacts related to oil spills and fires and disposal of other hazardous materials.

From a livelihood point of view, no relevant statistical data were available about the average productivity of agricultural crops and forest trees in Ogoniland and changes over time.

Aerial and field observations were conducted as part of the scouting surveys. Photographic records were gathered along with reference coordinates so as to cross-reference them with observations from other study segments.

Swampland vegetation (Bara, Gokana LGA)

Assessment of damage to mangroves

The scouting missions revealed extensive damage to the mangroves in the Ogoni study area and it was clear that the geographical extent was so wide that a combination of approaches would be needed to assess the overall condition of mangroves. This involved:

- aerial observations (from a helicopter) of the extent of mangrove damage, documented by aerial photography to show the progression of damage from the edge of the water to landward areas
- analyses of high-resolution satellite images to delineate impacted areas and to estimate the total mangrove area impacted by oil
- observations made from both land and water to understand the specific nature of the impacts, documented by photography
- sampling of soil on the substrata of mangrove vegetation, with a view to correlating it with the stresses on the vegetation
- sampling of hydrocarbons attached to the mangrove vegetation

Assessment of impacts on air pollution and public health

The Public Health Team designed an exposure and health questionnaire to ascertain how exposure to oil occurs and whether it is associated with adverse health effects. Students and faculty members from RSUST administered the questionnaire systematically in 10 highly exposed communities across the four LGAs. Reference communities (i.e. one with no documented oil spills or other significant known sources of petroleum hydrocarbons) were also selected (Okwale in Khana, Koroma in Tai and Intels camp in Eleme).

Medical records from four primary health-care centres (one in each LGA) serving the same highly exposed communities and from one primary health-care centre serving the reference community in each LGA were also collected and analysed.

Information from the questionnaire survey and review of medical records was combined with data from field sampling and a comparison made between the highly exposed communities and reference communities to identify any health effects that might be related to oil spills.

Preparatory work

Before gathering medical records or field samples, the Public Health Team participated in focus group discussions and sensitization meetings and listened to community concerns about the effects of oil. This information helped guide the selection of sampling locations and types of sample to be collected.

In addition, and prior to the collection of medical records, J.W. Igbara, working in cooperation with RSUST, undertook a review of public health issues associated with oil production in Ogoniland [34]. This study, which included visits to health institutions and interviews with health-care workers, took into account community complaints about fish kills, impacts on agricultural land, odours, drinking water tasting of kerosene, and a wide range of health effects from mild coughing and eye irritation to death. Many people expressed the view that environmental contamination from the oil industry had caused increased morbidity and mortality. Oral interviews with health-care workers and other key informants provided insights into health-care provision and the prevalence of disease and oil pollution issues in the study area. Some medical personnel believed that industrial activities were the cause of increased frequency of respiratory disorders (e.g. broncho- and lobar pneumonia, upper respiratory tract infections, asthma), skin conditions and gastroenteritis. Some also suggested that environmental contamination might be adversely affecting immune systems, thus increasing susceptibility to infectious disease.

Interviews and questionnaire

The Public Health Team supplemented Igbara's work through interviews with pharmacists, a traditional birth attendant and health-care professionals at facilities serving areas in each of the four LGAs where larger oil spills had occurred (Table 7). Interviewees were asked about the type and number of staff, dates of operation, medical record-keeping protocols, the number of patients seen daily, the number of beds, type of treatment provided and catchment area. There appeared to be five categories of primary health care:

Women leaders at Kpean community, Khana LGA, raising their health concerns during a sensitization meeting

government clinics, private clinics, pharmacists, traditional healers and the church. These are not mutually exclusive and the available options and choices made are changing with time. Choices are based, among other factors, on cost, accessibility, availability of services when needed (e.g. night/day), effectiveness and tradition/cultural preferences. Prenatal (called antenatal care in Ogoniland) care seems to be provided increasingly by government-funded health clinics. At least some government clinics provide free prenatal care and care for young children. However, it was not clear what fraction of the population chooses to give birth at health centres rather than at home and/or with traditional birth attendants.

Responses from community members and medical professionals helped guide selection of both the communities in which an exposure and health survey was conducted by questionnaire, and the health-care facilities where medical records were collected.

The questionnaire was used in those communities expected to have incurred some of the highest exposure to petroleum from oil spills, and included some of the communities in which air sampling and medical record collection were implemented. The questions asked – based on meetings with community members, community leaders and health-care providers – covered the respondent's demographic characteristics; pathways of exposure to petroleum from oil spills and other sources of petroleum hydrocarbons (e.g. cooking practices, smoking, local food consumption, drinking water source); and health information (e.g. health history and current symptoms, source and level of satisfaction with health-care services). Respondents were not asked directly about oil contamination.

The questionnaire was reviewed by two individuals with detailed knowledge of the community being studied, and pilot-tested by several Ogoniland residents working in UNEP's project office. RSUST students, who had been given advance training to ensure accuracy and consistency, conducted the questionnaire survey orally, with the assistance of an interpreter where needed. Heads of household were interviewed systematically until approximately 20-25 per cent of the dwellings in each community had been covered.

Table 7. Summary of samples collected by the Public Health Team

LGA	Community	Village	VOCs	$PM_{2.5}$ & PM_{10}	Rainwater	Drinking water	Medical records	Health questionnaires
Eleme	Agbi-Ogale				x	x		
	Agbonchia	Okpee	x		x			x
	Akpajo	Nsisioken	x	x	x			
	Aleto		x	x				
	Alode	Nkeleoken	x	x				
	Ebubu	Ejamah	x	x	x		x	x
	Ebubu	Obolo		x				x
	Ebubu	Oyaa-Ejamah	x					
	Ebubu	Egbalor						x
	Obajioken-Ogale				x	x		
		Ekporo		x				
Tai	Biara/Botem		x	x				
	Gio		x	x				
	Korokoro	Aabue	x	x	x	x		x
	Koroma		x	x				
	Kpite	LGA Headquarters	x	x			x	
	Kpite	Muu Boogbara	x		x			x
	Sime	Omunwannwan	x					
	Sime	Aabue						
	Norkpo 1		x		x			
Gokana	K. Dere		x		x			x
	B. Dere		x					
	Bera							x
	Bodo	Debon	x	x				x
	Bodo	Sugi-Sivibirigbara	x				x	
	Bodo	Kegburuzo Junction	x					
	Bodo-West		x	x				
	Kpor	Orboo-Ooodukor	x	x				
	Kpor	Kpalaade	x	x				
Khana	Kwawa	Wiikuekakoo	x		x			x
	Kaa							x
	Kpean	WIIYAKARAGU		x		x	x	
	Kpean	Wiiborsi	x	x	x			x
		Uewaagu	x	x				
	Okwale		x		x		x	x
	Port Harcourt	RSUST-Nkpolu-Oroworukwo	x	x				
		Intels Camp	x					

Field sampling and analysis

All field sampling took place between July and December 2010 in those communities where bigger oil spills had occurred. Sampling locations were selected according to information gathered from community members, community leaders and health-care providers, as well as from environmental monitoring data and historical information that indicated the location and extent of oil spills. The sampling programme is summarized in Table 7.

The Public Health Team's environmental monitoring programme included collection of drinking water and rainwater used for domestic purposes and measurements of outdoor air from both highly exposed communities and reference communities. These samples, combined with samples of soil, sediment, surface water, drinking water, groundwater, fish and agricultural crops collected by other UNEP scientists from the same or nearby communities, shed light on human exposure to oil-related contamination. Together these samples allowed for assessment of cumulative exposure across different media including soil and drinking water.

Rainwater and drinking water

Sampling of drinking water was warranted given that UNEP detected petroleum hydrocarbons in surface water and groundwater samples. In response, the Public Health (PH) Team collected drinking water samples in addition to those already collected by the Contaminated Land (CL) Team.

Some community members expressed concern about rainwater quality, reporting that they historically used rainwater for drinking and other purposes, but that it is now contaminated and can no longer be used for this purpose. In response to this concern, UNEP collected 35 rainwater samples from rainwater collection vessels and three rainwater samples directly from the atmosphere.

Rainwater from collection vessels represents actual exposure because people are using it for washing, bathing, cleaning food and drinking. These samples reflect any contamination that originates in the rainwater, from the rainwater catchment system, and, if the collected rainwater is uncovered for any period of time, from contamination that deposits from the air (e.g. bird droppings). Most often, the catchment system collected rainwater from a roof into a metal or plastic collection vessel. Samples of rainwater collected directly from the atmosphere reflect contamination found in rainwater in the absence of any contribution from a catchment system and/or aerial deposition onto uncovered rainwater storage vessels.

Drinking water and rainwater sampling locations included places where the community had complained about rainwater quality; this applied also to the reference community. Drinking water and rainwater from collection vessels were sampled and analysed using the same methods employed by the Contaminated Land Team. Rainwater was sampled from the atmosphere using stainless steel containers placed on a stool 1 metre off of the ground in an open area without trees or other elevated vegetation or structures. The time between onset of direct collection of rainwater and storage of the rainwater in a freezer ranged from a matter of minutes to six hours, depending on how long it took to collect a sample of sufficient quantity and transport it to the freezer.

Rainwater and drinking water samples were not filtered before laboratory analysis.

UNEP expert consulting health-care centre staff

Outdoor air

Oil spills can influence air quality. Ubong (2010) reviewed air quality data available for Ogoniland, some of which reflected conditions near oil spills, including some measurements of total VOCs [35]. UNEP's air sampling programme expanded on this work by collecting air samples from spill areas where the highest concentrations of petroleum hydrocarbons were expected in air, based on results from UNEP's investigation of soil and surface water. Priority was given to locations where UNEP detected and/or observed the highest concentrations of oil contamination on or near the ground surface or sheens on surface water. In addition, air samples were analysed for individual VOCs rather than total VOCs because the toxicity of total VOCs depends on the composition of the mixture.

The outdoor air sampling programme is summarized in Table 7 and Map 8. It included 22 VOC samples from oil spill areas, 20 VOC samples from nearby communities, 2 VOC samples from reference locations and 23 respirable particulate samples from oil spill areas and nearby communities. Nearly all the samples were collected during the dry season, which lasts from March to November. However, two sampling locations were re-sampled in December to allow for comparison between wet season and dry season air quality.

On each sampling day, air samples were collected from the oil spill area and from the community area nearest the oil spill. Samples from the oil spill location provided a 'fingerprint' of VOC release from the worst oil spills in each LGA. Samples taken from the closest community location provided measures of exposure to these worst spills, combined with background exposure from other sources of petroleum hydrocarbons, such as vehicle exhausts. Air samples were also collected from the reference community in Okwale; these samples represented conditions in Ogoniland with limited land development and no known petroleum-related operations, both of which can influence the concentration of petroleum hydrocarbons in air. Air samples were also collected from two urban reference locations just outside Ogoniland, at the Intels Camp and RSUST Campus in Port Harcourt.

A Thermo Scientific Particulate Monitor DataRAM 4 is used to measure air quality, Bodo West

Map 8. Location of air quality and public health studies

Samples were collected and analysed for selected VOCs using USEPA Method TO-17, which involves sampling with thermal desorption tubes and laboratory analysis with gas chromatography/mass spectroscopy. Thermal desorption sampling tubes were manufactured by Markes International (Markes Part No: CI-AAXX-5017 Stainless Steel TD sampling tube (industrial standard 3 1/2 "x1/4"; prepacked with Carbopack [Mesh 60/80]) and conditioned and capped with brass long-term caps. Air was drawn through the thermal desorption tube at a flow rate of approximately 50 ml per minute using an SKC AirCheck 2000 pump. The sampling train was affixed to ladders to elevate sample tubes to about 1.5 metres (i.e. approximate breathing height). The pump calibration was checked in the field at the beginning and end of each sampling period. A dual tube sampler was set up at each sampling location, with one tube sampled for approximately one hour and the other tube sampled for approximately four hours from mid-morning to mid-afternoon. Security constraints prevented longer deployment of air samplers, though desired laboratory detection limits were still achieved. One field blank tube was collected on each sampling day.

Air concentrations of respirable particulate matter ($PM_{2.5}$ µm and PM_{10} µm) were measured at each community sample location on each air sampling day using a DataRam4 (Thermo Electron Corporation, DR-4000 Model). $PM_{2.5}$ and PM_{10} concentrations were each measured for a ½-hour to 1-hour period with the instrument elevated to an approximate breathing height of 1.5 metres.

Particulate sampling locations largely overlapped VOC air sampling locations and included areas with varying amounts of nearby vehicle traffic, waste burning and garri (cassava) processing, all of which can contribute to particulate concentrations in air. In all locations the DataRam4 was placed in open, outdoor areas. The ground surface varied widely among sites, from sand to dense vegetation.

Medical records

The Public Health Team considered that medical records could be helpful in identifying unusual symptoms or disease patterns associated with living near oil spills. Many community members reported that they sought health care from pharmacists and traditional healers, but the team did not find evidence that these providers maintained patient or client records. Some general hospitals and primary health-care centres held records for as long as 10 years, some even longer, while others only had records for the previous six months. Medical records available at primary health-care centres and general hospitals generally included the patient's name, age, sex, community and LGA names, complaint or diagnosis, and treatment. Some included additional information such as body weight and occupation. Diagnoses are not confirmed by testing at primary health-care centres.

All records reviewed by the Public Health Team were maintained in handwritten log books and summarized on forms provided by the Rivers State Ministry of Health. The primary health-care centres were selected for collection of medical records because, unlike general hospitals, they serve localized areas that could be matched to oil spill locations. In addition, a general hospital that served the reference community could not be identified.

The team selected one primary health-care centre from each LGA that serves communities where large oil spills had occurred and a fifth primary health-care centre in the reference community. Medical records for the previous year (i.e. 1 September 2009 to 31 August 2010) were collected using a portable scanner so that data analysis could be performed using original records. As noted earlier, some medical facilities maintain records for as long as 10 years, but many do not. Therefore, the one-year period was selected because most primary health-care centres keep records for this length of time, allowing for comparison among them.

UNEP expert examining medical records in a handwritten log book

Table 8. Location and number of health records collected

Primary health-care centre	Number of medical records analysed
Agbonchia	1,196
K'Dere	1,581
Kpite	543
Kwawa	1,421
Okwale	268

After agreeing to participate and indicating that records were available for the previous year, the primary health-care centre in Agbonchia, Eleme could not provide records prior to February 2010, despite repeated attempts to obtain earlier records from current and retired staff. There was insufficient time within the study schedule to select and collect records from an alternative centre. While these missing data are important from a temporal perspective, their exclusion did not adversely affect the number of records relative to other primary care centres. The total number of records analysed for each primary health-care centre is given in Table 8, with differences attributable to the relative number of records available from each centre.

Original medical records were transcribed onto a single database (in Microsoft Excel) and a subset of records from each primary health-care centre was reviewed to ensure accurate data entry.

Remote sensing

The components of the environmental assessment of Ogoniland in which remote sensing (Table 9) played a key role were: land-use study, for example tracking changes in land cover; vegetation surveys, including impacts of oil on mangroves; assessing pollution of creeks and other water bodies; and research into the artisanal refining of crude oil in primitive stills (see 'Artisanal refining', page 102).

Unlike all other components of UNEP's study for which it was only possible to obtain a snapshot at the time of the assessment, for those issues studied through remote sensing analyses of changes over time were achievable. However, since satellites did not exist when oil industry operations commenced in Ogoniland in the 1950s, a baseline comparison dating back to this period was not possible.

In addition, satellite images were used intensively as a primary source of information for daily operations in the field. These included:

- navigation, from scouting exercises through to full site assessments
- land-cover mapping
- change-detection analysis – images acquired on different dates were available for most of the sites, showing changes over time in vegetation, new houses, fire, etc.
- oil-spill detection – radar images were used to detect oil spills outside Ogoniland

Table 9. Summary of all satellite/aerial images used during the remote sensing analyses

Satellite	Spatial resolution	Acquisition dates	New acquisition / Archive	Primary use	Source
WorldView 2	50 cm	02/01/2011	New acquisition	Detailed mapping; Change detection	DigitalGlobe
Ikonos	1 m	2006-2007	Archive	Detailed mapping; Change detection	GeoEye
SPOT 5	2.5 m	17/01/2007	Archive	Detailed mapping; Change detection	SPOT IMAGE
Aster	15 m	19/01/2007 03/01/2007	Archive	Land-cover mapping	ERSDAC
Landsat TM	30 m	08/01/2003 17/12/2000 19/12/1986	Archive	Land-cover mapping	GLOVIS
Landsat MSS	80 m	15/05/1976	Archive	Land-cover mapping	GLOVIS
SPOT 4-5 VEGETATION	1 km	1998-2010 10-day synthesis	Archive	NDVI trend	VITO
ENVISAT	90 m	26/09/2010	Archive	Oil spill detection	ESA
SRTM	90 m	2000	Archive	Digital elevation model	CGIAR
Helicopter	10 cm	November 2011	New acquisition	On site verification	

Table 10. Software programs used in GIS mapping of Ogoniland

Software	Use
ESRI ArcGIS	Cartography; geocoding; digitization
ESRI SpatialAnalyst	Spatial analysis
ErMapper	Satellite image compression
ErMapper	Satellite image compression
GoogleEarth / GoogleEarth PRO	Data visualization; real time tracking
Erdas	Ortho-rectification; image mosaics
Idrisi	Image classification
Surfer	Contour modelling
Strater	Borehole log production
MapWindow	Garmin waypoints and tracks management software

GIS/cartography

GIS mapping/cartography was used extensively in the Ogoniland assessment (Table 10), with more than 200 maps generated at a scale of 1:5,000. A 1:50,000 cartographic atlas was also produced, giving all those working in the field access to the same information. The atlas was frequently updated as new data arrived from the field.

Spatial analyses included proximity analysis, which recorded the distances between contaminated sites and community wells and settlements, as well as contaminant dispersion. Statistical analyses were carried out, for instance on shifts in land cover, changes to land-cover classification and areas of land impacted by contaminated sites. In addition, groundwater modelling was carried out to generate contaminant-plume contours and to depict groundwater flow direction.

Land cover classification methodology

The Landsat archive contains a number of images of Ogoniland dating back as far as 1976. The best early image, from 1986, was used to develop a classification for that year. The best readily available recent imagery came from Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER) images from 2007. Initially, it was thought that 2007 was sufficiently recent to provide a good indication of the current status of land cover in Ogoniland. This may have been true for some parts of the terrestrial area but further research showed that major changes have taken place since January 2009 in the mangroves adjoining Ogoniland.

Since no recent images were available, UNEP requested that the very high-resolution WorldView-2 satellite be programmed for acquisition in the study area. Due to the high cost of this acquisition, only a portion of the entire Ogoniland region could be captured. The image was taken on 7 January 2011 to provide an example of the current status in a selected area.

Example of an area classified as an industrial zone

The classification method adopted for the project was a two-stage hybrid procedure which used both spectral measurement from satellite images and stratification of the area into broad zones; the latter was used to make sure that within each zone the assignment of classes was appropriate. For example, pixels classified as mangrove should only occur in the mangrove zone, and pixels classified as urban should only occur in the urban zone.

First, the satellite-derived spectral information in the visible, near infrared and short-wave infrared regions of the spectrum were clustered by an unsupervised algorithm into spectrally similar clusters based solely on their spectral properties (colours). How these clusters related to land-cover classes was not known at this stage. It was assumed that different land-cover types in the landscape could be distinguished by their spectral properties. This is generally true of a range of landscape features – water, urban areas, vegetation and bare soil all have rather different visual characteristics.

To fully capture the range of diversity in the images, it was found that approximately 60 clusters had to be identified. The next step was to assign land-cover class names to each of the spectral clusters. This was done by a manual process of image interpretation, referring to any ancillary information that was available, including ground photographs and GoogleEarth images.

Each sample was assigned a unique identification number and the exact location was registered

The output of this stage was a first estimate of land cover in Ogoniland.

Different land-cover types generally have different visual characteristics – but only to a certain extent. Some land-cover types may appear spectrally similar; for example areas of freshwater swamp forest may appear very similar to mangroves but are different land-cover classes. Similarly, some urban areas may appear very similar to bare soil in rural areas. To ensure consistency of the land cover classification, a set of zones or strata were defined and each processed to ensure internal consistency according to a set of simple rules. The following zones were defined:

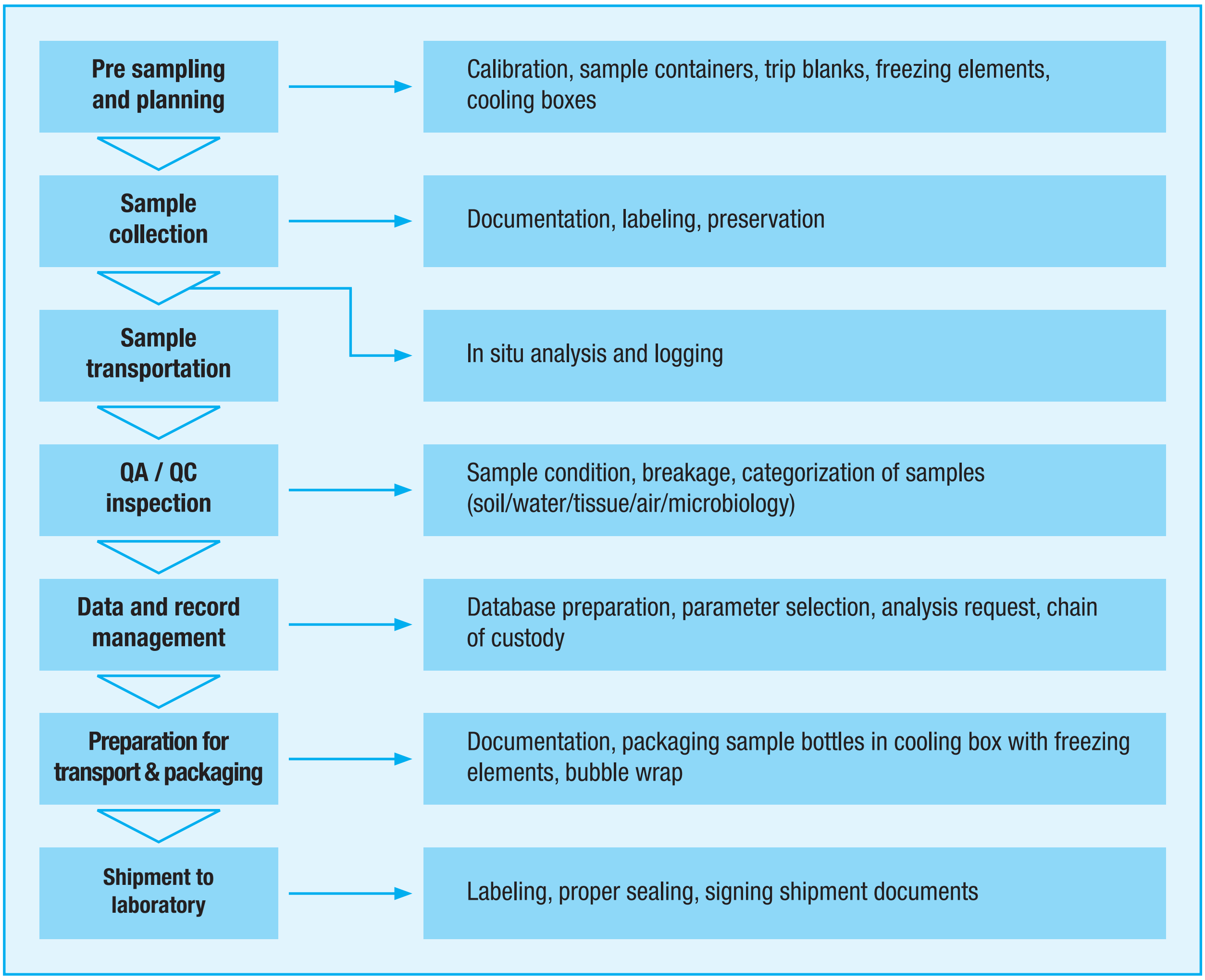
- Terrestrial zone
- Mangrove zone
- Freshwater riparian vegetation zone
- Forest zone (non-riparian)
- Coastal zone
- Urban / industrial zone
- Rural village zone
- Bare areas (areas with no vegetation)

A series of GIS procedures was developed to apply a set of generic principles in each zone; for example, mangroves can only occur in the mangrove zone. If mangrove pixels were found in other zones, they were reassigned to an appropriate land-cover class in the relevant zone.

Sample management

The field component of the UNEP study was a massive undertaking. Over 4,500 samples were collected and submitted to two international laboratories, both accredited to meet the international standard (ISO 17025) for testing and calibration laboratories. Thus, a robust sample management programme was an absolute necessity, the main objective being to safeguard the integrity and quality of the samples sent to the laboratories for analysis – essential if the laboratories were to generate a quality result. Samples collected in the field were kept in a cool box and were brought to the project office where they were stored in a freezer while chain of custody and customs forms were completed. Within 24 hours of collecting the samples, they were sent to the appropriate laboratories, again in cool boxes with sufficient ice packs. Figure 6 depicts the sample management flowchart used in this project.

Figure 6. Flowchart depicting the management of samples collected for laboratory analysis



Quality control samples

A majority of the errors in environmental analysis can be attributed to improper sampling, cross contamination and improper sample storage and preservation. Quality control samples are a way to measure precision, accuracy, representativeness, comparability and completeness. Essentially, two types of quality control samples were considered during the scientific investigation period of the Ogoniland project, namely:

- **Trip blank** – a sample that originates from analyte-free water taken from the laboratory to the sampling site and returned unopened to the laboratory with the VOC samples. One trip blank accompanies each cooling box containing samples submitted for VOC analysis. The trip blanks are used to assess the quality assurance/quality control (QA/QC) of sample preservation, packing, shipping and storage
- **Field blank** – an analyte-free sample that is collected in a sample bottle and sent to a laboratory for final analysis

Field blanks and trip blanks were collected for only a subset of the water samples. When sample concentrations were close to concentrations detected in blanks, they were qualified accordingly. Detected concentrations less than two times the field blank were negated (qualifier 'U') and detected concentrations between two and five times the field blank were qualified as estimated with potential high bias (qualifier 'J+'). This approach is consistent with the United States Environmental Protection Agency's (USEPA) National Functional Guidelines for Organics and Inorganics.

Field measurements

The various on-site measurements were performed with standard, calibrated equipment which differed from one parameter to another.

A Hatch Multimeter was used for monitoring basic parameters such as pH, conductivity and temperature.

To monitor fine particulate matter in outdoor air, with different fractions such as the inhalable fraction $PM_{10,}$ respirable fraction $PM_{2.5}$ and ultrafine fraction PM_1 (particles measuring less than 1 micron), a portable Thermo Scientific Particulate Monitor DataRAM 4 (DR-4000) was used. The same instrument was also used to measure air temperature and humidity.

To determine naturally occurring radioactive materials, an Automess 6150 AD 6/H calibrated dose-rate meter was used along with an Automess alpha-beta-gamma probe 6150 AD-17 (0.1-10000 cps) surface contamination probe.

Over 4,500 samples were collected for analysis

Analytical measurements

Though contaminated site assessment is an established industry, there is still no consistency in setting standards on measurement of hydrocarbons.

The main issue is that crude oil, or petroleum hydrocarbon, is a mix of thousands of individual hydrocarbons. Individually identifying each of them and setting standards presents a very complex – and expensive – challenge. Simply lumping all the hydrocarbons together to create a single standard would prevent differentiation between a hydrocarbon that is very toxic and another which is not.

The Nigerian legislation, EGASPIN, is based on a parameter referred to as mineral oil, though no specific analytical methods or carbon range are specified.

The Total Petroleum Hydrocarbon Criteria Working Group (TPHCWG) in the United States developed a methodological approach that takes into account the carbon chain length, solubility and toxicological effects of hydrocarbons in the mixture. TPHCWG divided petroleum hydrocarbons into two main groups: aromatic and aliphatic compounds.

As leaching factors and volatilization factors span many orders of magnitude, the TPHCWG classified aromatic and aliphatic hydrocarbons into a number of fractions with leaching factors and volatilization factors that lie in the same order of magnitude. With these so-called transport fractions, their transport and fate in the environmental compartments can be modelled more appropriately than with a single TPH value. For this reason, UNEP used the TPHCWG method of carbon banding (Table 11).

Since relevant Nigerian legislation is based on a single parameter, for the purpose of this report the broadest possible range of hydrocarbons analysed (C5-C44 for soil and C5-C35 for water) was used for comparison with mineral oil and reported as TPH. Where appropriate, individual parameters (e.g. benzene) or groups (e.g. BTEX or TPH) are reported and explained.

Table 11. Banding for hydrocarbons in TPH Criteria Working Group analyses

Samples	Hydrocarbon banding	
	Aliphatics	Aromatics
Soil	>C5-C6 >C6-C8 >C8-C10 >C10-C12 >C12-C16 >C16-C21 >C21-C35 >C35-C44	>EC6-EC7 >EC7-EC8 >EC8-EC10 >EC10-EC12 >EC12-EC16 >EC16-EC21 >EC21-EC35 >EC35-EC44
Water	>C5-C6 >C6-C8 >C8-C10 >C10-C12 >C12-C16 >C16-C21 >C21-C35	>EC6-EC7 >EC7-EC8 >EC8-EC10 >EC10-EC12 >EC12-EC16 >EC16-EC21 >EC21-EC35

Laboratory analyses of NORM

Gamma spectrometry for the determination of natural radioactivity in collected samples was performed in Switzerland at the Spiez Laboratory's ISO/EN 17025-accredited testing laboratory for the determination of radionuclide concentration (accreditation number STS 028). Gamma spectrometry was performed with high-purity Germanium (HPGe) CANBERRA detectors with high relative efficiencies.

The same testing laboratory was used to carry out inductively coupled plasma mass spectrometry (ICP-MS) of the collected samples. This process is able to determine the existence of medium- and long-living radioisotopes, as well as non-radioactive elements. For this analysis, a Finnigan Element XR high-resolution (sector field) mass spectrometer was used.

The procedures applied and measurements taken for both analyses fulfilled the international norm.

Field data collection for remote sensing

A large number of GPS (Model GPS 60™) instruments were used to record geographic coordinates of pollution on the ground and the points from which samples were collected by the different thematic teams. GPS was also used to map the road network and accessibility for the purposes of planning daily transportation to and from sampling sites.

Using GPS cameras (Caplio 500SE GPS embedded model), more than 10,000 geo-referenced photographs were taken in Ogoniland during the course of the study. The photographs were used extensively during the scouting exercise, reconnaissance, boat trips and helicopter flights, allowing for geo-traceability of the information photographed in the field. The photographs were also used as ground truthing for the land-cover mapping work, which served to improve the accuracy of the land-cover classification.

GPS-embedded, rugged laptop computers were used in the field to verify any spill reported by SPDC, record new spills reported by Ogoni communities or spills discovered by the UNEP team during fieldwork.

UNEP technical assistant using a GSP instrument during a reconnaissance exercise, January 2010

Review of institutional issues

National legislation and institutions

UNEP's review attempted to cover the whole range of institutions dealing with legislation related to environmental management and oil and gas production in Nigeria, touching also on cross-cutting issues such as community-company-government interaction, transparency, fiscal issues and law enforcement. The assessment was carried out by a thorough review of available documentation (published reports, legislation, research papers, etc.). In addition, many institutions, both at federal and state level, were contacted and interviewed, though not all those contacted were available. Community members were interviewed to the extent possible given the challenges of accessibility and security.

SPDC procedures

The Shell Petroleum Development Corporation has a set of documents which form the operational basis for handling oilfield assets and emergencies. A review of these procedures was undertaken for the purpose of this assessment, based on the following documents:

- SPDC Corporate Oil Spill Response, Clean-up and Remediation Manual, SPDC 2005-00572, April 2005
- Overview of Process and Standards for Oil Spill Clean-up and Remediation, SPDC Document, April 2006

In addition, three specific advisories issued by Shell Global Solutions and which form the basis of SPDC internal procedures were also reviewed:

- Framework for Risk Management of Historically Contaminated Land for SPDC Operations in Niger Delta, OG.02.47028
- Framework for Risk Management of Historically Contaminated Land for SPDC Operations in the Niger Delta: Mangroves and other Swamp Areas, OG.03.47062
- Remediation Management System, 2010

3.7 Contamination assessment criteria

Contamination criteria, in the context of this report, are specifications of concentration of a pollutant against which a judgement is made as to whether or not it is acceptable. Criteria need to be differentiated from standards and guidelines. Standards are specifications set by a statutory body, often national, and are therefore legally enforceable. Guidelines on any given issue, on the other hand, whether made by government, industry organizations or international organizations, present ideals that are considered desirable but which are not legally enforceable. From a technical point of view, criteria, guidelines or standards are almost always derived from the same scientific basis and could often be the same.

Contamination assessment criteria – a numerical value above which a site could be deemed to be contaminated – are of importance from several angles. Firstly, the degree to which observed values vary from the assessment criteria is an indication of the degree of contamination, and therefore the degree of risk to which the environment is subjected. Secondly, assessment criteria determine the degree of environmental clean-up and restoration required at a site. This in turn dictates the policy and technological approaches to be used, both of which have a direct bearing on the cost of the clean-up operations.

A chemical substance is considered a pollutant when its concentration is above a harmful threshold. Such thresholds can have different connotations in different contexts. A chemical substance could be harmful to people directly; it could be harmful to the quality of air or water, which may in turn harm people; or it could be harmful to other biota, for example animals, but may or may not harm people. However, it is fair to say that in most situations harm is ultimately defined from an anthropocentric perspective. Table 12 shows the comparison of risk-based screening levels for some of the frequently regulated hydrocarbon pollutants [65]. It can be seen that the screening levels for the same parameter can vary, and vary substantially, between countries. There are scientific and policy reasons, such as a society's risk tolerance, as to why different countries may have different values for contamination criteria for the same pollutant.

Though the international community has more than 30 years of experience in different parts of the world on systematic assessment and clean-up of oilfield contamination, there is not yet an

Table 12. Comparison of country specific risk-based screening levels for hydrocarbon-related components in soil

Parameter	Country				
	Canada	China	Netherlands	Thailand	UK
Benzene	0.0068	0.2	1	6.5	0.33
Toluene	0.08	26	130	520	610
Ethyl Benzene	0.018	10	50	230	350
Xylenes	2.4	5	25	210	230

All values are in mg/kg

Soil caked into a crust of dried crude oil

internationally accepted guideline on what level of hydrocarbons constitutes contamination. It is against this background that the Ogoniland assessment team had to review the available criteria and make its recommendations.

It must be stated that defining the level of environmental clean-up is ultimately a policy decision for the Federal Government of Nigeria, and wherever national legislation exists with regard to a particular issue, it is recommend that the legislation be followed, except in cases where there are sound scientific reasons to adopt a more stringent line to protect public health and welfare. In addition, when it is felt appropriate to point out instances where particular legislation may need revision or clarification, it has been done. Until such revisions or clarifications are made, however, the existing legislation will have to be complied with.

Standards for soil

The Nigerian legislation dealing with soil and water contamination from oil operations is handled by the Federal Government's Department of Petroleum Resources. The Environmental Guidelines and Standards for the Petroleum Industries in Nigeria (EGASPIN), issued in 1992, set out the standards which are currently the minimum operating requirement for the oil industry in Nigeria [7].

EGASPIN proposes two possible options for pollution incidents: (i) application of the Standard Guide for Risk-Based Corrective Action Applied at Petroleum Sites, prepared by the American Society for Testing of Materials (E1739-95, reapproved 2010); or (ii) an approach based on 'intervention values and target values'. Even though the EGASPIN document itself was reissued in 2002, no further guidance has been produced in the last 20 years, such that the approaches suggested in 1992 still form the operational basis for the oil industry in Nigeria.

EGASPIN defines intervention values as those that "indicate the quality for which the functionality of the soil for human, animal and plant life are, or threatened with being seriously impaired. Concentrations in excess of the intervention values correspond to serious contamination". Target values are defined as those which "indicate the soil quality required for sustainability or expressed in terms of remedial policy, the soil quality required for the full restoration of the soil's functionality for human, animal and plant life. The target values therefore indicate the soil quality levels ultimately aimed for".

In reviewing site contamination, UNEP has used the EGASPIN standards for soil (Table 13), which demonstrate the presence of higher levels of hydrocarbons and reveal continuing legislative non-compliance. However, this report makes recommendations for review of the EGASPIN (see Chapter 5). It is therefore expected that before the final clean-up is undertaken, a new set of standards will be introduced.

Standards for groundwater

The safety limits for groundwater pollution are also set out in the EGASPIN as both intervention and target values. Since some Ogoniland communities (those within the study area at least) use groundwater for drinking, without any treatment or monitoring, it is important that contamination levels of groundwater are compared against the criteria for drinking water quality. EGASPIN standards for groundwater are also presented in Table 13.

Standards for drinking water

WHO guidelines on drinking water

The World Health Organization (WHO) has developed and issued guidelines on drinking water quality for over 60 years. These guidelines – based on best available information on the risks associated with the consumption of water – have become the universal benchmark for setting drinking water standards. The risks associated with drinking water are constantly evaluated by WHO and the guidelines updated accordingly [36].

Nigerian national drinking water standards

The Nigerian Industrial Standard (NIS) 554:2207 deals with standards for drinking water quality nationally [37]. The standard was developed by the Ministry of Health, working through a technical committee of key stakeholders. Table 14 provides a comparison of the maximum levels of contaminants permissible according to Nigeria's drinking water standard and the corresponding WHO guideline.

Table 13. EGASPIN target and intervention values for soil and groundwater

Substance	Soil/sediment #		Groundwater	
	Target value	Intervention value	Target value	Intervention value
A. Aromatic compounds	(mg/kg dry material)		(µg/l)	
Benzene	0.05	1	0.2	30
Ethyl benzene	0.05	50	0.2	150
Phenol	0.05	40	0.2	2,000
Toluene	0.05	130	0.2	1,000
Xylene	0.05	25	0.2	70
B. Metals				
Barium	200	625	50	625
E. Other pollutants				
Mineral oil	50	5,000	50	600

The values given for soil are for 20 % soil organic matter with a forumula given for calibrating for other soil organic matter concentrations

Table 14. Comparative environmental standards for drinking water

Contaminant	Nigerian drinking water standard (µg/l)	WHO guideline (µg/l)
Benzene	No standards set	10
Toluene	No standards set	700
Ethyl benzene	No standards set	300
PAHs	7	No standards set
Arsenic	10	10
Barium	700	70
Mercury	1	6
Mineral oil	3	No standard set

Table 15. WHO air quality guidelines

Standard	$PM_{2.5}$	PM_{10}
Annual mean	10 µg/m³	20 µg/m³
24-hour mean	25 µg/m³ n	50 µg/m³

Air quality standards

No local air quality standards currently exist in Nigeria. In 2006, the WHO published guidelines for respirable particulate matter [38], as shown in Table 15.

In the absence of local standards, the WHO guidelines are used as a reference.

There are certain chemicals which were analysed in the assessment but for which no internationally recognized guidelines exist. In such cases, reference to any available standard is provided, primarily to give the observed values some context. No specific recommendations are made by UNEP on such standards.

3.8 Limitations, challenges and constraints

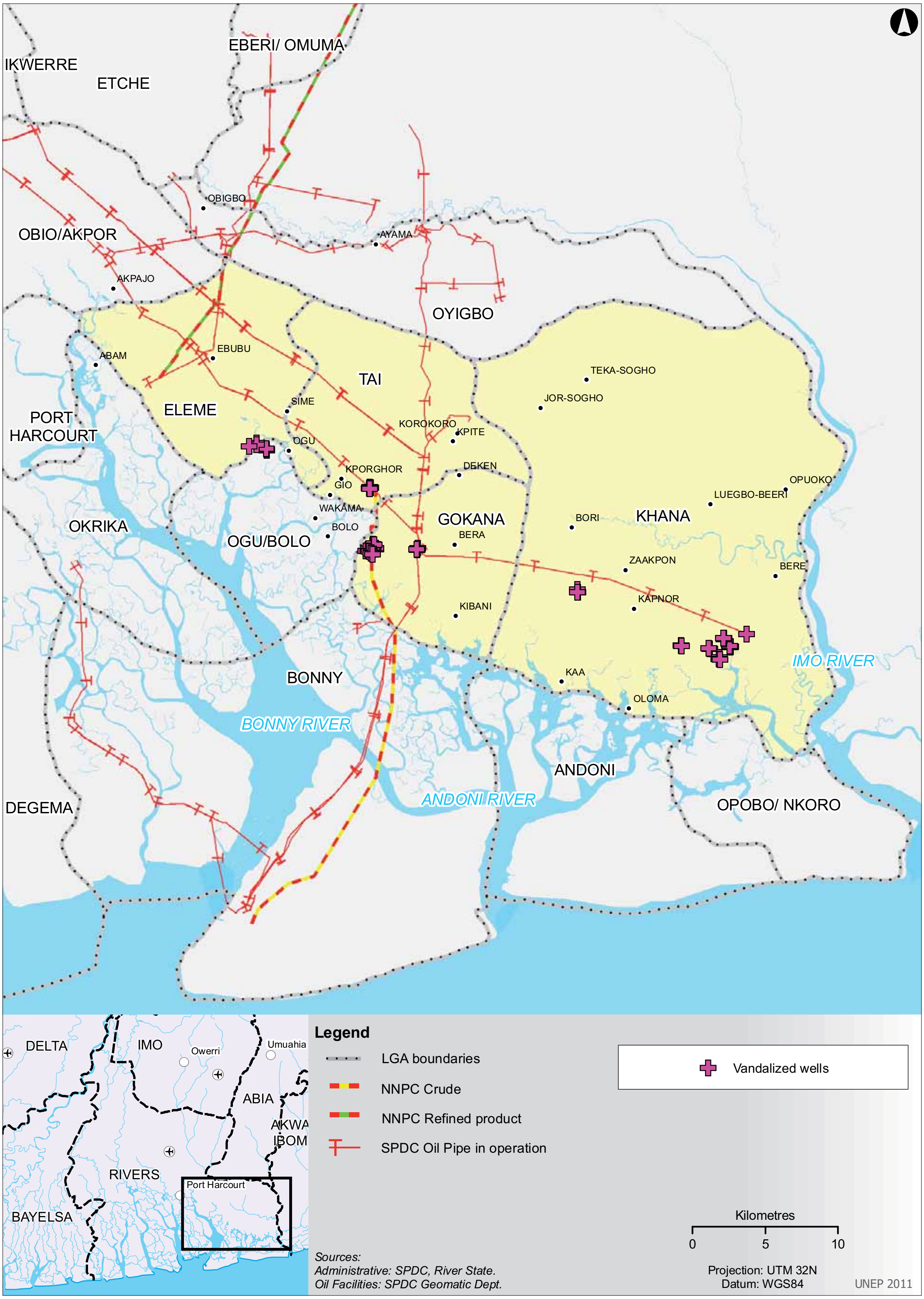
In carrying out a project of this scope, some constraints are inevitable. While every effort was made by the UNEP assessment team to limit the impact of these constraints on the scientific integrity of the study, the issues encountered are summarized here so that those who read this report may understand the context in which the work was undertaken.

Scientific constraints

There is no baseline information available on either the nature of the environment or socio-economic status of the community prior to the initiation of oil exploration. In fact, useful, recent and robust information covering Ogoniland is also not available. This includes a lack of reliable data about the quantity of oil spilled in the region. Consequently the observed situation has to be compared with a presumed baseline condition.

Despite many challenges, there was generally a strong spirit of cooperation between UNEP and Ogoniland communities

Map 9. Location of vandalised monitoring wells



The Nigerian Navy provided support during some field visits (note the navy vessel in the background)

In a number of sectors, the report lacks statistical coverage. For example, monitoring of drinking water was done on an opportunistic basis around contaminated sites. There are thousands of drinking water wells in Ogoniland (and there is no record of how many or where). This study did not seek to identify all possible locations of drinking water wells and then undertake a statistically appropriate sampling approach.

As the time available at individual sites was always restricted and the possibility of returning to a site was never known in advance, the study focused on collecting the minimum number of samples needed to form a reasonable picture of the contamination. The study could not, therefore, involve collecting duplicate samples.

This assessment compares the measured value of pollutants on the ground with established legal standards or other international guidelines. The findings based on this could be used as a basis for initiating public health protection measures on a preventive basis. This could also be used as a legally acceptable basis for site clean up. However, a more resource efficient approach will be to undertake site-specific risk assessments followed by consultations between the operator, regulator and community to establish clean-up levels for each site.

Security constraints

United Nations Department of Safety and Security (UNDSS) specifications are contractually binding and non-negotiable. In the UNDSS classification, Port Harcourt is a Phase III duty station, meaning that special security precautions must be observed. This was an aspect that the UNEP team working on the environmental assessment of Ogoniland had to keep in mind at all times, especially when in the field.

While the UNEP project team was rarely under any threat and maximum security was provided by the local government authorities, there were times when UNDSS advised the UNEP team to refrain from fieldwork. This obviously had an effect on the pace of on-the-ground surveys.

Of the 180 groundwater monitoring wells drilled by the project team, 38 were vandalized (Map 9, page 89) and could no longer be used for sampling.

Access restrictions

Traditional practices in Ogoniland are such that an elaborate procedure of consultation is mandatory prior to visiting a specific site. Two teams, a Community Liaison Team and a Land

The number of samples taken at each location was influenced by safety and access considerations

Access Team, were deployed to facilitate access to sites of interest. A considerable amount of time was invested in this essential activity, but however well the advance planning was carried out, there were repeated occasions when the project team was prevented from entering specific sites. In every instance the UNEP team complied with the wishes of the community, although the underlying reasons for denial of access often remained unclear. A policy was adopted whereby once a team had twice been prevented from visiting a site, the site was documented as 'inaccessible'. As a consequence, there are still some sites in Ogoniland that may be contaminated but which UNEP was unable to assess.

Information constraints

It was the intention of the UNEP team to identify all possible locations in Ogoniland that have been contaminated by oil industry operations. UNEP solicited, and received, information from all stakeholders, both the Ogoni community and SPDC, regarding such sites. Whenever such information was received, reconnaissance visits were arranged, subject to the security constraints

Samples were transported from field locations to laboratories in the shortest possible time mentioned above. The project team also visited oilfield infrastructure even when there was no specific information on contamination.

One of the observations made by UNEP during the course of the study was that vegetation had continued to grow and cover contaminated areas even though remediation measures had not been carried out. This was partly because some vegetation types can vigorously survive hydrocarbon pollution and partly because many vegetation types need only limited, comparatively clean amounts of topsoil to re-establish. Thus, even in cases where severe contamination had penetrated deeply, superficial vegetation cover gave the site a healthy appearance. Given that the oil industry has been operating in Ogoniland for more than 50 years while contamination records only go back 25 years, there could easily be other locations where contamination still exists below the surface but is obscured by vegetation.

Unfortunately, UNEP received insufficient information to enable it to undertake comprehensive assessments of oil operations in Ogoniland by companies other than SPDC. This included Port Harcourt Refinery Company and Pipelines and Products Marketing Company. Consequently, only spills that were apparent on the surface, and/or reported by the Ogoni community in the case of non-SPDC properties, were assessed by the UNEP team. The implication is that there may still be contaminated areas in Ogoniland about which there is currently no intelligence available to UNEP on which to base further surveys.

Sample management constraints

As previously described, analysis of all the samples collected in Ogoniland was undertaken in appropriately accredited laboratories in Europe. Many of the analytical parameters (e.g. VOCs) are sensitive to the temperature at which they are preserved. While all efforts were taken to maintain temperatures at the required levels during transportation of sample materials, and to get samples to laboratories in the shortest possible time, some degree of loss of contaminants is to be expected in the analytical results. Therefore, the reported results could be lower than the actual concentration in the sample when it was collected.

Ill-defined boundaries

While it was agreed that the geographic scope of the environmental assessment be limited to Ogoniland, there is no clearly agreed official definition of what constitutes Ogoniland. Boundaries, even between local government areas in Ogoniland, are not well defined and always disputed. Consequently, the UNEP study may have captured some information from outside Ogoniland while inadvertently leaving out areas that may be perceived by some as part of Ogoniland. At all times, the project team tried to err on the side of caution. Whenever there were people living in an area, their opinion on whether or not the area lay within Ogoniland was taken as correct. Greater difficulty was experienced in areas where oil industry operations were apparent but there was no community presence, such as at Bodo West.

Vertical delineation of contamination

While the horizontal delineation of contamination was challenging (no visible signs on the surface), vertical delineation was even more difficult given the wide fluctuations in groundwater levels. On reaching groundwater, any contamination can penetrate to considerable depths. The UNEP survey used only shallow augers for groundwater analysis, with a maximum sampling depth of 5 metres. At a number of locations, chemical analyses revealed that contamination may have gone deeper.

Time frame

The assessment of contaminated sites always calls for decisions on the number of samples to be taken at a particular location. In general, this is primarily driven by the cost of subsequent analysis of the samples. However, in Ogoniland there was an additional variable to be dealt with: the amount of time available to the UNEP team to work safely at a site, with the added consideration that a second visit, while highly desirable, might not prove feasible. Consequently, the sampling approach had to be tailored to capture the breadth, depth and intensity of contamination from the lowest feasible number of samples. However, whenever access was more freely available, the opportunity was always taken to supplement initial sampling.

Assessment of Contaminated Soil and Groundwater

Soil samples were taken at multiple locations and at multiple depths and investigated for hydrocarbon contamination. Groundwater was studied where it was possible to reach the groundwater table
© UNEP

Assessment of Contaminated Soil and Groundwater

4.1 Field observations of the current situation on land

Though oil production in Ogoniland has ceased, the UNEP assessment team visited accessible oilfields and oil-related facilities in the region, including both pipeline and facility rights of way as well as decommissioned and abandoned facilities.

Rights of way consist of land along pipelines and around other oilfield infrastructure which are, by law, owned and managed by oil companies to facilitate easy access for routine maintenance as well as emergency response. SPDC practice is for rights of way around facilities to be fenced, while those along pipelines are kept clear of habitation and vegetation but not fenced. In most cases pipelines are buried. Rights of way act as buffer zones between oil facilities and local communities, so that any incident, such as an oil spill or fire, does not impinge directly upon areas of human habitation. In any well-functioning oil industry operation, maintaining rights of way is both essential to and indicative of good environmental management.

On the whole, maintenance of rights of way in Ogoniland is minimal, arising in part from the fact that the oilfield has been closed since 1993 and access for the operator is somewhat limited. The entire gamut of oil operations in Ogoniland took place on soil which is very productive. This means that, unless regularly maintained, the land on which oil facilities and rights of way are located can very quickly become overgrown with vegetation. There are several locations within rights of way where lack of maintenance is evident and of serious concern.

Habitation on or close to oilfield facilities

The UNEP team observed that the oilfield in Ogoniland is interwoven with the Ogoni community, with many families living close to oilfield facilities. In some cases it is unclear whether the settlements came before or after the oil installations. This is true for both pipeline rights of way and rights of way to facilities.

A house constructed on a well pad (Yorla 9, Khana LGA)

A traditional house, made from combustible material, adjacent to a pipeline (Ebubu Obolo, Eleme LGA)

In at least one instance, at Yorla 9, the assessment team came across a family that had built its house within metres of the oil well, on the well pad itself. The family, with very young children, was also using the land around the well pad, within the oil well right of way, for farming. This observation is disturbing in many ways. To begin with, from a safety point of view, especially where children are concerned, it is wholly inappropriate that the family home is located so close to the wellhead. An immediate hazard is that the children may fall and drown in the (currently unprotected) well pit around the wellhead. Moreover, surrounding the well site are a number of other mud and water pits which, even if uncontaminated, are also potential hazards to both children and adults. In addition, the family is unprotected from fire, which is not unusual at disused oil wells in Ogoniland.

In some locations the project team observed buildings very close to rights of way; indeed in extreme cases the right of way itself had ceased to exist owing to the construction of farms and houses along it. An entire village of the Hausa community, for instance, lies along what appears to be a flare pipeline next to a flow station. Furthermore, the Hausa houses are made of readily combustible materials.

With respect to pipeline rights of way, three concerns arise:

- Communities living very close to or on rights of way are at personal risk from pipelines which are operational. While there is no obvious day-to-day danger from buried pipelines, where there are open well pads the potential for oil spillages and associated fire could put vulnerable communities at risk, both physically and legally

- As communities along rights of way go about their daily lives, the possibility that some of their activities may inadvertently cause an accident cannot be ruled out. Drilling of a well for drinking water or digging out a septic tank, for example, can both cause damage to a pipeline which may result in a leak, leading to a fire and possible explosion, endangering workers as well as the neighbouring community

- The establishment of a community or individual homes on or close to a right of way defeats the very object of the right of way and prevents rapid access to the facility should an accident needing specialist intervention occur

Chief Vincent Kamanu at part of an SPDC facility overgrown with vegetation (Gio, Tai LGA)

That communities have been able to set up houses and farms along pipeline rights of way is a clear indication of the loss of control on the part of both the pipeline operator and the government regulator. This is a serious safety breach. In addition, other poor and marginalized families may follow suit and construct their own houses within rights of way of other oilfield facilities.

Unmanaged vegetation

The project team observed overgrown wellheads and pipeline rights of way at several sites. In some cases, excessive vegetation growth prevented access by the UNEP team.

While overgrown vegetation does not cause an immediate danger to the facilities, there are concerns. Firstly, a small spill around the facility or on the right of way may not be noticed as quickly as it would be in a cleared area. This may, in turn, lead to a fire, causing damage to the facility, the vegetation and the local community.

Dense vegetation at these sites also indicates a lack of regular attention from the operator. This in turn will encourage encroachment by individuals wishing either to make use of the site for building or farming, or to tap into the facility. Consultations with SPDC on this matter revealed that in a number of situations where there appeared to be a lack of control, the pipelines were listed as "abandoned" and no longer operational. However, no information was available on whether these facilities were decommissioned following international best practice in terms of site remediation or, literally, abandoned. It is not uncommon in many pipeline abandonments for oil to remain in the pipeline. Until such time that pipelines – and associated rights of way – are closed down in a professional manner, they will continue to pose potential risks to the community.

Facilities not in operation

Some oil facilities that are no longer in operation have never been formally decommissioned and abandoned. Left without maintenance and exposed to the elements in a coastal region these facilities are vulnerable to corrosion. In the specific context of Ogoniland, where site security is at best irregular and unauthorized access commonplace, such facilities are highly prone to damage.

Visits to a number of facilities confirmed this understanding. Most alarming was the situation at Bomu flow station in K-Dere. When the UNEP team first visited this location, the fences (since fixed) were broken and oil contamination was visible within the site. Given that the area around this facility is densely populated, this is a very serious situation from the point of view of both community safety and security of the facility.

Conditions such as these at oilfield facilities indicate a lack of control on the part of the operators. In a properly maintained facility, a flow station should be secure, with no oil on the ground and minimal fugitive emissions.

Decommissioned and abandoned facilities

In any oilfield operation some assets are routinely decommissioned when they no longer serve a productive purpose, or are no longer economically viable. Typically, such assets are first operationally abandoned by decoupling them from the main infrastructure, mothballed (left without maintenance) and at an appropriate time properly decommissioned. SPDC has internal guidelines on 'Well and Field Assets Abandonment Standards and Strategy'.

In the case of Ogoniland, the situation is rather more complex. Because SPDC departed the Ogoni oilfield in an abrupt and unplanned manner, within a volatile security context, a number of resources were left abandoned even though that was not the intention. Decisions were taken subsequently to abandon other facilities. In fact, records show that a number of facilities were abandoned prior to the 1993 close-down.

While the SPDC database shows a number of pipelines and assets referenced as "abandoned" or "decommissioned", the way in which some facilities were left does not seem to have adhered to SPDC's own standards. UNEP's reconnaissance routinely came across oilfield resources which had evidently been abandoned in an uncontrolled fashion. This varied from pipelines left open and lying in trenches (possibly deserted midway through pipe-laying operations), to oil facilities left standing but without subsequent maintenance. The bottom line is that the current state of the abandoned facilities of oil field structure in Ogoniland do not meet with international best practices.

A view of the Bomu flow station (K-Dere, Gokana LGA)

Abandoned oil field infrastructure (Bodo West, Bonny LGA)

The abandoned facilities in Ogoniland pose both environmental and safety risks. From an environmental point of view, there is no indication as to whether the various containers lying around are full or empty, or what they contain(ed). Corrosion of metallic objects leads to ground contamination by heavy metals. Attempts by criminal elements to recover objects for sale as scrap may lead to safety risks, both on and off oilfield sites, while children playing on these facilities also face health risks.

Well blowouts

'Blowout' is oil industry terminology for a situation in which control of a well is lost during drilling or operation. More frequent during drilling, blowouts lead to the release of hydrocarbons (crude oil, produced water and associated gas) into the environment. Often, the mixture will catch fire and burn until such time as the well is brought back under control – a process which may take weeks or even months if control is to be achieved by the drilling of a relief well. Although the Ogoniland oilfield has been closed since 1993, formation pressure, corrosion and illegal tapping can cause wells to blow out, leading to oil spills and fires.

The UNEP team witnessed one such incident in 2006 during aerial reconnaissance of Ogoniland. A massive fire was raging at the Yorla 13 oil well and apparently continued burning for over a month. Such fires cause damage to the vegetation immediately around the well site and can produce partly burned hydrocarbons that may be carried for considerable distances before falling on farmland or housing.

No blowouts were reported during the main field period of UNEP's assessment in 2009 and 2010.

The control and maintenance of oilfield infrastructure in Ogoniland is clearly inadequate. Industry best practice and SPDC's own documented procedures have not been applied and as a result, local communities are vulnerable to the dangers posed by unsafe oilfield installations. The oil facilities themselves are vulnerable to accidental or deliberate tampering. Such a situation can lead to accidents, with potentially disastrous environmental consequences.

An oil well on fire (Yorla 13, Khana LGA)

The cumulative impact of artisanal refining puts significant environmental pressure on Ogoniland

4.2 Field observations concerning illegal oil-related activities

Illegal tapping of oil wells and pipelines

Bunkering is an oil industry term for supplying oil to a ship for its own use. In Ogoniland (and the wider Niger Delta) this term refers to the illegal tapping of oil industry infrastructure with a view to procuring oil illegally.

A number of defunct SPDC oil wells are located in the Ogoniland creeks. However, the wells still contain oil and are self-flowing, such that by operating the well valves, crude oil (along with gas and water) can be produced. During one visit the assessment team observed a group of people tapping into these wells and transferring oil to small boats. This happened in broad daylight, without any apparent hesitation, even in the presence of the UNEP team. The oil collected was either transferred to larger boats for onward shipment or used locally for illegal artisanal refining (see following section).

SPDC informed UNEP that by November 2010 all the wells had been sealed and capped. No further tapping was observed by the UNEP team during subsequent visits.

Similarly, there are SPDC and NNPC pipelines through Ogoniland that still carry crude oil. There are frequent reports of these pipelines being tapped illegally, in some cases leading to spills and fires. Though UNEP did not directly observe such incidents on the ground, this does not mean that such incidents did not take place during UNEP's fieldwork period. As there are no externally visible signs while pipelines are being tapped for oil (unlike the highly visible artisanal refining – see next section) and access to sites always had to be negotiated days in advance, only with precise intelligence and community support would it be possible to observe live operations.

Artisanal refining

The process of artisanal refining typically involves primitive illegal stills – often metal pipes and drums welded together – in which crude oil is boiled and the resultant fumes are collected, cooled and condensed in tanks to be used locally for lighting, energy or transport. The distilleries are heated on open fires fed by crude oil that is tipped into pits in the ground. As part of the oil burns away, some seeps into the ground. A typical artisanal refinery may comprise just one operating still and the entire refinery may be no more than 100 square metres in area. Others, however, are much bigger, containing multiple stills operating simultaneously. Stills are always located at the water's edge, primarily to facilitate the transportation of both the crude oil and refined products. The crude is usually stored in open containers or open pits, increasing the risk of fire.

Artisanal refining of crude oil has a tradition reaching back to the Biafran War, when the Biafran Government advocated the development of low-tech refineries in Biafra to make up for the loss of refining capacity during the course of the conflict. The same low-tech methods of refining continue in the Niger Delta to the present day and hundreds of artisanal refineries are to be found along the creeks. Their presence is obvious, even from a distance, marked by dark plumes of smoke rising from the fires. The practice represents a huge environmental, health and safety problem.

Owing to security constraints, UNEP could only observe live refining operations from the air. Once refining operations are complete, those taking part usually leave their tools on site, presumably with the intention of returning at a later date. It was evident to the UNEP surveyors that the operation is run on a very small scale, with minimal investment.

For reasons that could not be determined, the number of artisanal refineries has proliferated in Ogoniland since January 2009. Satellite images of the region taken in January 2009 and again in January 2011 show the increase in this activity (Map 10).

Aerial view of artisanal refining site (Bodo West, Bonny LGA)

Map 10. Satellite images give evidence of the increase in artisanal refining between January 2009 (left) and January 2011 (right)

Aerial view of a typical artisanal refining site in operation (Bodo West, Bonny LGA)

UNEP is fully aware that unemployment and the absence of new job opportunities in the region may drive some of the local community members to take up this occupation. There is a high risk of self-harm from artisanal refining – a large number of accidents, fires and explosions on refining sites claim dozens of lives every year, quite apart from the longer-term health effects of ingestion, absorption and inhalation of hydrocarbons. Given the circumstances under which these refineries operate (regularity of the practice; dozens of workers to be transported in and out, accommodated and fed; huge smoke plumes above the distilleries all day indicating the locations even from a distance, etc.), it is hard to understand why no action is taken by the local and regional authorities, police, army or navy to stop the practice.

While the footprint of individual artisanal refining operations is localized, the cumulative impact exerts a significant environmental stress on Ogoniland. The main problems are:

- clearance of coastal vegetation when setting up an illegal artisanal refinery, leaving land vulnerable to erosion
- contamination of soil and groundwater in the immediate vicinity
- damage to surrounding vegetation from fire and smoke
- spread of pollution beyond the refinery area – any crude left behind after the refining process can be picked up by higher tides and transported over a wider area
- contamination of water in the creeks and coastal and mangrove vegetation, as well as soil exposed to layers of oil at low tide
- air pollution – those involved in the artisanal refining process are at high risk of exposure to extreme levels of hydrocarbons, which can have both acute and chronic impacts, while the smoke blowing from the area can adversely affect entire communities

Although the impacts of each illegal refinery are small, the cumulative effect risks an environmental catastrophe, the costs of which would far outweigh the short-term economic benefits derived. Unless artisanal refining of crude oil is brought to a swift end through effective regulatory action, in conjunction with developmental and educational initiatives, it has the capacity to cause further serious damage to the ecosystem and livelihoods of the coastal communities in Ogoniland and beyond.

The fact that these operations are ongoing and proliferating in full view of the enforcement agencies is indicative, at best, of a lack of effective preventive measures and, at worst, of collusion.

4.3 Geological observations

The geological profile of Ogoniland, including the depth and quality of groundwater, is a key factor when assessing contaminated sites. Soil type and grain-size distribution are crucial to the mobility of crude oil in soils and to the groundwater conditions that determine the spread of contamination plumes.

Soil

For soil sampling, UNEP drilled some 780 boreholes to depths of up to 5 metres, along with a further 180 boreholes down to a maximum of 14 metres for groundwater monitoring. In addition, UNEP had access to one deeper borehole of 50 metres, drilled by a local contractor. Based on the data from approximately 960 boreholes, the soil properties in Ogoniland can be described reasonably well.

Figure 7 presents a number of logs of soil sectioned from north to south in Ogoniland. The southernmost point lies on the edge of the creeks at an elevation of 1.5 metres above sea level, while the northernmost point lies 20.6 metres above sea level.

Three observations are evident from this profile: (i) the shallow geology of Ogoniland is highly variable with wide variations over short distances; (ii) the shallow formations range from gravelly sand to clay and everything in between; and (iii) there is no continuous clay layer across Ogoniland. This information itself is not surprising. No uniform layering can be assumed for Delta sediments, as erosion and deposition from the rivers' side arms cause vertical and lateral discontinuities that provide pathways for the migration of liquid hydrocarbons and contaminated groundwater. The diversity of soil types and the extent of sedimentary layers on drilling sites showed little lateral correlation.

Groundwater

Of the 180 groundwater monitoring wells drilled by UNEP in Ogoniland, a topographic survey was conducted for 142. The shallowest observed water

Figure 7. Soil logs from across Ogoniland, along with groundwater depths

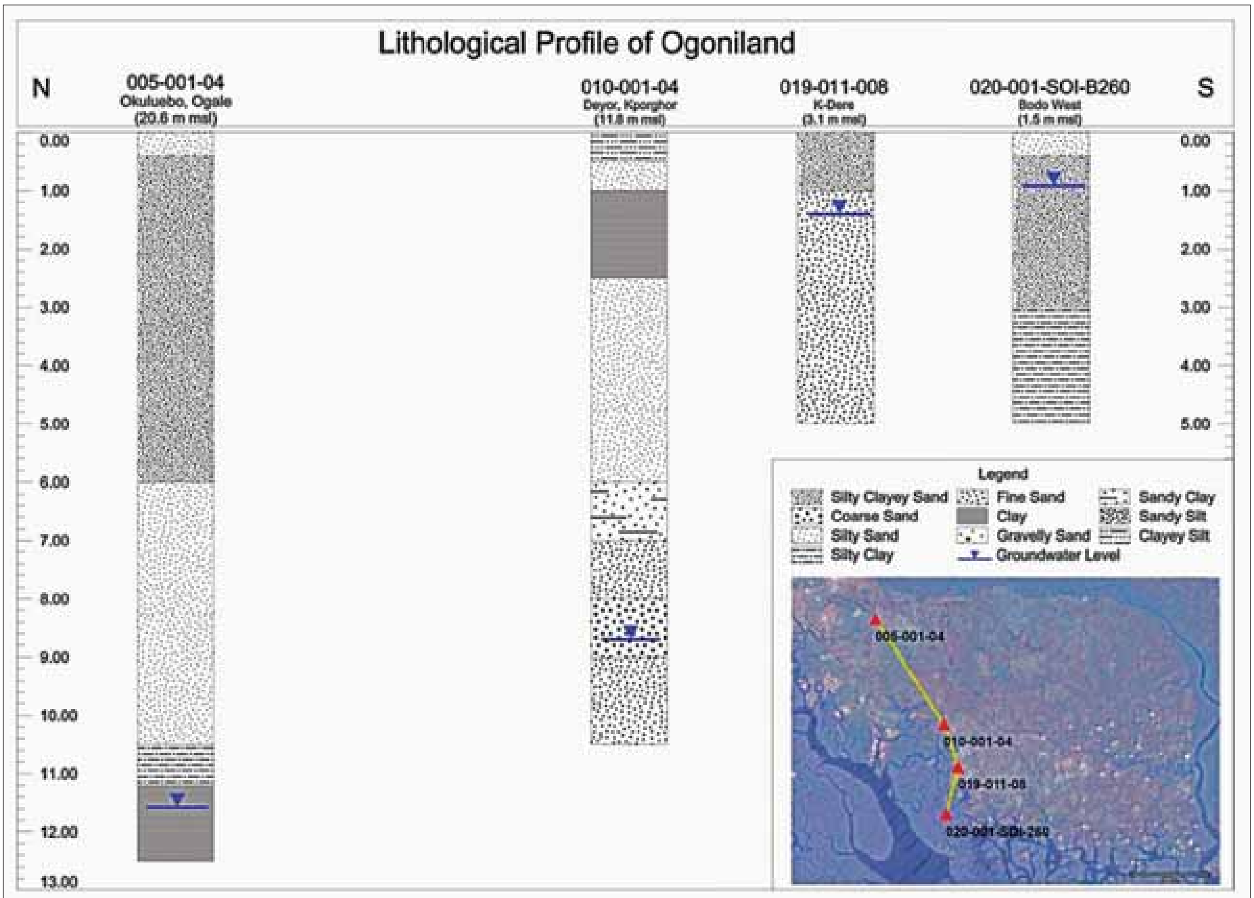
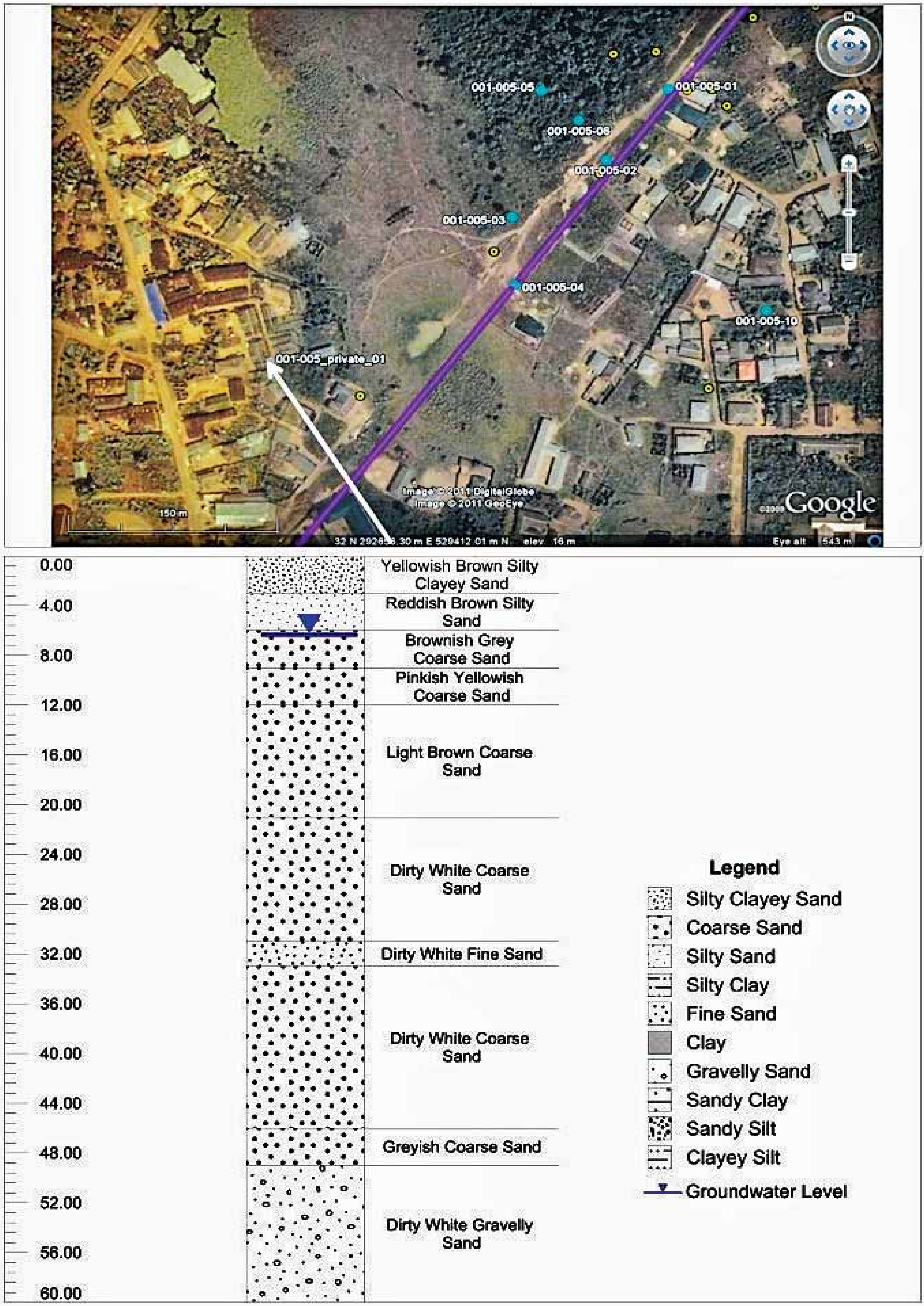


Figure 8. Soil logs from Nsioken Agbi Ogale, Eleme LGA



level was 0.7 metres below ground level while the deepest was 14 metres below ground level.

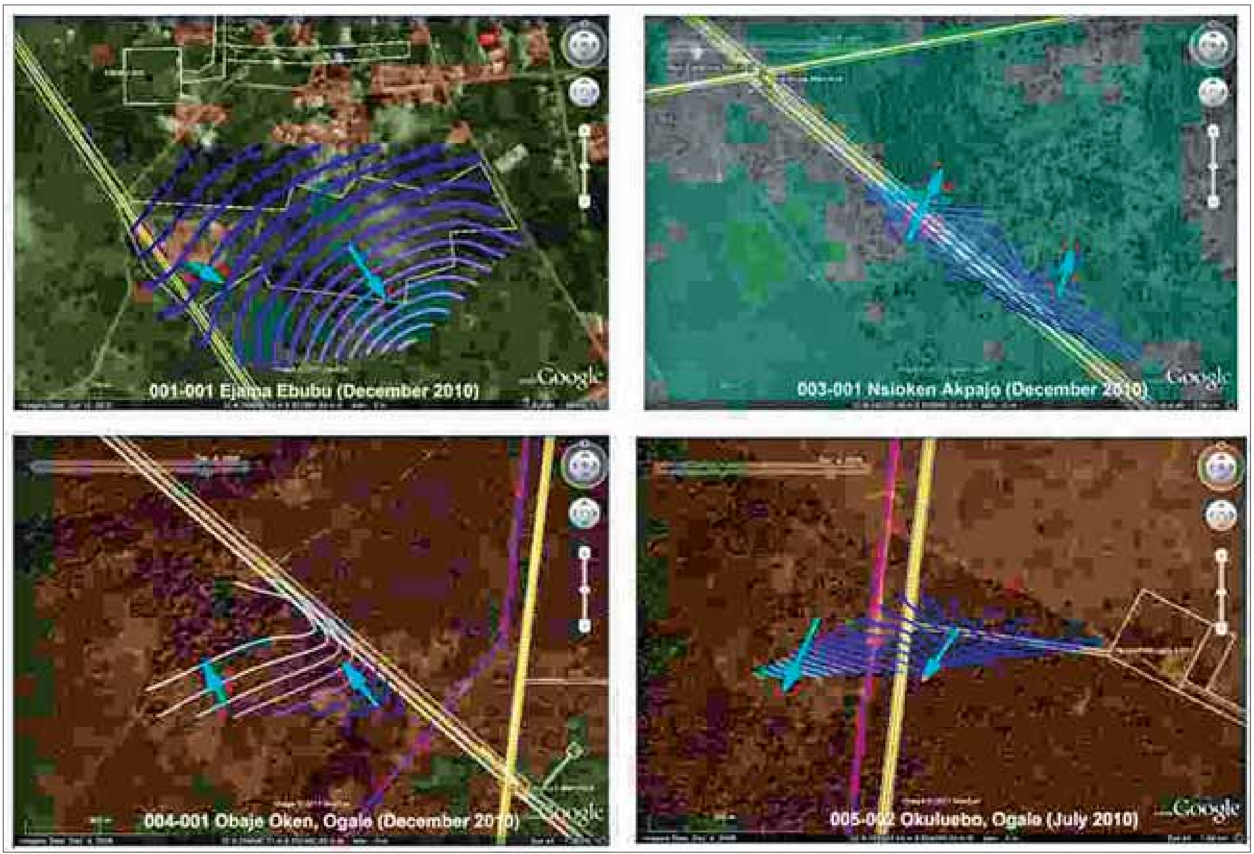
Figure 7 shows the profile of groundwater on a north-south cross section, in which the depth of the water table varies with the prevailing land profile. The groundwater situation in Ogoniland is typical of a delta environment. In areas close to the creeks, the water table lies close to surface. In intertidal areas in the mangrove zones, the groundwater level rises and falls with the tidal rhythm, while in the interior there are localized swamps into which groundwater drains. The water table fluctuated seasonally in all wells, especially those furthest from the coast.

UNEP technical assistant and Rivers State university students collecting groundwater samples

While investigating groundwater contamination at one site, UNEP came across a family drilling deeper boreholes to obtain clean water. Here, the opportunity was taken to obtain a deeper geological profile of the area (Figure 8). The geological profile indicated that there is indeed only one aquifer, which is being tapped by both shallow wells and deeper boreholes. As impermeable layers of clay are highly localized in Ogoniland, interconnectivity with underlying aquifers could not be excluded any of the sites investigated.

While no general flow direction was detected of groundwater in Ogoniland, the flow was typically directed towards the nearest creek or swamp (Figure 9).

Figure 9. Variable groundwater flow direction in Ogoniland (blue arrows indicate flow direction)



4.4 Contamination assessments

Soil and groundwater contamination

As discussed in Chapter 3, the study investigated 69 different sites for contamination of soil and, where possible, groundwater. Samples of soil were taken at multiple locations within each site, and at each sampling location within a site, samples were taken at multiple depths. Groundwater samples were taken either from dedicated wells drilled for that purpose or from boreholes made to take soil samples.

The sites investigated fall into the following groups:

- SPDC pipeline rights of way
- SPDC legacy sites (e.g. abandoned facilities)
- Suspended SPDC facilities (e.g. wells, flow stations and manifolds never formally abandoned)
- NNPC crude oil pipelines
- NNPC product lines

Table 16 provides a summary of the sites investigated, categorized into the above groupings. At a number of locations within Ogoniland, NNPC pipelines and SPDC pipelines share rights of way. In such instances these were classified as SPDC pipelines, though it was not evident if the spill investigated originated from an SPDC or NNPC crude pipeline.

Table 16. Summary of sites investigated in the various categories

Site classification	Number
SPDC pipeline rights of way	34
SDPC legacy sites	6
Suspended SPDC facilities	22
NNPC crude oil pipelines	2
NNPC product line	3

Two further sites were investigated in detail: an artisanal refinery site and a 'fly-tipping' site (i.e. where waste of unknown origin was being disposed of within Ogoniland).

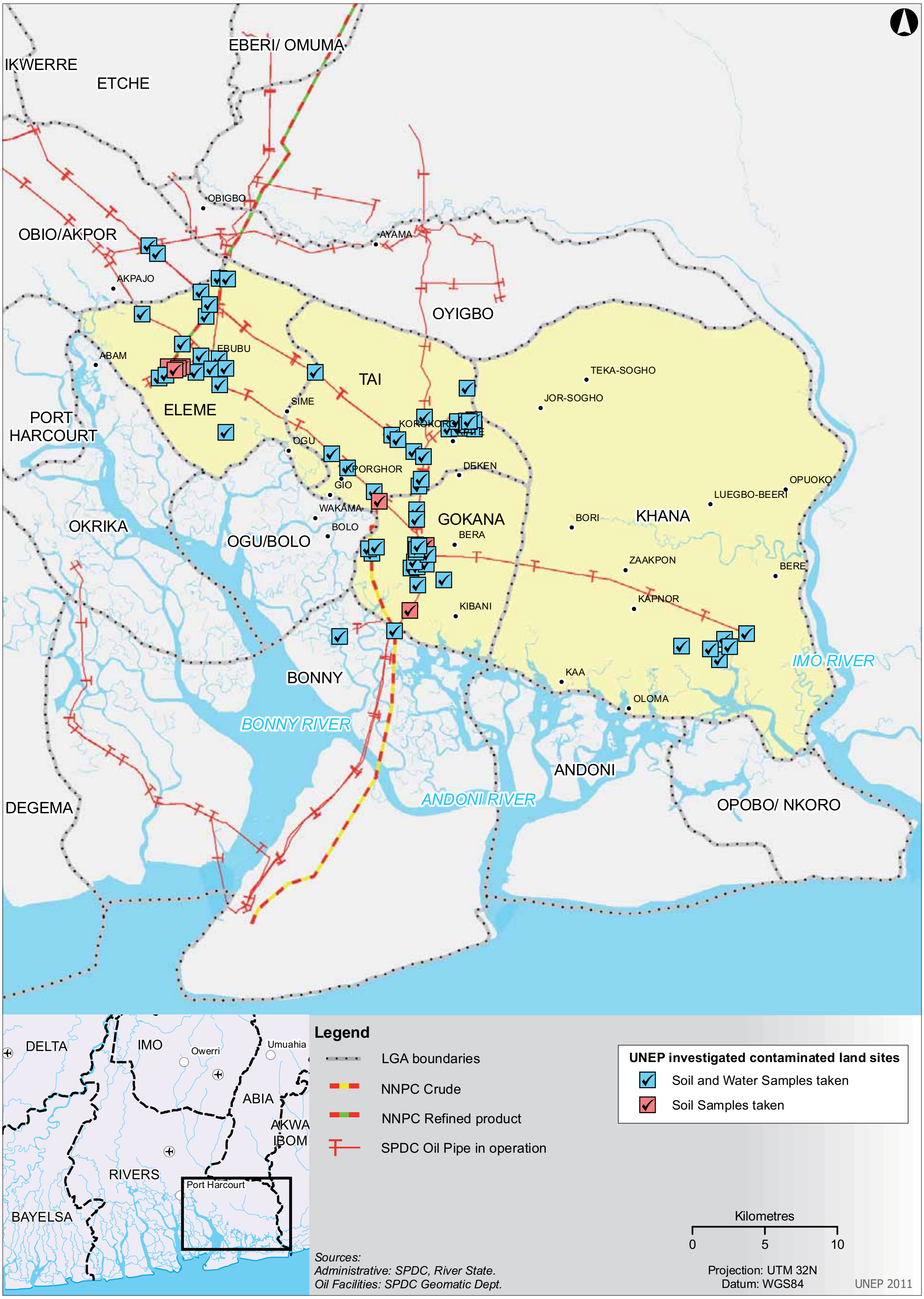
The locations of the sites investigated are presented in Map 11. All sites were investigated for hydrocarbon contamination in soil, while groundwater was investigated where it was possible to reach the groundwater table.

In the following section, findings from representative sites in each of the above categories are presented as case studies. The studies serve to illustrate the prevailing environmental situation in Ogoniland. For each of the sites, site-specific observations, results and conclusions are given, along with site-specific recommendations. Information on all other sites is then presented in tabular form. Taken together, this information provides an overview of the nature and extent of hydrocarbon contamination in Ogoniland.

To accompany this summary report, individual reports for 67 of the sites investigated have been prepared. Each report contains site-specific information on soil profiles, soil and groundwater contamination, proximity to community and depth of penetration of hydrocarbon contamination, concluding with site-specific recommendations. Together, the reports amount to more than 1,000 pages. They will be submitted to both SPDC and the Government of Nigeria and will be available online to interested stakeholders. The supporting database, complete with the analytical data, will also be made publicly available.

The recommendations given in this report are meant to achieve immediate risk reduction. However, prior to initiating comprehensive clean-up, consultation with the regulators, risk assessments and community consultations need to be undertaken during the next phase of the project.

Map 11. Location of soil investigations site along with groundwater sampling



Case study 1 SPDC pipeline right of way – 001-001 Ejama-Ebubu, Eleme LGA

Site description. Ejama-Ebubu is probably the most infamous of the oil spill locations in Ogoniland, the original spill occurring here during the Biafran War more than 40 years ago. There have been multiple spills and clean-up attempts since.

The Ejama-Ebubu spill site is situated in the Ejama-Ebubu community, Eleme LGA. Here, the 20-inch Rumuekpe manifold to Bomu manifold trunk line and the 28-inch Rumuekpe to Bomu trunk line run parallel from north-west to south-east. The initial pipeline right of way had a width of 25 metres. After the original spill and the ensuing fire, an area of 85,000 square metres was surrounded by a concrete block wall to the east of the pipeline. Although the contaminated area has been secured, much of the wall has collapsed and, with no guards present, uncontrolled access is possible at all times.

Land use. Prior to the oil installation the land appears to have been a combination of agricultural holdings and swamps. The nearest housing areas are approximately 300 metres east of the 1970 spill point and less than 20 metres north of the compound wall. The areas to the west and south are currently used for plantations of cassava (*Manihot esculenta*) and other crops. The swamp drains into a lagoon lined by trees with thick undergrowth to the west. The stream leaving the lagoon is still used by community members for washing, swimming and other purposes.

Spill and remediation history. During the Biafran War in 1970, the now abandoned Rumuekpe manifold to Bomu manifold trunk line was damaged. Crude oil spilled flowed downwards in an easterly direction into a lagoon approximately 200 metres east of the pipeline. From the lagoon the oil washed further into creeks, leading to contamination of downstream areas. Part of the area caught fire, evidenced by crusts of ash and tar or bitumen over the main contaminated area.

Community guide at Ejama-Ebubu, Eleme LGA

Table 17. Summary of results of soil and groundwater investigations at the Ejama-Ebubu site

UNEP site code	qc_001-001
Site name	**Ejama-Ebubu**
LGA	Eleme
Site description	SPDC pipeline right of way
Total Investigated Area (m^2)	169,712
Number of soil samples	92
Number of groundwater samples	15
Number of drinking water samples	2
Number of surface water samples	1
Deepest investigation (m)	6.00
Maximum soil TPH (mg/kg)	49,800
Number of soil measurements greater than EGASPIN intervention value	36
Deepest sample greater than EGASPIN intervention value (m)	6.00
Number of wells where free-phase hydrocarbon was observed	1
Maximum water TPH (µg/l)	485,000
Number of water measurements greater than EGASPIN intervention value	8
Presence of hydrocarbons in drinking water	No
Number of soil measurements below 1 metre	62
Number of soil measurements below 1 metre greater than EGASPIN intervention value	23
Total volume of soil above intervention value (m^3)	105,302
Total volume of soil above target value (m^3)	236,077

SDPC records show that other spills took place in 1992 and in November 2009. Multiple attempts at remediation have taken place. A mobile thermal desorption unit (TDU) was brought to the site but, according to anecdotal information from the community, it was never used. In 2006, a remediation contract was awarded and some excavation took place. Burnt and highly contaminated soil was moved to the sides of the area and deposited in two large piles, each of approximately 5,000 cubic metres, near the northern and southern walls of the site. The work was abandoned midway through, though no consistent explanation for this has been forthcoming from SPDC or the community. Apart from the measures described, no significant remediation activities have been undertaken, even though the spill is now over four decades old.

Visual observations on site. Preliminary site visits were carried out by UNEP in late 2009.

In the central and more heavily contaminated areas, large lumps of ash and tar are still present. In other places the soil is caked into crusts of dried crude oil. The heavily contaminated soil deposited at opposite ends of the site are not covered, allowing rainwater to infiltrate. Contaminants leaching from piles of soil form oily sheens and slicks on pools of water and on flowing water, which eventually ends up in the lagoon.

On dry days, the sun heats up the piles of contaminated sand, liquefying the oily and asphalt components, thus remobilizing them into the underlying soil.

During the rainy season, the water level of the lagoon rises by more than 1 metre, washing the oily residues further downstream.

There is no control of surface water runoff, so that contaminated leachate is able to enter and pollute surface waters leaving the area.

Sample analysis. A number of soil and groundwater samples were collected. A summary of the contamination detected is presented in Table 17. Results of soil analyses are presented in Map 12. Where a number of samples were taken at a given location (at multiple depths), the weighted average of the contamination is used. The higher values along the north-west edge are from the contaminated soil that was dug and piled up in that area during an earlier clean up attempt.

Conclusions. Although the spill is over 40 years old and repeated clean-up attempts have been made, contamination is still present at the site. The observed levels of contamination are higher than Nigerian Government standards and SPDC's specifications. Natural attenuation processes have not reduced pollution to acceptable levels. There are two possible reasons for this. Firstly, the area is so heavily contaminated that biological processes alone have not been able to break down the hydrocarbons without active human intervention. Secondly, the presence of a surface crust from burning and/or the piling up of the most contaminated spoils have prevented biodegradation.

In addition to spreading laterally, pollution has spread vertically, contaminating more soil and reaching the groundwater.

Considering the size of the area, the quantity of pollution remaining and the fact that it is very close to human habitation, urgent intervention is warranted with respect to remediation of soil, groundwater and the creeks. Moreover, given the gravity of the pollution and the fact that contamination extends to a ground depth of more than 5 metres, the standard SPDC approach of *in situ* remediation by enhanced natural attenuation (RENA) will not be appropriate at this location.

Site-specific recommendations:

1. The impacted area should be demarcated and appropriate signage erected to indicate that the site is heavily polluted; similar signage should be placed in affected swamps and creeks
2. Where community land is impacted, inhabitants should be informed
3. A community-based security and surveillance system should be put in place to ensure compliance with the restrictions introduced to protect public health
4. The site should be reworked to prevent runoff from the area reaching downstream swamps
5. Runoff from the area should be monitored and if necessary treated while the clean-up initiative is being developed
6. Monitoring of well water should be introduced to act as early warning for surrounding communities not yet impacted by groundwater pollution emanating from the site
7. Prior to site clean-up, additional soil sampling, along with the excavation of trial pits, should be carried out to delineate the area requiring treatment
8. A detailed plan should be prepared for (i) clean up of the contaminated soil and (ii) risk reduction at the site. Additional guidance on clean-up of contaminated soil is provided in Chapter 6.
9. A detailed plan should be prepared for (i) clean up of the contaminated water and (ii) risk reduction in the community. Additional guidance on clean-up of contaminated water is provided in Chapter 6.
10. During the clean-up, excavation water should be carefully managed to ensure that pollutants do not escape into the environment.

A summary table of contamination at other sites investigated along the SPDC pipeline right of way is presented in Table 17. From the summary presented in the table, the following key observations can be made:

1. At 22 of the 33 investigated sites along SPDC pipeline rights of way, soil contamination exceeded the limits set by Nigerian national legislation
2. At 19 of these 22 locations, contamination extended deeper than 1 metre (i.e. below the area reached by RENA treatment)
3. At 19 of the 33 sites, groundwater pollution exceeded the intervention values set in Nigerian legislation (EGASPIN)
4. At five of the investigated sites hydrocarbons were detected in the drinking water used by neighbouring communities

Detailed results from the investigation at these sites, including spill history, contamination contours and presence of sensitive receptors, along with site-specific recommendations, are presented in the site fact-sheet available online.

Map 12. Contamination values for Total Petroleum Hydrocarbons at Ebubu-Ejama site, Eleme LGA

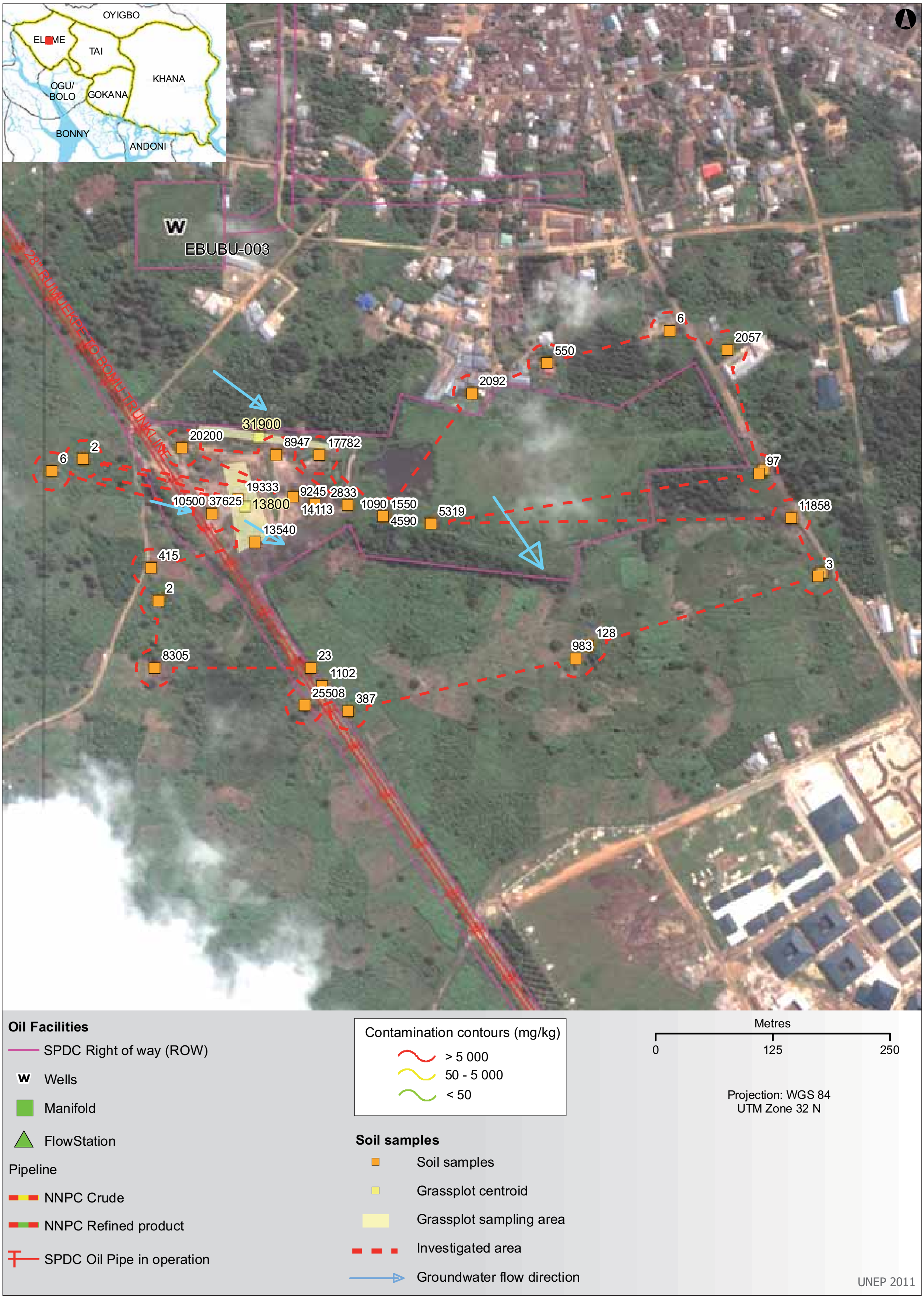


Table 18. Summary of contamination of investigated sites along SPDC pipeline rights of way

UNEP site code	LGA	Number of soil samples	Number of groundwater samples	Deepest soil investigation (m)	Maximum soil TPH (mg/kg)	Number of soil measurements >EGASPIN	Deepest soil sample >EGASPIN (m)	Maximum water TPH (ug/l) (CL samples)	Hydrocarbons in community wells	Number of water TPH measurements >EGASPIN	Number of samples with TPH >EGASPIN below 1 m
qc_013-002	Tai	48	10	5	9,200	7	5	1760000		5	6
qc_012-001	Eleme	132	10	5	36,900	17	5	133000		5	14
qc_009-006	Tai	62	2	5	12,300	4	3	162000		1	3
qc_009-003	Tai	1	1	8.5	645			53.1	yes		
qc_005-009	Tai	68	5	6.5	2,930			26900	yes	2	
qc_003-005	Obio/Akpor	13	1	5	629			9540		1	
qc_002-002	Eleme	43	4	3.8	4,220			16500		4	
qc_019-045	Bonny	11	3	3.4	1,400			277000		1	
qc_019-044	Gokana	30	4	5	9,990	1	2	109000		3	1
qc_019-020	Gokana	70	7	5	52,200	18	5	29600	yes	7	13
qc_019-002	Gokana	27	5	5	34,500	10	4	32000		2	7
qc_019-001	Gokana	18	8	2.5	10,400	1	2.5	116000		6	1
qc_010-009	Tai	9	1	2	5,620	1	1.2				1
qc_010-004	Tai	38	8	5	36,200	4	4	543			2
qc_009-010	Tai	274	4	5	34,100	63	5	1140000		3	48
qc_005-002	Eleme	42	7	11.8	8,580	11	3.08	2740000		3	9
qc_004-004	Eleme	6	1	2.58	3,740						
qc_003-002	Eleme	23		3	13,400	3	3	91.7			2
qc_003-001	Obio/Akpor	77	13	8	3,680			427			
qc_002-004	Eleme	4	3	2.32	126			11600		1	
qc_002-003	Eleme	7	2	9	15,300	1		25100		1	
qc_008-008	Tai	45	4	5	567			10			
qc_009-004	Tai	125	5	5	23,100	51	5	74700		2	45
qc_019-006	Gokana	46		5	2,640			10			
qc_010-005	Gokana	18		5.2	10,500	5	4.6				4
qc_010-001	Tai	58	5	10	6,210	3	5	130000		2	2
qc_019-009	Gokana	27		5	43,600	10	5	15	yes		7
qc_019-007	Gokana	4		5.1	14,600	4	5.1	43900		2	4
qc_004-001	Eleme	151	16	5.2	7,570	2	2.6	1720000		9	2
qc_002-009	Eleme	7		2	7,370	1	0.5				
qc_002-007	Eleme	16		3	5,810	1					
qc_002-006	Eleme	46		5.2	11,100	5	4				4
qc_001-009	Eleme	51	4	5	841			12	yes		

Case study 2 SPDC suspended facilities – Bomu Manifold, K-Dere, Gokana LGA

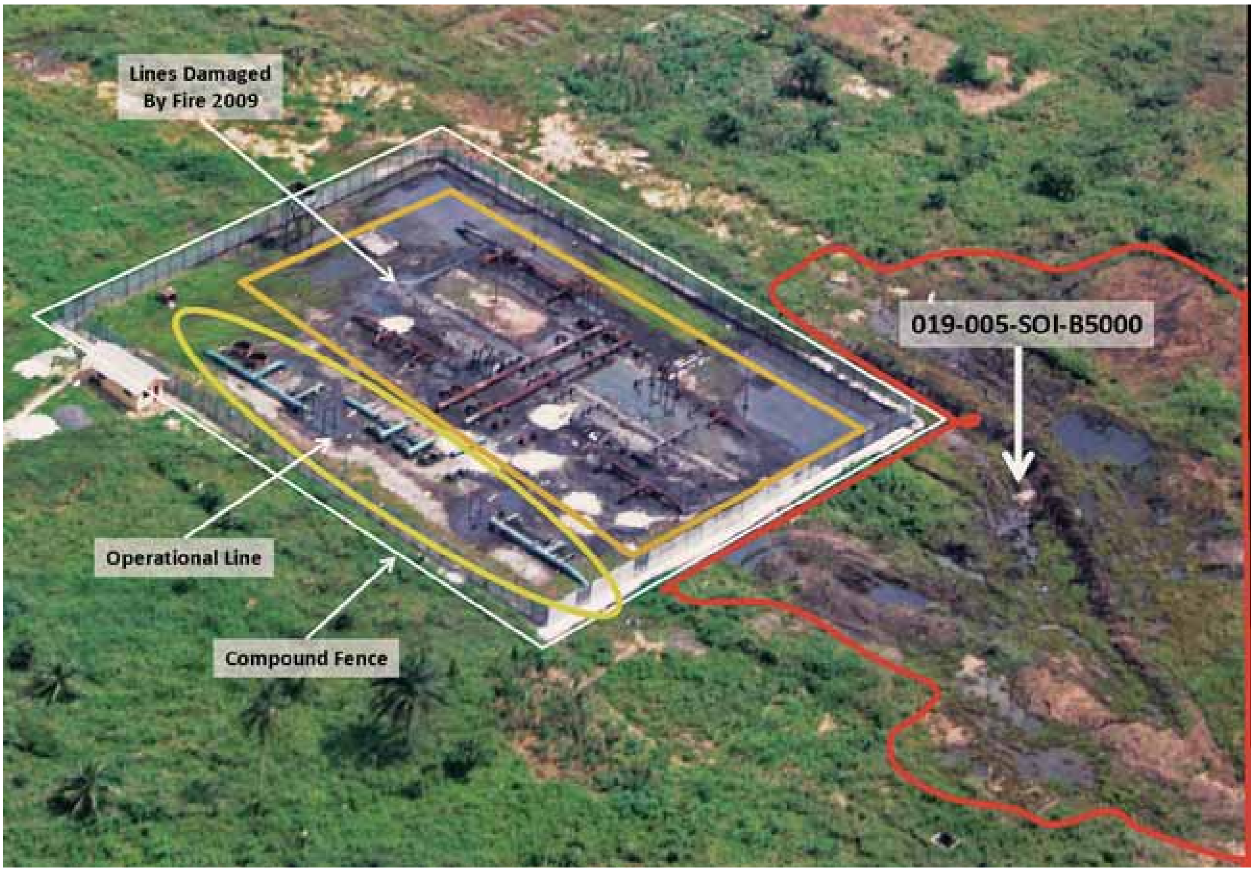
Site description. The Bomu manifold is situated to the east of K-Dere and Kpor in Gokana LGA. It connects five northbound pipelines (28-inch Rumuekpe to Bomu trunk line; 20-inch Rumuekpe manifold to Bomu manifold trunk line; 24-inch Nkpoku to Bomu trunk line; 12-inch Egberu manifold to Bomu trunk line; 36-inch Rumuekpe to Nkpoku trunk line) to four southbound pipelines (disused 6-inch Yorla to Bomu trunk line; 10-inch Bomu flow station to Bomu tie-in manifold delivery line; 24-inch Bomu to Bonny trunk line; 28-inch Bomu to Bonny trunk line).

The manifold covers an area of 5,000 square metres. It is surrounded by a 3-metre high wire-mesh fence with two separate gates, both of which are wide enough to provide access for heavy machinery. The site is currently guarded by SPDC staff and armed army personnel. Access is possible only with a permit issued by SPDC.[3]

Most of the pipes and manifold infrastructure are above ground. Outside the manifold area, pipes run below ground.

The area inside the fence is visibly heavily polluted with crude oil, which is seeping through the fence and contaminating several thousand square metres of soil outside the complex. There is no trench or perimeter drain system around the manifold.

Land use. The nearest inhabited houses are approximately 220-250 metres to the west in K-Dere. A primary school and a local community health-care centre are located some 300 metres to the north-west of the manifold and an abandoned house lies about 100 metres to the south. The area immediately bordering the manifold to the north and east is covered by a cassava plantation. No grazing animals were observed on the site. An old flow station, reportedly damaged during the Biafran War and later decommissioned, is located 150 metres to the east, while a



Arial view of the Bomu manifold (K-Dere, Gokana LGA)

3 The fence was mended and security provided after the initial UNEP site visit.

newer flow station, also inoperative but only partly decommissioned, lies 90 metres to the west. The Bomu 1 and Bomu 24 wellheads are situated 80 metres to the north-west and 160 metres to the south-west, respectively.

Spill history. At the time of the sampling visits, in August and December 2010, half of the infrastructure was scorched and inoperative. Local community members reported that a fire had occurred in April 2009 following an oil spill on the Trans-Niger Pipeline, which transports 120,000-150,000 barrels per day through Ogoniland. Information about the amount of oil spilled, the duration of the leakage and the duration of the fire were not available; local community members mentioned that the fire lasted "several days". Workers on the manifold stated that since the fire only one of the two pipelines leading into and out of the manifold was operating.

Other spills in the manifold occurred in October 1990 (twice), February and March 2001 and January and October 2003.

According to SPDC information, two remediation projects have been completed in the Bomu manifold area in the past, while for the latest spill a two-tier assessment and contracting process were under way.

Visual observations on site. Most of the manifold area inside the fence is covered in oily residues, soot and ash. Oil is seeping from the concrete seal through the fence into the surrounding area. The extent of the contamination covers the manifold area itself and an additional 19,000 square metres of land outside the manifold. Of this, some 9,000 square metres are heavily polluted, the concentration of oil on the surface being above saturation, resulting in an oily sheen on pools of standing water and a strong oily smell. Some of the still operational pipes are leaking and the oil collected from them is stored in an open container with a volume of approximately 10 cubic metres.

A small trench leading south from the manifold is heavily contaminated with oil. It leads into a small collection pond covering an area of approximately 600 square metres adjacent to the abandoned house south of the manifold, before continuing to connect with a small creek that flows south towards Bodo. Next to the abandoned house the sampling team found an open, hand-dug well in which the groundwater was approximately 1 metre below surface level, the same level as groundwater found in the monitoring wells on the site.

In the cassava plantation to the east, the plants appear to be somewhat inhibited in their growth and overall health.

Sample analysis. A summary of the soil and groundwater investigations is presented in Table 19.

The highest soil contaminations, at 63,600 mg/kg TPH, were found in the top 0.60 metres of a borehole in the most heavily contaminated area directly bordering the southernmost part of the manifold (019-005-SOI-B5000). This is extremely high and is far above the EGASPIN intervention value of 5,000 mg/kg. Contamination gradually decreased with depth until at 4-5 metres below ground surface (bgs) concentrations fell below 20,000 mg/kg (Figure 10).

Conclusions. While the site is currently fenced, environmental contamination is migrating both laterally and vertically. The measured hydrocarbon values significantly exceed the EGASPIN intervention values for both soil and groundwater and therefore intervention and risk reduction measures are needed for both.

A small portion of crude oil has gathered in a collection pond, with runoff seeping from the site via a trench leading southwards into the creeks. The trench is heavily contaminated and will need to be excavated and cleaned up.

Free phase oil and contaminated soil should have been removed in the days immediately after the spill and fire, as this would have prevented the lateral and vertical spread of the pollution. Nearly two years after the incident, still nothing appears to have been done, enabling the contamination to spread further, thereby increasing the extent and cost of the remediation effort.

There are definite signs of crude oil-related groundwater contamination in the whole manifold area. Continued emission of petroleum-related contaminants needs to be halted immediately to reduce risks to the surrounding communities.

Since there is no systematic drainage collection system in place around the manifold, crude oil is being washed off into the surrounding fields. At the time of UNEP's field visits, fresh crude oil was found in a trench leading southwards. During the rainy season in particular, runoff from the manifold is contaminating surrounding areas. Considering the seriousness of the pollution and the fact that contaminants have penetrated to a depth of 5 metres or more below ground surface, the standard SPDC approach of *in situ* RENA will not be appropriate at this location.

Table 19. Summary of results of soil and groundwater investigations at the Bomu Manifold site, Gokana LGA

UNEP site code	qc_019-005
Site name	Bomo Manifold
LGA	Gokana
Site description	SPDC operating site
Area Investigated (m^2)	37,988
Number of soil samples	56
Number of groundwater samples	5
Deepest investigation (m)	5.00
Maximum soil TPH (mg/kg)	63,600
Number of soil measurements greater than EGASPIN intervention value	21
Deepest sample greater than EGASPIN intervention value (m)	5.00
Maximum water TPH (µg/l)	3,410
Number of water measurements greater than EGASPIN intervention value	1
Presence of hydrocarbons in surface water	yes
Number of soil measurements below 1 m	38
Number of soil measurements below 1 m greater than EGASPIN intervention value	17
Total volume of soil above intervention value (m^3)	38,257
Total volume of soil above target value (m^3)	62,775

Site-specific recommendations:

1. The impacted area should be demarcated and appropriate signage erected to indicate that the site is heavily polluted; similar signage should be placed in the impacted drains
2. Where community land is impacted, inhabitants should be informed
3. The site should be reworked to prevent runoff from the area into downstream areas
4. Runoff should be monitored and if necessary treated while the clean-up plan is being developed
5. Monitoring of well water should be introduced to provide an early warning mechanism for surrounding communities not yet impacted by groundwater pollution emanating from the site
6. Prior to site clean-up, additional soil sampling, along with excavation of trial pits, should be carried out to delineate the area requiring treatment
7. A detailed plan should be prepared for (i) clean up of the contaminated soil and (ii) risk reduction at the site. Additional guidance on clean up of contaminated soil is provided in Chapter 6
8. A detailed plan should be prepared for (i) clean up of contaminated water and (ii) risk reduction at the site. Additional guidance on clean-up of contaminated water is provided in Chapter 6
9. During the clean-up, excavation water should be carefully managed to ensure that pollutants do not escape into the environment

Figure 10. Vertical profile of contamination at 019-005-SOI-B5000

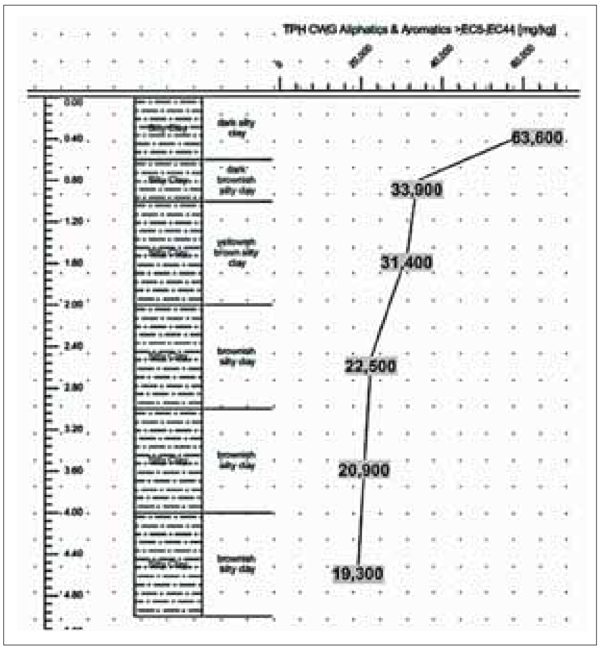


Table 20. Summary of contamination of investigated SPDC suspended facilities

UNEP site code	LGA	Number of soil samples	Number of groundwater samples	Deepest soil investigation (m)	Maximum soil TPH (mg/kg)	Number of soil measurements >EGASPIN	Deepest soil sample >EGASPIN (m)	Maximum water TPH (ug/l) (CL samples)	Hydrocarbons in community wells	Number of water TPH measurements >EGASPIN	Number of samples with TPH >EGASPIN below 1 m
qc_019-014	Gokana	16	2	3.2	389			11,500	yes	2	
qc_019-021	Gokana	26		5	7,620	2	3				2
qc_009-002	Tai	44	2	5	1,040			10,900		1	
qc_008-002	Tai	58	2	5	1,880			42,800	yes	1	
qc_007-001	Eleme	58	3	6	442			10			
qc_019-035	Gokana	16	1	2.6	3,480			10,300	yes	1	
qc_019-032	Gokana	21	2	2.2	1,220			49			
qc_019-010	Gokana	32	5	5.2	139,000	5	2	172,000		5	1
qc_019-004	Gokana	18	1	5	23,200	8	2.6	32			4
qc_015-003	Khana	36		3	8,830	1	1.5	10			1
qc_015-002	Khana	45	2	5	20,400	3	3.5	288			3
qc_015-001	Khana	42	2	3.5	8,200	5	3	358,000		1	2
qc_014-004	Khana	18	3	2.6	198			519			
qc_014-001	Khana	24	2	2.6	157			2,140		1	
qc_008-007	Tai	75	1	7.4	11,200	25	5.6				22
qc_008-004	Tai	72	2	5	4,860			47			
qc_008-003	Tai	127	2	5.2	10,800	9	5	22,600		2	9
qc_001-002	Eleme	25	4	3	10,400	6	3	1,980	yes	3	3
qc_001-004	Eleme	8	4	6.5	533			13,200		2	
qc_008-010	Tai	60	3	5	6,700	5	5	360			5
qc_008-009	Tai	53	2	5	4,030			1,180,000		1	

A summary of contamination at other SPDC suspended facilities investigated by UNEP is presented in Table 20. From the summary presented in the table, the following key observations can be made:

1. At 10 of the 21 UNEP-investigated sites along SPDC suspended facilities, soil contamination exceeded the limits set by Nigerian national legislation
2. At all 10 of these locations, contamination penetrated deeper than 1 metre below the surface (i.e. below the area targeted by RENA)
3. At 11 of the 21 sites, groundwater pollution exceeded the intervention value set in Nigerian legislation
4. At four of the investigated sites, hydrocarbons were detected in drinking water used by neighbouring communities

Case study 3 SPDC legacy site – 008-010 Korokoro flow station

Site description. Korokoro flow station is situated in Bue Mene community, Korokoro, less than 100 metres from the nearest inhabited houses, less than 250 metres from a school and within 500 metres of a fish farm. There are two wellheads (Korokoro 4 and Korokoro 8) immediately adjacent to the flow station, which is surrounded by a mostly damaged fence. Access control is non-existent, such that both wellheads are unsecured and easily accessible.

Land use. The flow station covers approximately 7,000 square metres. Parts of the site are used for cassava plantations. Approximately 50 per cent of the surrounding neighbourhood consists of housing with fruit and vegetable gardens. The rest of the surrounding area is covered by about 20,000 square metres of bush and forest, as well as plantations of cassava and other crops.

Spill history. Five oil spills at the flow station were recorded by SPDC: in July 1986, in August, September and December 1989 and in January 1990. No spills were reported at the wellheads.

Visual observations on site. The area of the flow station is overgrown with small trees, shrubs and undergrowth. The infrastructure, including gas-liquid separators and oil-water separators, is still in place. All technical installations appear not to have been cleaned before the station was shut down. Outside the flow station, approximately 100 metres to the east, a rectangular depression of some 200 square metres indicates the area formerly used for gas flaring. Superficial soil contamination could be seen here, as well as in the cassava plantation about 100 metres to the north-east, where three of the spill incidents were reported.

Sample analysis. A summary of the soil and groundwater investigations is presented in Table 21.

The soil contamination data are presented in contour form in Map 13.

Investigation of the soil and groundwater showed evidence of significant soil contamination in the flow station area, with the wellhead areas also contaminated by TPH. Soil TPH concentrations reached a maximum of >14,000 mg/kg in the topsoil, with concentrations of 5,000-6,000 mg/kg found at 4-5 metres depth in the centre of the contaminated area, where three of the spills were reported; sampling from two boreholes demonstrates how variably contamination is distributed in the soil in this area (Table 22).

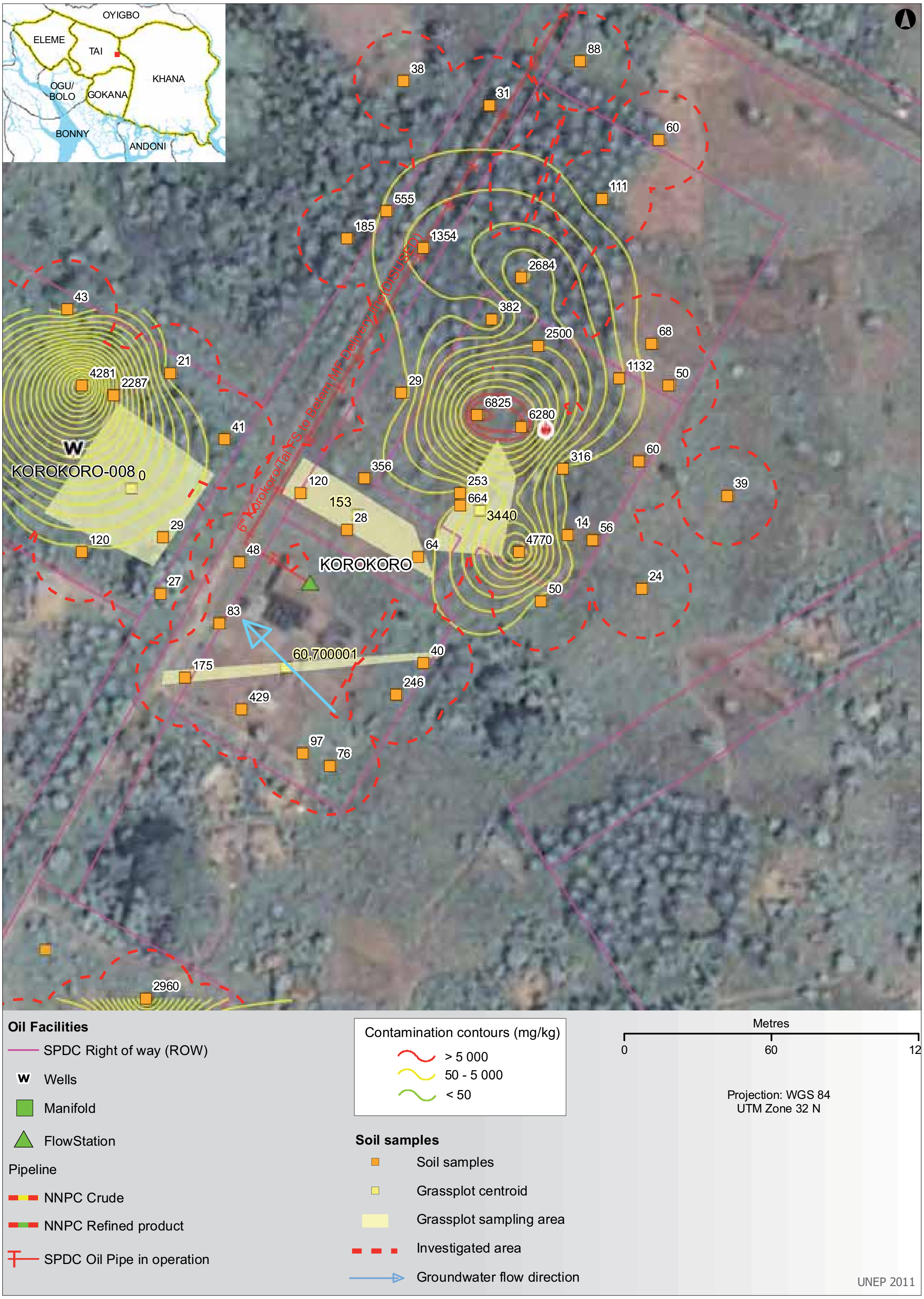
Borehole B180 was drilled in an area where oil had spilled onto the ground and seeped down to the maximum sampling depth of 5 metres, at which depth the concentration of TPH was 6,530 mg/kg. Borehole B600, drilled 20 metres away from B180, showed no detectable contamination down to 1 metre deep. Below one metre, TPH contamination reached 13,500 mg/kg, slowly decreasing to 5,430 mg/kg at a depth of 5 metres.

The high level of TPH at 5 metres shows not only that the upper soil profile does not retain contamination, thus facilitating vertical migration, but also that crude oil is able to reach greater depths. Sample B600 thus demonstrates how deceptive uncontaminated surface soil can be in relation to contamination at greater depths.

Table 21. Summary of results of soil and groundwater investigations at the Korokoro flow station, Tai LGA

UNEP site code	**qc_008-001**
Site name	**Korokoro flow station**
LGA	Tai
Site description	SPDC legacy site
Investigated area (m^2)	41,052
Number of soil samples	204
Number of groundwater samples	4
Number of drinking water samples	4
Deepest investigation (m)	5.20
Maximum soil TPH (mg/kg)	14,200
Number of soil measurements greater than EGASPIN intervention value	13
Deepest sample greater than EGASPIN intervention value (m)	5.00
Maximum water TPH (µg/l)	769
Number of water measurements greater than EGASPIN intervention value	2
Presence of hydrocarbons in drinking water	no
Number of soil measurements below 1 m	171
Number of soil measurements below 1 m greater than EGASPIN intervention value	12
Total volume of soil above intervention value (m^3)	3,390
Total volume of soil above target value (m^3)	48,501

Map 13. Contamination contours at Korokoro Well 8, Tai LGA



Given human smell detection levels for petroleum hydrocarbons of between 200 and 500 mg/kg, the average human being would probably not notice the contamination in the top 1 metre of soil around the B600 sampling location.

General conclusions. Considering that the oil spills took place between 1986 and 1990, natural attenuation, or biodegradation of contaminants, has not proven effective in reducing contaminant concentrations to safe levels in the affected area. Remediation of the whole area is advisable but this has apparently never been carried out, even though pipeline rights of way on the site are currently being used for agricultural purposes. Superficial decontamination by enhanced natural attenuation – so far the only remediation method observed by UNEP in Ogoniland – will not solve the environmental problems at this site. Contamination reaches to a depth of at least 5 metres below ground surface, and areas that are apparently uncontaminated at the surface may be highly contaminated underground.

Table 22. Vertical Profiling of TPH concentrations in Korokoro flow station, Tai LGA

Soil sampling borehole	Depth interval (m)	TPH (mg/kg)
008-010 B180	0.0-0.4	14,200
	0.4-1.4	6,810
	1.4-2.6	6,020
	2.6-4.0	5,630
	4.0-5.0	6,530
008-010 B600	0.0-0.7	433
	0.7-1.0	285
	1.0-2.0	13,500
	2.0-3.0	6,460
	3.0-4.0	5,620
	4.0-5.0	5,430

Site-specific recommendations:

1. The impacted area should be demarcated and appropriate signage erected to indicate that the site is heavily polluted
2. The site should be reworked to prevent water from pooling and infiltrating downwards, carrying oil with it
3. Monitoring of well water should be introduced to provide an early warning for surrounding communities not yet impacted by groundwater pollution emanating from the site
4. The flow station should be decommissioned following industry best practice
5. Prior to site clean-up, additional soil sampling, along with excavation of trial pits, should be carried out to delineate the area to be treated
6. A detailed plan should be prepared for (i) clean up of the contaminated soil and (ii) risk reduction at the site. Additional guidance on contaminated soil clean-up is provided in Chapter 6
7. A detailed plan should be prepared for (i) clean-up of the contaminated water and (ii) risk reduction at the site. Additional guidance on contaminated soil clean-up is provided in Chapter 6
8. During the clean-up, excavation water should be carefully managed to ensure that pollutants do not escape into the environment

A summary of contamination in the SPDC legacy sites investigated by UNEP is presented in Table 23. From the summary presented in the table, the following key observations can be made:

1. At four of the five SPDC legacy sites investigated by UNEP, soil contamination exceeds the limits set in Nigerian national legislation
2. At three of these locations, contamination has penetrated more than 1 metre below the ground surface (i.e. below the area targeted for treatment by SPDC)
3. At four of the five sites, groundwater pollution exceeded the intervention values set in Nigerian legislation

Table 23. Summary of contamination of investigated SPDC legacy sites

UNEP site code	LGA	Number of soil samples	Number of groundwater samples	Deepest soil investigation (m)	Maximum soil TPH (mg/kg)	Number of soil measurements >EGASPIN	Deepest soil sample >EGASPIN (m)	Maximum water TPH (ug/l) (CL samples)	Hydrocarbons in community wells	Number of water TPH measurements >EGASPIN	Number of samples with TPH >EGASPIN below 1 m
qc_016-001	Khana	85	13	5.2	8,820	2	0.4	77,000		3	
qc_019-033	Gokana	6		2	331			10			
qc_009-001	Tai	21	6	3	9,030	2	2	213,000		4	1
qc_005-001	Eleme	35	3	9	9,220	6	3	3,590		2	6
qc_019-012	Gokana	49	3	5	29,600	11	5	588,000		4	11

Case study 4 NNPC trunk line spill – 019-013 1990 pipeline leak in K-Dere

Site description. Approximately 2 km west of K-Dere in Gokana LGA, the 24-inch NNPC Bonny to Port Harcourt Refinery trunk line runs in a north-south direction transporting crude oil from Bonny Terminal to the Port Harcourt Refinery. The pipeline right of way is neither secured nor guarded and is easily accessible via a 150-metre dirt track off the main tarmac road leading out of K-Dere to the west.

Land use. To the west of the spill site is a forest area of approximately 60,000 square metres. The areas to the east and south are used for cassava and palm tree plantations.

Spill history. The pressurized pipeline ruptured catastrophically in 1990, killing three workers at the site. Local community members accompanying UNEP reported that oil from the pipeline was sprayed high into the air, contaminating many tens of thousands of square metres. Aside from the 1990 incident, no other spills have been reported from this site.

Visual observations on site. The spill site itself, extending over approximately 1,000 square metres, is obvious from the covering of ash and slag generated by the ensuing fire. An area of some 5,000 square metres immediately around the spill point is devoid of all vegetation. Oil crusts can be seen on the soil surface in the surrounding areas. The soil is hydrophobic, such that rain falling onto the ground hardly infiltrates.

The bare soil is prone to erosion and this has carved out gullies leading into a nearby small tidal creek north-west of the blowout point. The assessment team estimated that sediment in the creek is highly contaminated over an area of 20,000 square metres.

The contamination in the immediate vicinity of the spill was never remediated, as suggested by the soil sampling results.

NNPC trunk line spill (K-Dere, Gokana LGA)

Table 24. Summary of results of soil and groundwater investigations at the K-Dere NNPC pipeline rupture site, Gokana LGA

UNEP site code	qc_019-013
Site name	**NNPC pipeline rupture**
LGA	Gokana
Site description	NNPC crude pipeline
Investigated area (m^2)	40,348
Number of soil samples	52
Number of groundwater samples	4
Number of surface water samples	1
Number of free-phase water samples	1
Number of CL sediment samples	1
Deepest investigation (m)	5.50
Maximum soil TPH (mg/kg)	32,600
Number of soil measurements greater than EGASPIN intervention value	13
Deepest sample greater than EGASPIN intervention value (m)	5.00
Maximum water TPH (µg/l) (CL samples)	5,650
Number of water measurements greater than EGASPIN intervention value	2
Presence of hydrocarbons in sediment (CL) above EGASPIN intervention value	yes
Total volume of soil above intervention value (m^3)	4,818
Total volume of soil above target value (m^3)	26,843

Sample analysis. A summary of the investigations is shown in Table 24.

Soil contamination data are presented in contour form in Map 14.

The vertical profile of contamination is also of interest (Table 25). The main contaminants were TPH, with maximum concentrations of 32,600 mg/kg at a depth of 0-0.10 metre in sample B5000 and 28,300 mg/kg at a depth of 2-3 metres in sample B5010.

The sediment sample 019-011-SED-5000, taken from the creek, proved to be highly contaminated, laboratory results showing TPH at 32,600 mg/kg. The gas chromatography (GC) fingerprint of the oil at a depth of 2-3 metres was identical with that found in the sediment from the creek, proving the linkage between source and impact (Figure 11a and 11b). The hydraulic connection between contaminated land and creeks will have important implications for the sequence of remediation to be carried out. Until the land-based contamination has been dealt with, it will be futile to begin clean-up of the creek as pollutants will continue to migrate towards the creek, re-contaminating water, sediments and vegetation.

Table 25. Vertical profiling of contamination at the NNPC pipeline rupture site, Gokana LGA

Soil sampling borehole	Depth interval (m)	TPH (mg/kg)
019-011-SOI-B5000	0-0.10	32,600
	0.10-0.50	20,200
	0.50-1.00	11,000
	1-2	7,060
	2-3	10,300
	3-4	10,400
	4-5	10,100
019-011-SOI-B5010	0-0.40	16,900
	0.40-1	12,900
	1-2	9,720
	2-3	28,300
	3-4	21,300
	4-5	12,600

Groundwater in this area has been impacted with TPH concentrations near the contamination centre reached 1,360 µg/l and 2,800 µg/l. However, the fact that this area is remote from nearby communities and the water is currently not used for irrigation give an opportunity to contain and clean up the contamination before potential receptors are reached through this pathway.

Map 14. Contamination contours at NNPC spill, K-Dere Gokana LGA

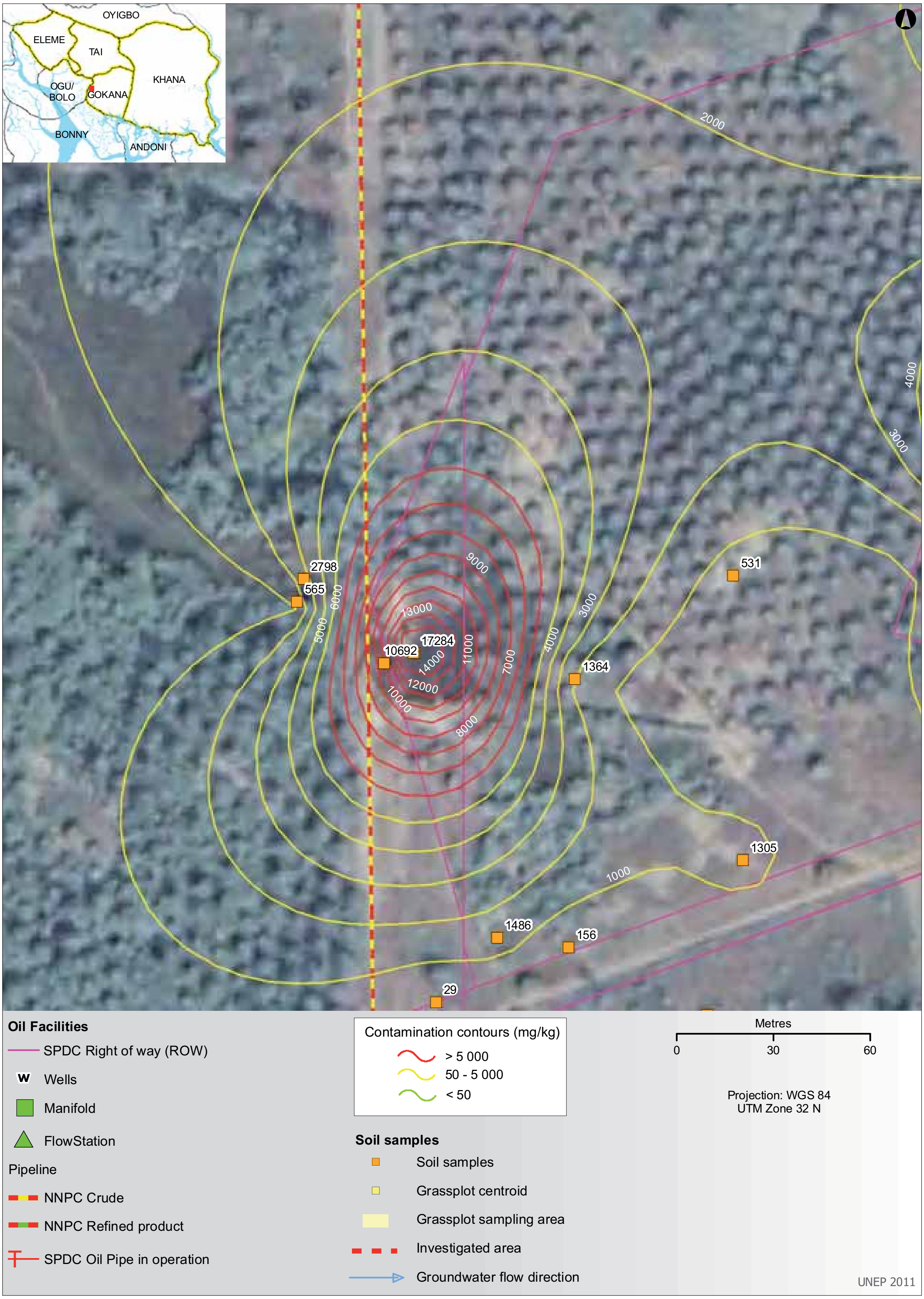
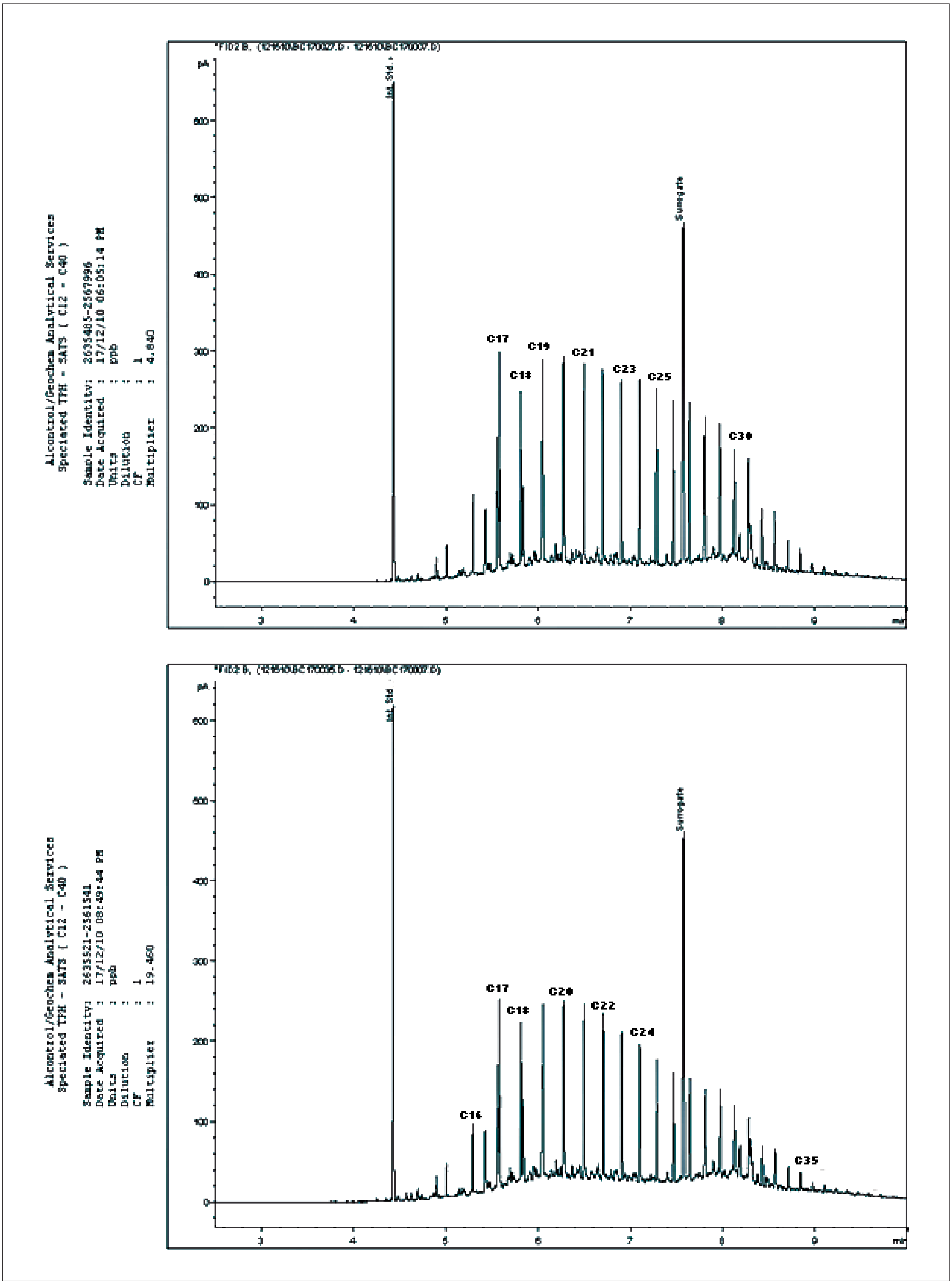


Figure 11a and 11b. Gas chromatography (GC) fingerprint of sample 019-011-SED-5000 at 0-0.1 metre depth (top) and sample 019-011-SOI-B5000 at 2-3 metres depth (bottom)



General conclusions. Soil contamination arising from the 1990 NNPC pipeline blowout impacted an extensive area. No effective remediation has taken place at either site, such that an area of approximately 5,000 square metres has been impacted and is devoid of any vegetation. Soil contamination extends to a depth of at least 5 metres.

The soil in the core affected area must be considered highly contaminated, based on the concentrations of hydrocarbons, and is currently unfit for any further use. The absence of any protective vegetation has led to soil erosion and heavy contamination – via transport and deposition of contaminated particles – of the adjacent creek and possibly the surrounding agricultural land. Direct runoff of oil for the duration of the rupture, and subsequent sub-surface transfer of contamination, also cannot be ruled out. Since the waters in the creek are tidal, the hydrocarbon coating of the sediment grains will be washed off or dissolved, or the sediment itself may be transported, leading to further downstream contamination.

UNEP investigations have shown that 20 years after the oil spill on this site, natural attenuation has not been effective.

Site-specific recommendations:

1. The impacted area should be demarcated and appropriate signage erected to indicate that the site is heavily polluted
2. The site should be reworked to prevent runoff from the area into the nearby creek
3. A leachate monitoring system and, if necessary, leachate treatment should be established
4. Monitoring of well water should be introduced to provide an early warning for communities not yet impacted by groundwater pollution emanating from the site
5. Prior to site clean-up, additional soil sampling, along with excavation of trial pits, should be carried out to delineate the area to be treated
6. A detailed plan should be prepared for (i) clean up of the contaminated soil and (ii) risk reduction at the site. Additional guidance on clean up of contaminated soil is provided in Chapter 6
7. A detailed plan should be prepared for (i) clean up of the contaminated water and (ii) risk reduction at the site. Additional guidance on clean-up of contaminated water is provided in Chapter 6
8. Further assessment of the creek should be carried out to map the extent of pollution and to decide whether it would be appropriate to undertake dredging at a later stage, once the contaminated land has been treated
9. During the clean-up, excavation water should be carefully managed to ensure that pollutants do not escape into the environment

A summary of contamination at the investigated NNPC pipeline site at K-Dere is presented in Table 26.

Table 26. Summary of contamination on the NNPC pipeline site

UNEP site code	LGA	Number of soil samples	Number of groundwater samples	Deepest soil investigation (m)	Maximum soil TPH (mg/kg)	Number of soil measurements >EGASPIN	Deepest soil sample >EGASPIN (m)	Maximum water TPH (ug/l) (CL samples)	Hydrocarbons in community wells	Number of water TPH measurements >EGASPIN	Number of samples with TPH >EGASPIN below 1 m
qc_019-046	Gokana	72	3	5	2,900			2,320		2	

Case study 5 NNPC product line spill – 001-005 Nsisioken Agbi, Eleme LGA

Site description. An NNPC product pipeline from Port Harcourt refinery runs to Umu Nwa Nwa through Nsisioken Agbi in Eleme LGA. The pipeline crosses a number of other pipelines at Nsisioken Agbi, including the SPDC-owned 28-inch Rumuekpe to Bomu trunk line, the 36-inch Nkpoku to New Ebubu (Oghale) trunk line and the abandoned 20-inch Rumuekpe manifold to Bomu manifold trunk line. The pipeline runs underground but is otherwise not secured and there are no signs or fences to indicate the route of the pipeline.

Land use. A number of houses have been built next to the pipeline over a linear distance of approximately 500 metres, the closest house being approximately 10-15 metres from the pipeline. All the houses in this area have fruit and vegetable gardens and water is taken from hand-dug wells or deeper boreholes. A sacred forest is located west of the spill site, covering approximately 45,000 square metres. An area of wetlands lies downhill to the south-west of the spill site, the water surface covering some 20,000 square metres in the dry season, rising to 100,000 square metres during the rainy season. A small cassava plantation is situated between the sacred forest and the wetland.

Spill history. The NNPC trunk line transports refined products, including gasoline and diesel or kerosene. No data on spills on NNPC pipelines were made available to the UNEP team. The spill investigated by UNEP was found during reconnaissance visits, together with community representatives, along known pipeline rights of way. According to local anecdotal information, the spill occurred around 2005 close to the area of housing, some 300 metres uphill from the wetland. Groundwater was contaminated to a distance of at least 600 metres from the source of the spill. A few residents claimed to have smelt oil in their drinking water.

Other spill incidents on this site have not been reported by local representatives. No additional data were available from NNPC.

Visual observations on site. A dirt road follows the trunk line downhill. Visible signs of spilled oil could be seen, such as dark crusts on the soil surface, as well as oily sheens on standing pools of water.

During test borehole drilling, especially close to the pipeline, an intense kerosene smell could be detected. Free-phase hydrocarbon was recovered from the drilled well.

Sample analysis. A summary analysis of the contamination is presented in Table 27.

Given that the nearby community draws water for drinking, cooking and washing from the area, the most important observation at this site was the presence of free-phase hydrocarbon on water at the source of the leak and the presence of dissolved hydrocarbons in the area. Most worrying, the water had very high concentration of benzene, a known carcinogen. In addition to methane, the samples also revealed the presence of methyl tertiary butyl ether (MTBE). MTBE is not a part of crude oil but an additive added to refined products at the refinery, so its presence proved that the spill was indeed that of a refined product (e.g. gasoline) rather than crude oil.

Soil contamination at the site is presented in contour form in Map 15.

General conclusions. Contamination of soil on the spill site extends over a wide area. Contaminants are being leached from the soil to the groundwater and transported over a distance of more than half a kilometre to community drinking water wells. Severe contamination of drinking water by toxic and carcinogenic substances presents an acute health hazard.

Site-specific recommendations:

1. The acute health risks to the surrounding community make it essential that clean-up of the site be treated as highest priority
2. An alternative water supply should be made available immediately. All community wells in which

Field work in Nsisioken Agbi, Eleme LGA benzene and/or MTBE have been detected should be marked and the community requested not to consume any further water from these wells

3. Comprehensive monitoring of drinking water quality in all household and public drinking-water wells should be carried out within a radius of 1 km of the spill location
4. The impacted area should be demarcated and appropriate signage erected to indicate that the site is impacted
5. Prior to site clean-up, additional soil sampling, along with excavation of trial pits, should be carried out to delineate the area to be treated
8. The initiation of clean-up at this site is made more complex by the presence of swampland and a sacred forest. In preparing detailed clean-up plans, community consultation will be needed. Innovative technological options which can achieve pollutant removal without disturbing the sacred forest may have to be employed

A summary of contamination in the investigated NNPC pipeline rupture site at Nsisioken Agbi is presented in Table 28.

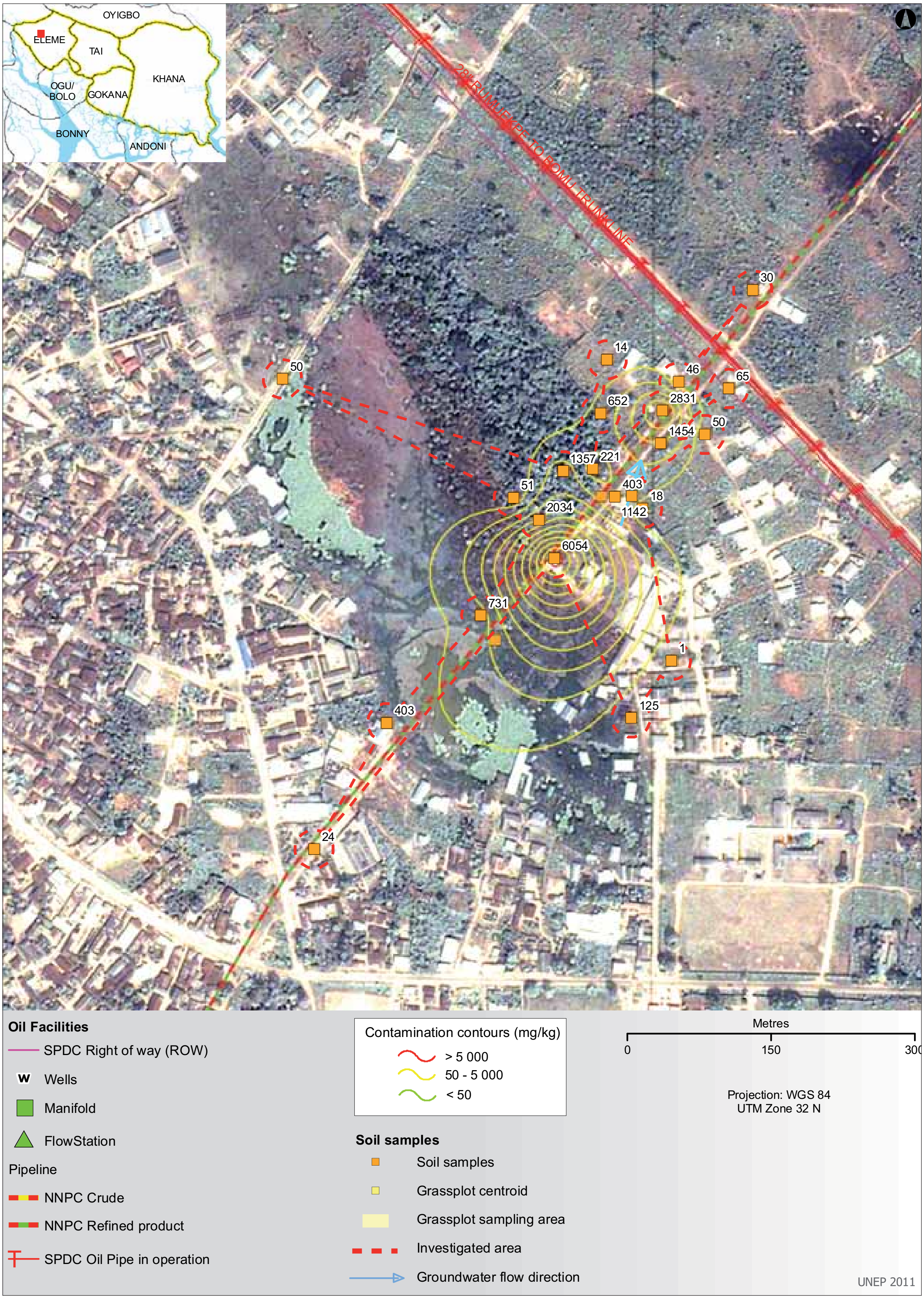
Table 27. *Summary of investigation of soil and groundwater at the Nsisioken Agbi Ogale NNPC pipeline rupture site, Eleme LGA*

UNEP site code	**qc_001-005**
Site name	**Nsisioken Agbi**
LGA	Eleme
Site description	NNPC product pipeline
Investigated area (m^2)	26,995
Number of soil samples	66
Number of groundwater samples	7
Number of drinking water samples	20
Number of surface water samples	2
Number of free-phase water samples	2
Number of sediment samples	2
Deepest investigation (m)	6
Maximum soil TPH (mg/kg)	7,310
Number of soil measurements greater than EGASPIN intervention value	2
Deepest sample greater than EGASPIN intervention value (m)	2
Maximum water TPH (µg/l) (samples)	86,100
Number of water measurements greater than EGASPIN intervention value	5
Presence of hydrocarbons in drinking water	yes
Presence of hydrocarbons in surface water (CL)	yes
Presence of hydrocarbons in sediment (CL) above EGASPIN intervention value	yes
Number of soil measurements below 1 m	48
Number of soil measurements below 1 m greater than EGASPIN intervention value	2
Total volume of soil above intervention value (m^3)	10,025
Total volume of soil above target value (m^3)	38,366

Table 28. Summary of contamination at the investigated NNPC product line

UNEP site code	LGA	Number of soil samples	Number of groundwater samples	Deepest soil investigation (m)	Maximum soil TPH (mg/kg)	Number of soil measurements >EGASPIN	Deepest soil sample >EGASPIN (m)	Maximum water TPH (ug/l) (CL samples)	Hydrocarbons in community wells	Number of water TPH measurements >EGASPIN	Number of samples with TPH >EGASPIN below 1 m
qc_002-008	Eleme	13		3	2,950						
qc_004-006	Eleme	38		5	13,200	6	2	181			3

Map 15. Contamination contours at Nsioken, Agbi, Ogale, Eleme LGA



Case study 6 Fly tipping of oilfield waste - 001-022 – oil waste dump site

Site description. Site 001-022 is located in Oken Oyaa, Ejama, approximately 700 metres west of Ejama Farming Camp, 1.2 km south-east of Ejama-Ebubu and 4 km north of Onne. It lies in the bend of SPDC's 28-inch Rumuekpe-Bomu trunk line and the 20-inch Rumuekpe manifold to Bomu manifold right of way and is located inside a borrow pit belonging to a local landowner. It is outside the SPCD right of way and is freely accessible. According to anecdotal evidence, the landowner has leased the area to an unknown waste management company. The borrow pit does not comply with EGASPIN regulations in that it is neither lined with 1 metre of re-compacted or natural clay/cement with a hydraulic conductivity ≤1 x 10-9 m/s, nor sealed in an equivalent manner. The site is not an authorized disposal site.

Land use. The area was formerly used for sand mining, apparently for construction purposes. There is some agriculture, and private and commercial housing is concentrated along a nearby expressway and in a new real estate project some 500 metres north of the site.

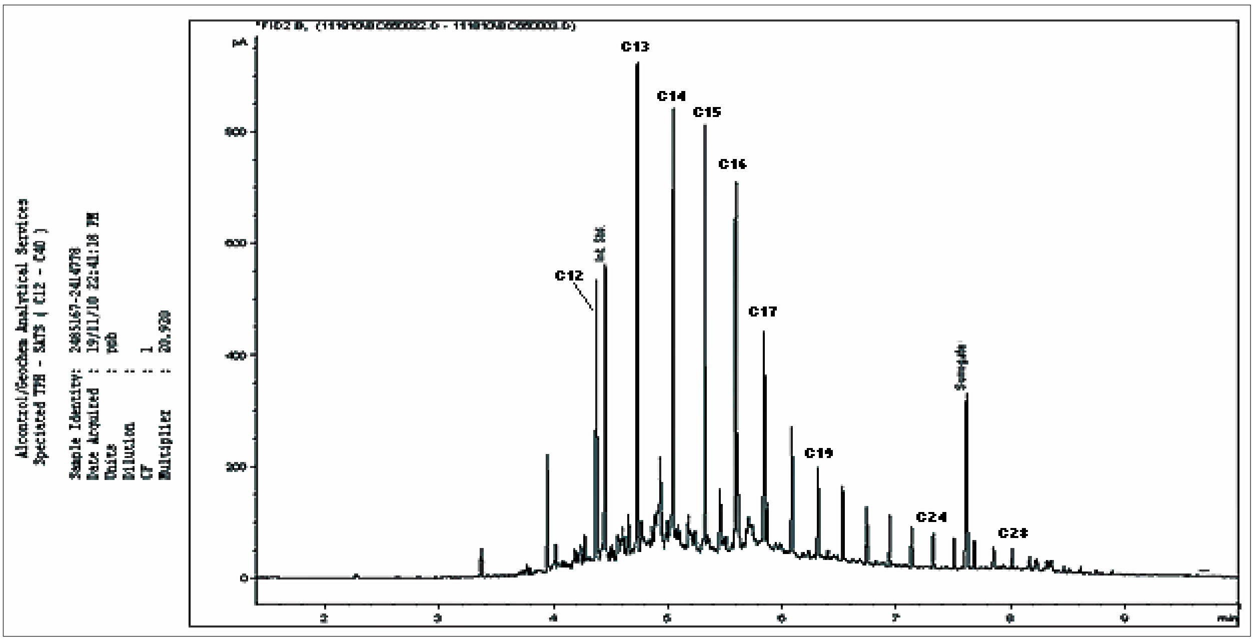
Spill history. There is no spill history as such, as it is not physically related or connected to any oilfield infrastructure in the vicinity. The waste observed by the UNEP assessment team had evidently been dumped a few days, or weeks at the most, prior to the site visit, as a satellite image dated 12 June 2010 does not show any waste at the location. The waste, disposed of in several hundred 'Big Bags' (1 cubic metre reinforced plastic transport bags), amounted to 1,000-1,500 cubic metres of oil mixed with grey clay containing small rock fragments. Oil was seeping from the bags, forming puddles in the ground.

Sample analysis. Samples taken directly from the waste bags had 54,300 mg/kg TPH. This is clearly above the EGASPIN intervention value of 5,000 mg/kg.

Some of the bags were broken and oil had already leached into the soil. Most of the 31 soil samples collected from around the waste were only slightly contaminated, with TPH concentrations below 500 mg/kg in 28 samples and below 50 mg/kg in 10 samples. Some of the samples had elevated levels of barium (maximum 2,630 mg/kg), which raises the possibility that the waste may have come from drilling operations (in which barium is used as a weighting agent).

Fly tipping of oilfield waste in Ogoniland (Oken Oyaa, Eleme LGA)

Figure 12. GC fingerprint of the oil phase sample 001-022-X-100 from a Big Bag



Gas chromatograph-flame ionization detector (GC-FID) fingerprints of the aliphatics fraction (C12-C40, see Figure 12) revealed that the oil was a fresh and unweathered crude oil. An analogous series of n-alkanes are clearly visible, indicating relatively fresh oil. Below this a small unresolved complex mixture can be seen, indicating the presence of some weathered material.

General conclusions. Examination of the site and subsequent laboratory analysis revealed the likely source of the material to be cuttings from oil drilling operations. It falls to the responsible authorities to monitor the movements of hazardous waste from source to end point under a duty of care. The fact that waste of this type is being disposed of in an open and unlined pit proves that the chain of custody between waste generator, waste transporter and waste disposal facility in the region is not being adhered to. The local environmental authority, lacking a proactive support network, is obviously not in a position to monitor instances like this. The case also demonstrates a lack of control by the operator of the site from where the material originated.

As there are currently no oil drilling operations in Ogoniland and the oil was relatively unweathered, the source of the dumped waste must lie outside Ogoniland. Whatever the case, the EGASPIN requires that an operator take care of "the containment and recovery of any spill discovered within his operational area, whether or not its source is known. The operator shall take prompt and adequate steps to contain, remove and dispose of the spill". Furthermore, each oilfield operator is required to identify the oil produced by gas chromatograph-mass spectroscopy (GC-MS) fingerprinting on a field-by-field basis. Whether this provision is applicable for disposal of solid hydrocarbon wastes is for the Government of Nigeria to decide.

Site-specific recommendations:

1. The dumped waste material should immediately be removed to a landfill with proper containment
2. Appropriate action should be taken against the operator of the facility and use of the borrow pit at Oken Oyaa for disposal of waste must cease immediately
3. Additional monitoring should be carried out at the site after the waste material has been removed and while clean-up plans are in preparation

Case study 7 SPDC remediation site 008-002 – Korokoro Well 3, Korokoro, Tai LGA

Site description. The site is located approximately 500 metres north-east of Korokoro, Tai LGA, and is part of the Aabue community lands. The site itself consists of Korokoro Well 3 and the surrounding rights of way, the latter covering an area of 7,900 square metres. The wellhead area, accessible via a tarmac road, is not fenced or guarded and is therefore freely accessible. The average height of the ground surface is 17-18 metres amsl.

The well was drilled and completed in March 1963 but has not been producing oil since the early 1990s. During drilling operations, groundwater was found at 2.56 metres bgs.

SPDC provided no information about maintenance cycles.

Land use. A small household is situated approximately 10 metres to the north of the right of way. A hand-dug well serves as the water supply. The wellhead area is surrounded by cassava fields. The soil consists of yellowish-brown silty or sandy clay.

Spill history. Spills reported by SPDC took place in 1992 (Incident No. 1992-00119), 1993 (Incident No. 1993-00299), 2000 (Incident No. 2000-00230) and 2003 (Incident No. 2003-00149). According to SPDC, the cause of the spill was sabotage each time, though UNEP was unable to verify this. An area of 12,000 square metres was contaminated and remediation was completed. No information was available as to the delimitation of the remediated area, the form of remediation, or the year in which remediation took place.

Visual observations on site. The site was overgrown with elephant grass at the time of the sampling field visit. Along the south-eastern boundary, distinct signs of soil contamination by crude oil were found, covering an area of approximately 800 square metres inside and outside the right of way. The contamination had a visible impact on the size and health of the cassava plants.

The former tailings pit was easily identifiable as a rectangular, shallow, dry depression in the ground next to the wellhead. Sampling revealed that oil-based muds had been used for drilling. Except for the tailings pits, all the soil profiles on the site revealed soil in natural bedding, indicating that the SPDC remediation attempt had consisted of enhanced natural attenuation.

Korokoro Well 3 (Tai, LGA)

Table 29. Summary of soil and groundwater investigations at Korokoro Well 3

UNEP site code	qc-008-007
Site name	**Korokoro Well 3**
LGA	Khana
Investigated area (m^2)	
Number of soil samples	74
Deepest investigation (m)	7.6
Maximum soil TPH (mg/kg)	11,200
Number of soil measurements greater than EGASPIN intervention value	25
Deepest sample greater than EGASPIN intervention value (m)	5.6
Number of soil measurements below 1 m	57
Number of soil measurements below 1 m greater than EGASPIN intervention value	22
Volume of soil exceeding the EGASPIN intervention value (m^3)	
Volume of soil exceeding the EGASPIN target value (m^3)	

Although the visible impact of contamination on the site was limited to an area of approximately 800 square metres, the contamination was far more extensive below ground. Mobile phase hydrocarbons were found at a depth of 5 metres, even beyond the right of way. In all, the contamination footprint covered some 20,000 square metres.

A summary of the chemical investigations carried out at the site is presented in Table 29.

A groundwater monitoring well (008-002-01) was constructed next to the former tailings pit but sampling was not possible as crude oil phase on the groundwater surface was present at a depth of 6 metres.

Vertical profiling of some of the sampling locations is presented in Table 30. This demonstrates not only that contamination has migrated vertically, but also that SPDC's clean-up activities, confined to the surface, failed to meet the EGASPIN intervention value (5,000 mg/kg), despite remediation of the site being declared complete.

Table 30. Vertical profiling of contamination at Korokoro Well 3

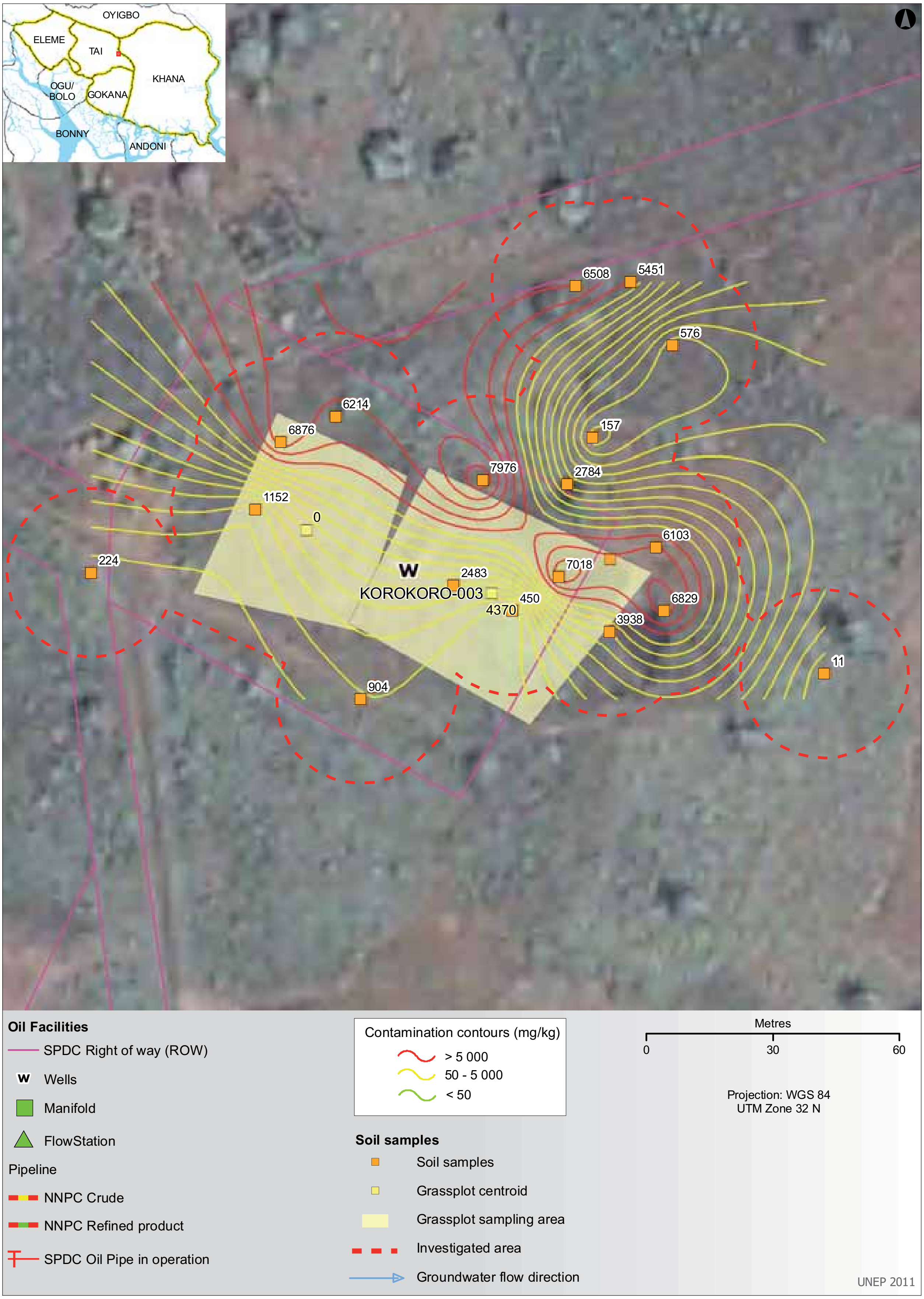
Sampling station	Depth from (m)	Depth to (m)	TPH (mg/kg)
008-002-SOI-B210	0	0.4	10,600
	0.4	1.0	4,830
	1	1.5	6,210
	1.5	2.0	11.1
008-002-SOI-B250	0	0.6	2,240
	0.6	1.0	4,300
	1.0	3.0	7,340
	3.0	4.0	5,880
	4.0	5.0	6,890
008-002-SOI-B350	0	0.8	2,060
	0.8	1.5	3,260
	1.5	2.3	2,850
	2.3	4.2	5,280
	4.2	5.0	4,310
008-002-SOI-B450	0	0.4	8,310
	0.4	1.2	9,050
	1.2	2.4	10,700
	2.4	4.6	4,200
	4.6	5.0	6,120
008-002-SOI-B252	0	1.0	2,330
	1.0	2.0	2,920
	2.0	3.0	6,990
	3.0	4.6	8,060
	4.6	5.0	9,510

General conclusions. Past remediation efforts cannot be considered either effective or successful. Concentrations of TPH still exceed EGASPIN intervention values, even in the surface soil (Map 16). Contamination extending to 5 metres bgs has not been affected by any remediation attempts. Pollution has migrated to the groundwater, as evidenced by the free-phase hydrocarbon found in the UNEP monitoring well.

Site-specific recommendations:

1. The impacted area should be demarcated and appropriate signage erected to indicate that the site is heavily polluted
2. The site should be reworked to prevent runoff from the area entering the nearby creek
3. Monitoring of well water should be introduced to provide an early warning for communities not yet impacted by groundwater pollution emanating from the site
5. Prior to site clean-up, additional soil sampling, along with excavation of trial pits, should be carried out to delineate the area to be treated

Map 16. Contamination contours at Korokoro Well 3, Tai LGA



6. A detailed plan should be prepared for (i) clean up of the contaminated soil and (ii) risk reduction at the site. Additional guidance on clean up of contaminated soil is provided in Chapter 6
7. A detailed plan should be prepared for (i) clean up of the contaminated water and (ii) risk reduction at the site. Additional guidance on clean-up of contaminated water is provided in Chapter 6
8. During the clean-up, excavation water should be carefully managed to ensure that pollutants do not escape into the environment

A summary of the locations in Ogoniland that have been classified by SPDC as "remediation completed" is presented in Table 31. The following key observations can be made from the information presented in the table.

1. At 10 of the 15 sites classified by SPDC as "remediation completed", hydrocarbon contamination exceeding SPDC's own site closure criteria was detected
2. At nine of these 10 locations, pollution has migrated below 1 metre, an area not targeted by SPDC for remediation
3. At eight of the 15 locations, the groundwater had TPH values exceeding the EGASPIN intervention value, but no clean-up attempt has yet been made
4. At two of the 15 sites, hydrocarbon contamination was detected in nearby community wells

Clean-up efforts by SPDC in Ogoniland are not leading to environmental restoration nor legislative compliance, nor even compliance with its own internal procedures.

Table 31. Summary of contamination of investigated SPDC remediated sites

UNEP site code	LGA	Site category	Number of soil samples	Number of groundwater samples	Deepest soil investigation (m)	Maximum soil TPH (mg/kg)	Number of soil measurements >EGASPIN	Deepest soil sample >EGASPIN (m)	Maximum water TPH (ug/l) (CL samples)	Number of water samples >EGASPIN	Number of community wells with TPH	Number of soil measurements below 1 m >EGASPIN
qc_009-006	Tai	SPDC right of way	62	2	5	12,300	4	3	162,000	1		3
qc_019-002	Gokana	SPDC right of way	27	5	5	34,500	10	4	32,000	2		7
qc_010-004	Tai	SPDC right of way	38	8	5	36,200	4	4	543			2
qc_003-002	Eleme	SPDC right of way	23		3	13,400	3	3	91.7			2
qc_019-021	Gokana	SPDC suspended facility	26		5	7,620	2	3				2
qc_008-002	Tai	SPDC suspended facility	58	2	5	1,880			42,800	1	yes	
qc_019-035	Gokana	SPDC suspended facility	16	1	2.6	3,480			10,300	1	yes	
qc_019-032	Gokana	SPDC suspended facility	21	2	2.2	1,220			49			
qc_019-010	Gokana	SPDC suspended facility	32	5	5.2	139,000	5	2	172,000	5		1
qc_019-004	Gokana	SPDC suspended facility	18	1	5	23,200	8	2.6	32			4
qc_015-003	Khana	SPDC suspended facility	36		3	8,830	1	1.5	10			1
qc_015-001	Khana	SPDC suspended facility	42	2	3.5	8,200	5	3	358,000	1		2
qc_014-004	Khana	SPDC suspended facility	18	3	2.6	198			519			
qc_014-001	Khana	SPDC suspended facility	24	2	2.6	157			2,140	1		
qc_016-001	Khana	SPDC legacy site	85	13	5.2	8,820	2	0.4	77,000	3		

Table 32. Location and Concentration of Hydrocarbons in Background Locations in Ogoniland

Community/LGA	Closest Contminated Site	Distance to Contaminated Site (m)	Cobalt mg/kg	Arsenic mg/kg	Barium mg/kg	TPH mg/kg
AKPAJO, ELEME	qc_003-001	322	0.92	0.3	9.8	Not Detected
OKULUEBO, ELEME	qc_005-006	444	2.12	1.54	21.9	Not Detected
KPITE, TAI	qc_009-001	425	0.72	1.07	13	Not Detected
NWIKARA-AGU, KHANA	qc_014-001	180	0.59	1.99	166	95.300
GBE, GOKANA	qc_019-034	168	0.21	0.3	1.25	4.140

Background concentration of hydrocarbons

Even though hydrocarbons are natural organic substances, unlike heavymetals, hydrocarbons are not generally present in the surface soil. A number of soil samples were taken during the assessment from locations away from areas contaminated by hydrocarbons and the results are presented in Table 32. While in most locations there is no presence of hydrocarbons, in two of the locations hydrocarbon is observed even 100 metres beyond the spill site. This could be symptomatic of the situation in Ogoniland where after oil spills, the hydrocarbon spread laterally by runoff contaminates soil much beyond the original perimeter of the spill. This value has particular importance while discussing the target value for clean-up.

Barium pollution

In extracting oil from the ground in Ogoniland, as elsewhere, the oil industry used barium sulphate to increase the density of the fluid used in drilling operations. During the drilling process, the cuttings which come up with the drilling fluid are separated and often disposed of in a pit next to the wellhead. Historically, these pits were unlined and, on close inspection, it is not uncommon to find a range of contaminants in them, including barium and hydrocarbons. Barium was therefore a subject of limited investigations during the UNEP assessment.

Barium (chemical element Ba), a soft silvery metallic alkaline earth metal, was detected in all the collected samples. However, this is not surprising since most heavy metals occur naturally and the presence of barium, does not, in itself, denote oilfield contamination or obvious harm. The Nigerian intervention value for barium is 625 mg/kg, a value that was exceeded in five samples in two locations examined during the UNEP study. Values at these sites ranged from 1,000 mg/kg to 3,050 mg/kg.

Since barium is not a pollutant that can be visually observed on the ground like hydrocarbon, these values represent individual sampling locations only and no conclusions can be drawn as to the full extent of the contamination problem. Thus, additional investigation is needed to discover if there is indeed extensive contamination by barium. Based on the results, a risk reduction strategy – possibly involving local containment, or excavation and transport – should be developed.

Naturally occurring radioactive material (NORM) results

On-site measurements. The ambient dose rates at all sites investigated, even at 'worst case' sites with fresh spillages of oil, was always found to be within the natural background level of 80±40 nanosievert per hour (nSv/h).

On-site measurements confirmed that NORM is present in very low concentrations in Ogoni crude oil and that it makes no detectable additional contribution to the ambient dose rate, within measurement uncertainties. An ambient dose rate in the range of about 100 nSv/h is of no radiological concern. As a reference, the annual dose limit – above background – for human beings is 1,000,000 nSv per year. Surface contamination measurements at all investigated sites were all within the natural background level of 3±2 counts per second (cps); this result is similar to the ambient dose rate finding.

Laboratory measurements. Uranium-235, Thorium-234, Actinium-228, Radium-226, Bismuth-214, Bismuth-212, Lead-212, Lead-214, Lead-210, Thallium-208 and Potassium-40 activity concentrations, measured by gamma spectrometry, were all above detection limits for soil samples but not for liquid samples. Radium-226 and Uranium-235 activities were calculated from the peak at 186 kilo-electron volts (keV) assuming radioactive equilibrium of Radium-226 with its parent Uranium-238 and of natural Uranium-235/Uranium-238 ratio. Liquid samples were measured by ICP-MS expressed in activity concentrations of Uranium-238, Uranium-235, Uranium-234, Thalium-232, Thalium-230 and Radium-226.

These results confirm the on-site findings: NORM is present in the environments assessed by UNEP in concentrations – in the low parts per million range – that would be expected for the geology of the region. Soil samples heavily contaminated with old spilled crude match the zero blank/reference sample and are within analytical or expected natural uncertainties. The conclusion of the laboratory analysis therefore is that NORM is by factors lower in crude oil than it is in the soil. This is confirmed by measurements of the liquids using ICP-MS. Uranium and measured daughter product concentrations in crude oil are lower – by a factor of 1,000 or more – than in local soil.

Visible hydrocarbon pollution on surface water and vessel used to transport oil

4.5 Discussion of institutional issues

UNEP's review of institutional issues in Nigeria led to a series of observations that have a direct bearing on the current environmental situation in the country. There are also implications for how jurisdictional gaps and overlaps between institutions can be improved so that sustainable environmental improvements can be achieved in Ogoniland. Some of the key observations are detailed below.

Multiple institutions with unclear mandates

Nigeria has a three-tier administration: federal, state and local government. Both the federal and state governments have ministries of environment but the Department of Petroleum Resources (DPR) – the 'technical arm' of the Ministry of Petroleum Resources – continues to have a role in regulating environmental issues as well.

The most important piece of legislation on environmental management in Nigeria is the 1992 Environmental Guidelines and Standards for Petroleum Industries in Nigeria (EGASPIN). This confers a statutory role on the DPR to manage all environmental issues arising from oil industry activities, including clean-up of contaminated sites. However, the National Oil Spill Detection and Response Agency (NOSDRA), created in 2006, has since also assumed responsibility for the latter role, though NOSDRA's mandate does not cover supervision of contaminated site remediation. More importantly, the two agencies have differing interpretations of EGASPIN, which further undermines clean-up operations in Ogoniland.

The overlap of authorities and responsibilities between state ministries and federal ministries is another issue which has an impact on environmental management on-the-ground. In the Nigerian system, central government agencies also have state or regional administrative offices. Separate state government agencies, which sometimes have similar mandates, often end up doing the same work. These overlapping efforts are not always coordinated and can lead to suboptimal environmental management.

Undergrowth shrouds a warning sign at Ogale, Eleme LGA

NOSDRA mandate and resources are not aligned

The National Oil Spill Detection and Response Agency came into being under the National Oil Spill Detection and Response Agency (Establishment) Act, 2006. The Act states that the organization's mandate "shall be to coordinate and implement the National Oil Spill Contingency Plan for Nigeria" [39]. The main focus of the Contingency Plan is on emergency response in the event of an oil spill. The NOSDRA Act also legislates for emergency response systems and capacity.

However, in the five years since its establishment, very few resources have been allocated to NOSDRA, such that the agency has no proactive capacity for oil-spill detection and has to rely on reports from oil companies or civil society concerning the incidence of a spill. It also has very little reactive capacity – even to send staff to a spill location once an incident is reported. In the Niger Delta, helicopters or boats are needed to reach many of the spill locations and NOSDRA has no access to such forms of transport other than through the oil companies themselves. Consequently, in planning their inspection visits, the regulatory authority is wholly reliant on the oil company. Such an arrangement is inherently inappropriate.

Equally important is the question of mandate when it comes to cleaning up a contaminated site. NOSDRA undertakes supervision of contaminated site assessment based on EGASPIN provisions. However, since the agency did not exist at the time EGASPIN was formulated in 1992 and reissued in 2002, the Act itself does not empower NOSDRA. Consequently, little training and few resources have been provided to enable NOSDRA to carry out this task.

At the time that NOSDRA was created, a clear directive should have been issued delineating the operational boundaries between NOSDRA and the DPR. In the absence of such clarification, both bodies continue to deal with contaminated site clean-up, coordination between the two is poor, and in extreme cases they take differing approaches to interpreting the rules.

Conflict of interest

Petroleum resources account for 80 per cent of national revenue and 95 per cent of export earnings, making the Ministry of Petroleum Resources, which licenses and regulates oil industry operations, a key ministry in Nigeria. In 1990, when the ministry, through its Department of Petroleum Resources (DPR), developed the EGASPIN, there was no federal Ministry of Environment (environment is currently part of the Federal Ministry of Environment, Housing and Urban Development). Moreover, it seemed logical at that time for the Ministry of Petroleum Resources to oversee the oil industry because of the strategic nature of the country's oil reserves as well as the technical nature of the industry and the specialized skills therefore needed to regulate it.

However, there is clearly a conflict of interest in a ministry which, on one hand, has to maximize revenue by increasing production and, on the other, ensure environmental compliance. Most countries around the world, including in the Middle East where oil is the mainstay of the regional economy, have placed environmental regulation within the Ministry of Environment or equivalent. It is noteworthy to mention in this context that after the 2010 *Deepwater Horizon* incident, it came to light that the US Offshore Energy & Minerals Management Office (under the Bureau of Ocean Energy Management, Regulation and Enforcement) responsible for the development of the offshore oilfield was also the body that issued environmental approvals. Even though other federal and local agencies had commented on the industry plans, President Obama called this a "cosy relationship between the oil companies and the federal agency that permits them to drill" [40]. Consequently, a new Bureau of Safety and Environmental Enforcement, under the US Department of the Interior, has been created, which is independent from the Department of Energy Resources.

Lack of resources

Resource limitations, both physical and human, are a feature of all Nigerian ministries. There are also other issues at play, involving various ministries at federal level as well as the contrasts between ministries at federal and state level. For example:

- Both DPR and NOSDRA suffer from a shortage of senior and experienced staff who understand the oil industry and can exercise effective technical oversight. The main reason for this is that individuals with technical knowledge in the field of petroleum engineering or science find substantially more rewarding opportunities in the oil industry

Inadequate regulatory requirements and enforcement are leaving communities exposed

- A typical pattern in Nigeria (as in other countries) is that offices in the federal capital of Abuja are better equipped with staff and resources than regional offices. This may not be a financial issue but staff may be reluctant to serve in the regions owing to poorer working conditions and opportunities, ranging from security to schooling for children and career advancement prospects. This is certainly an issue impacting both DPR and NOSDRA

- All government departments, both federal and state, lack office equipment and vehicles. Even when such resources are allocated there is often a shortage of funds for maintenance (e.g. maintaining vehicles and buying fuel for generators)

- State ministries of environment are even less well provided for in terms of human resources, equipment and infrastructure, and attracting quality staff is especially difficult

- Shortage of equipment is particularly troublesome for agencies having to respond to oil spills, which are often in areas inaccessible by road. In the absence of such resources, government agencies are at the mercy of oil companies when it comes to conducting site inspections.

Inadequate regulatory requirements and enforcement

The oil and gas sector in Nigeria is subject to comprehensive legislation which includes detailed environmental and technical norms. The most detailed and exhaustive standards and guidelines – the EGASPIN – were issued by the DPR in 1992 and reissued in 2002. However, the original Act dealing with the oil industry in Nigeria is the Petroleum Act, 1969, which empowers the Minister of Petroleum Resources to regulate for the prevention of pollution of water courses and the atmosphere. It is not entirely clear from reading EGASPIN if it was issued under the 1969 Act. Consequently, whether EGASPIN is a legally enforceable instrument or a non-enforceable guideline is also unclear. This issue was discussed with both DPR and NOSDRA officials, who all have varying interpretations on the legislative status of EGASPIN. UNEP's institutional assessment was not able to verify whether EGASPIN's legislative standing has been tested in the Nigerian courts.

Regardless of its formal status, for all practical purposes EGASPIN currently forms the basis for environmental management of the oil industry in Nigeria. It is a substantial document running to 361 pages divided into eight sections dealing with all aspects of environmental management of oil activities ranging from exploration to terminal operations.

UNEP's review examined two specific elements of EGASPIN:

- Part VIIIB, contingency planning for the prevention, control and combating of spills of oil and hazardous substances, and
- Part VIIIF, management and remediation of contaminated land.

For the purposes of this study, the most important aspect is the approach EGASPIN takes with regard to the criteria for clean-up operations following an oil spill.

EGASPIN recommends the use of the Risk-Based Corrective Action (RBCA) approach pioneered in the United States. However, section 8.1 of Part VIIIF states: "In the interim period whilst suitable parameters are being developed, the guidelines on remediation of contaminated land shall make use of two parameters, i.e. intervention values and target values (Table VIII F1)." Even though EGASPIN was first issued in 1992, the required guidance for a risk-based approach has not yet been developed and the 'intervention and target values' approach remains the operating principle in Nigeria today.

EGASPIN defines 'intervention value' (8.1.1) as indicating "the quality for which the functionality of soil for human, animal and plant life are, or threatened with being seriously impaired. Concentration in excess of the intervention values correspond to serious contamination". 'Target value' (8.1.2.1) is defined as indicating "the soil quality required for sustainability or expressed in terms of remedial policy, the soil quality required for the full restoration of the soils functionality for human, animal and plant life. The target values therefore indicate the soil quality levels ultimately aimed for". A list of intervention and target values is provided in Appendix VIII F1 of the EGASPIN.

While in the provisions discussed above EGASPIN is clear and in line with the terminology as applied elsewhere (e.g. in the Dutch Soil Act of 1987 which pioneered the use of intervention and target values), there is internal contradiction elsewhere. The more stringent part of the provision states, in section 2.11.3 of Part VIII:

"Any operator or owner of a facility that is responsible for a spill that results to (sic) impact of the environment shall be required to monitor the impacted environment alongside the restorative activities. The restorative process shall attempt to achieve the minimum oil content and other **target values (**quality levels ultimately aimed for) for BTEX, metals and polycyclic aromatic hydrocarbons (PAHS) in the impacted environment (also See Part VIII F).

(i) For all waters, there shall be no visible oil sheen after the first 30 days of the occurrence of the spill no matter the extent of the spill

(ii) For swamp areas, there shall not be any sign of oil stain within the first 60 days of occurrence of the incidence

(iii) For land/sediment, the quality levels ultimately aimed for (target value) is 50 mg/kg of oil content (See part VIII F)."

However, section 6.6 of Part VIII of the EGASPIN states:

"Remedial Action Closure. When Remedial Action Treatment has been undertaken and the **intervention values** (Risk Based Screening Levels (RBSLs) or Site Specific Target Levels (SSTLs) if RBCS (Risk Based Corrective System) is used) have been demonstrated to be achieved at the point of compliance, or containment or institution controls have been installed and monitoring and site maintenance are no longer required to ensure that conditions persist, then no further action shall be necessary, except to ensure that suitable institutional controls (if any) remain in place."

This latter section is an incorrect interpretation of the 'intervention value' and 'target value' approach to contaminated site management. Intervention value is not expected to be the point of compliance for close out of remedial action. The triviality of the above-quoted interpretation can be explained by taking as an example a site that has been contaminated with 5,001 mg/kg of hydrocarbons. Since it is above the intervention value of 5,000 mg/kg, a treatment plan has to be prepared and implemented. However, remediation work at the site can stop when the value has reached 4,999 mg/kg – in effect, by achieving just a 2 mg/kg reduction of hydrocarbons. In other words, the site can be considered to have moved from a situation where "the functionality of soil for human, animal and plant life are, or threatened with being seriously impaired" to a situation where it is legally acceptable to stop the treatment and even stop monitoring.

Discussions with the DPR clarified that they indeed expect the operator to achieve the target levels at which a remediated spill site can be closed. On the other hand, discussions with NOSDRA confirmed that they use the intervention values as the closure criteria for sign-off. NOSDRA also mentioned that, in their judgement, 5,000 mg/kg is a high target and that in their new legislation, currently in preparation, this will be lowered to 2,500 mg/kg.

Resolving the issue

It is evident from the above that Nigerian legislation is internally inconsistent with regard to one of the most important criteria for oil spill and contaminated site management; specifically the criteria triggering or permitting remediation closure. This is enabling the oil industry to legally close down the remediation process well before contamination has been fully eliminated and soil quality has been restored to achieve full functionality for human, animal and plant life.

This situation needs to be resolved for the whole of Nigeria, and in particular prior to initiation of the clean-up in Ogoniland. It should be mentioned in this context that the Government of The Netherlands, which pioneered the intervention and target value approach, has discontinued setting a target value for soil. Since both DPR and NOSDRA mentioned that they are working on new legislation, it may be opportune to make fundamental changes.

International best practice on contaminated site remediation currently depends on development of site-specific clean-up targets based on a robust source, pathway and receptor model. However, application of this model has to be done in a transparent manner so that the regulators fully comprehend what input data are used to obtain the clean-up targets and the sensitivity of each of these parameters. It has also been accepted internationally that health is just one of the risks to be managed through contaminated site remediation. Situations could arise where non-health risks, such as commercial reputation or community perception, would require the government and oil operator to agree on more stringent targets than would strictly be necessary from a health-risk management point of view.

Making legislation accessible

Another problem with current Nigerian legislation is its inaccessibility. Few texts are available online and many are not easily available even in paper form. In addition, printed copies of legislation, such as the 'Laws of the Federation of Nigeria', are extremely expensive and therefore limited to those able to bear the costs. Moreover, many secondary or very recent texts are available only at the issuing agency or from the government printing house in Lagos. Inaccessibility of legislation leads not only to a lack of transparency, but also to a loss of trust in the legal system. Making legislation readily accessible, cheaply and in a variety of forms, will help build confidence at all levels.

Review of SPDC's practices and performance

As an oil company with decades of experience in Nigeria, and as part of a larger, international organization with global reach, it is not surprising that the Shell Petroleum Development Company has established procedures for the range of environmental issues resulting from its oil exploration and production. SPDC is also backed up technically by Shell which provides a broad policy framework with corporate guidelines and specific technical assistance through Shell Global Solutions.

SPDC procedures

SPDC has documented procedures on all aspects of its business management. It was not the objective of the current study to undertake a systematic audit of all SPDC procedures and their implementation on the ground. However, in matters where there is a direct interface with the environmental contamination of Ogoniland, it was important first to identify the situation on the ground and then to verify whether that situation was a consequence of lack or deficiency of procedures, or laxity in enforcement of those procedures.

Of the three SPDC procedures dealing with environmental issues – oil spill response, oil spill clean-up and abandonment – quantitative assessment was only possible regarding site clean-up. A review of SPDC's performance in cleaning up contaminated sites is given below.

In undertaking this review, UNEP did not proactively look for SPDC-contaminated sites for assessment. Rather, once the on-the-ground assessment of contaminated sites had been completed, the team checked SPDC records to see how many of the sites were classified as 'remediation completed'. Where this was the case the site was assessed as to whether (i) it was still contaminated according to Nigerian legislation and (ii) the site met with SPDC's own internally set standards.

SPDC's approach to remediation

The SPDC Oil Spill Clean-up and Remediation Procedure (SPDC-2005-005716), the company's main operating document in guiding clean-up activities, was subjected to examination by UNEP. This procedure is based on a Shell Global Solutions report, 'Framework for Risk Management of Historically Contaminated Land for SPDC Operations in the Niger Delta (OG.02.47028)'. The report states:

"As the crude ages the lighter end will be lost through natural attenuation processes and as a result the viscosity will increase and vertical migration will further decrease. The high water table in many locations will also prevent deep infiltration of free product. It is expected therefore that any spills within the Niger Delta will migrate predominantly along the ground surface from areas of high topography to areas of low topography. *Trial pits have confirmed the shallow extent of soil contamination in many SPDC sites.*"

The report was based on a desk study and no field work was undertaken. So the trial pits, underlined in the above statement, refer to those excavated by SPDC as part of its own vertical delineation

Easily accessible disused wellhead (Bomu 27, Gokana LGA)

An Ogoniland site showing remediation by enhanced natural attenuation (RENA)

of contamination. It is useful to note that SPDC's internal procedures for vertical delineation of contamination state:

"*...trial pit should be excavated to at least 0.5 metres and no more than 1.5 metres below ground level (bgl)*"

"...hand augering should be down to at least 1 metres bgl and preferably to 2 metres bgl"

As already seen from UNEP's field sampling, contamination of hydrocarbons has migrated to depths of more than 5 metres in some instances. Hence, Shell Global Solutions' guidance note and the SPDC procedure for vertical delineation need to be revised to incorporate this new information.

Three points of particular interest in the SPDC document are:

1. Remediation by enhanced natural attenuation (RENA) is given as the primary method of remediation of oil-impacted sites

2. Soil remediation criteria are defined and, though the document makes provisions for using risk-based screening levels to indicate satisfactory completion of remedial activities to acceptable risk levels, a TPH value of 5,000 mg/kg (same as the EGASPIN intervention value) was validated as the end point

3. For groundwater the document states that "remediation of impacted potable (usable) groundwater shall be undertaken in conformity to the EGASPIN recommended **target** level of 10 ppm of dissolved TPH". However, there is no location in Ogoniland where groundwater remediation has been attempted

A number of criticisms can be made of the above approach:

The RENA approach to remediation. Hydrocarbons, once released to land, can be transferred and degraded through a number of natural processes, including:

- evaporation to the atmosphere
- combustion
- infiltration, alone or along with rainwater, to soil and eventually to groundwater
- overflow into swamps and water bodies
- runoff with rainwater to swamps and water bodies
- microbial degradation on the ground surface, or in soil, swamps, water or groundwater

The principle of enhanced natural attenuation for clean up of contaminated land is to augment one or more of the above processes so that the concentration of contaminants can be reduced.

After reviewing contaminated land clean-up issues in Nigeria, Shell Global Solutions endorsed the RENA approach. Hence it is SPDC's preferred procedure and 100 per cent of oil spill remediation in Ogoniland has been undertaken using the RENA approach.

Under RENA, contaminated land (topsoil) is initially ploughed over, either mechanically or manually, to increase aeration. Fertilizer is added to supplement the nutrient requirements of the bacteria as they break down the pollutants. The ploughed soil is then piled into neat windrows to further enhance the aeration process. Samples are taken from the windrows every quarter and once the SPDC specification of 5,000 mg/kg of TPH is reached, the windrows are levelled.

The implicit assumption in the RENA approach applied by SPDC is that the natural process being enhanced is bioremediation. All enhancing actions, whether ploughing, adding nutrients or windrowing, are applied to further natural biodegrading processes. In an ideal situation this approach is scientifically defendable. However, the reality on the ground in Ogoniland speaks otherwise. The RENA process is failing to achieve either environmental clean-up or legislative compliance. As seen in the analyses and case studies presented in this report, it is also failing to achieve compliance with SPDC's own procedures.

The case against RENA in Ogoniland. The following arguments could be made for discontinuing the use of RENA as an approach to remediation in Ogoniland:

1. The effects of temperature, rainfall and topography hamper the RENA approach at oil-impacted sites because no controls are in place to manage the following processes:

   (i) Oil-impacted sites are open and exposed to sun and air, leading to hydrocarbons evaporating and being carried away, risking exposure to on-site workers, neighbouring communities and nearby agricultural workers. No air monitoring, on-site or off-site, is undertaken

   (ii) They are continually exposed to rain, which falls on the windrows, leaching out hydrocarbon, which can then run off into nearby farms, communities, swamps or streams, contaminating a much wider area. Rain falling up-slope can also run off through the windrows. No measures are taken to prevent rainwater from reaching windrows, directly or through runoff, and no systems exist to collect runoff before it escapes from the site. Moreover, no system is in place even to monitor whether this is happening

   (iii) Soil remediation occurs *in situ* with no impermeable layer to prevent infiltration of oil, either by itself or with water, into the subsoil and then into the groundwater. There is no monitoring of this issue

2. Not all hydrocarbons are amenable to bacterial biodegradation, rendering the process unfeasible in situations where:

   (i) hydrocarbons are too toxic for the bacteria, and/or too recalcitrant for biodegradation and/or present in too high a concentration

   (ii) fire has occurred on the ground and the hydrocarbons have been burnt into a crust, mixing bituminous hydrocarbons with clayey soil

   (iii) the soil is very clayey in nature, making oxygen transfer difficult

3. Currently, SPDC undertakes RENA on the land surface layer only, based on the assumption that given the nature of the oil, temperature and an underlying layer of clay, hydrocarbons will not move deeper. However, this basic premise of limiting remediation to the surface soil is not sustainable since observations made by UNEP show that contamination can often penetrate deeper than 5 metres. The RENA approach, if using bioremediation as the primary process to be enhanced, will not work at depths below 1 metre due to difficulties with oxygen transfer

In addition, the UNEP team also noted the following on-site practices which further argue the case against RENA as an appropriate choice for site remediation:

4. Trenches cut from RENA sites to nearby water courses preferentially channel away spilled oil and runoff

5. In practice the top 1 metre of topsoil is not being tilled and mixed properly. Only the top 15-20 cm of soil is dug out and piled onto unploughed soil, so while the windrow may appear to be 30-40 cm high (i.e. the top of the windrow is 30-40 cm above the bottom of the excavated area), the depth of soil that has been broken down is, in fact, only 15-20 cm, thus also limiting any bioremediation to those 15-20 cm.

There are enough theoretical and practical reasons to recommend discontinuation of the RENA approach in Ogoniland for cleaning up contaminated land. While bioremediation or enhancing natural processes are workable approaches to achieving clean-up, they should only be adopted after proper characterization of affected sites, with adequate provision made for (i) controlling transfers of oil off-site due to runoff, infiltration and other processes, and (ii) monitoring and supervision.

SPDC clean-up specifications

The second most important element of SPDC procedures, after the primacy given to RENA, is the recommended values for clean-up.

SPDC uses 5,000 mg/kg TPH as its remediation criterion for soil. While no specific reason has been given for choosing this value, it was the assumption of NOSDRA that the value was taken from the EGASPIN intervention value of 5,000 mg/kg.

As discussed previously, the EGASPIN document, which forms the basis for the SPDC procedure, suffers from issues of internal inconsistency. In one section the legislation defines a 'target value' of 50 mg/kg TPH as the desired end point for restoration after oil spill, while in a section on remediation of contaminated land an 'intervention value' of 5,000 mg/kg TPH is given for remediation closure.

A trench made from a RENA site to a nearby watercourse (Bodo West, Bonny LGA). The fluid in the channel is degraded crude oil

During the early phase of discussions with SPDC, UNEP was informed that the remediation close-out value of 5,000 mg/kg TPH set by SPDC was not drawn from the EGASPIN but was based on a risk assessment. If this was a corporate decision, it is not stated as such in the SPDC documentation, nor is it communicated to the authorities as required by EGASPIN. However, the SPDC procedure does mention the guidance provided by the Shell Global Solutions document mentioned above.

Development of contaminated site clean-up criteria based on health risk assessment was first proposed by the American Society for Testing of Materials (ASTM) 'Standard Guide for Risk-Based Corrective Action Applied at Petroleum Release Sites' [41]. The basic philosophy of this approach is to model potential exposure of a sensitive receptor to hydrocarbon contamination through viable pathways. A target level of contamination in the environment is set based on acceptable exposure of the receptor. This approach has many merits as it makes the decision more objective and more resource efficient. However, in developing a risk-based screening level of 5,000 mg/kg TPH, applicable to all sites in the Niger Delta, the following key issues have been overlooked:

1. The varied geology of the Niger Delta differs significantly over short distances. Applying a uniform set of input data parameters (e.g. soil organic matter) across all sites is therefore not appropriate unless the sensitivity of clean-up levels to such generic inputs is properly considered.

2. Different countries have different thresholds for policy-driven parameters, such as acceptable additional cancer risk. Thresholds ranging from 1 per 10,000, to 1 per 1,000,000 people have been used. WHO guidelines are based on 1 per 100,000. Shell Global Solutions has used the acceptable risk threshold of 1 per 10,000 as there was no applicable national legislation. However, this was done without consulting the national authorities and explaining the likely impact on clean-up criteria. For example, using a risk threshold of 1 per 100,000, as used by WHO, would have resulted in a clean-up threshold of 500 mg/kg in some instances. This lower threshold would have needed a different technological approach to clean-up and would have significantly increased the costs of clean-up to the company.

Table 33. SPDC selection criteria for appointing remediation contractors

Description	Maximum score (%)	Minimum score (%)
Past performance		
Regulatory certification of completed site	10	6
HSE performance or (HSE plan in case of new vendors)	6	3
Managerial competence	4	2
Nigerian content development	5	3
HSE record		
Leadership and commitment	8	5
Toolbox documentation	5	3
Manpower resources & competence assurance	7	4
Hazards & effects management	10	6
Timely service delivery		
Adequate manpower	10	6
Financial capability	8	6
Technical competence	5	2
Management of community issues		
Evidence of previous work in the community/a community	5	3
Knowledge of community sensitivities	7	4
Evidence of successful completion	10	7
Total	**100**	**60**

3. There are scientific uncertainties as to what constitutes a reasonable health criteria value for a pollutant. A decision on what is appropriate for Nigeria should not be taken in isolation, without consultation, and without explaining what impact it may have on the clean-up criteria.

It is recommended that SPDC works with the Nigerian regulators to clarify the paradox of remedial intervention and target values being the same. They should also agree on a consultative approach to setting site-specific clean-up values.

The final point of interest concerning the SPDC documentation is their selection criteria matrix for appointing contractors to undertake remediation work (see Table 33).

Flare arrangements at disused flow station

Two issues are instructive here: (i) 'technical competence' in the table represents just 5 per cent of the potential score allocated; and (ii) the relative importance assigned to past performance in obtaining a 'regulatory certification of completed site' compliance versus technical competence.

In its 'Execution Strategy for Oil Spill Response, Clean-up and Remediation of Impacted Sites in East and West', SPDC identifies some of the major weaknesses of its old strategy [42]. The following were some of the observations made in 2007:

- Lack of timely and effective oil-spill containment and recovery were identified as the major causes of escalated spread of spills in the environment and consequently higher clean-up costs
- Clean-up cost estimates were based on the estimated volume of a spill and the estimated area of impact prior to recovery of the free-phase product. Thus the actual area requiring clean-up was often exaggerated, which translated into exaggerated cost estimates
- No process was put in place to ensure that resources paid for in contracts were actually provided and utilized
- Incidences of poor clean-up leading to secondary clean-up before remediation were prevalent (meaning that the first clean-up after the oil spill was not appropriate or adequate and necessitated a second clean-up before the RENA approach could be initiated at the site)

SPDC Remediation Management System. In January 2010, a new document, 'Remediation Management System' (RMS), was adopted by all Shell Exploration and Production Companies in Nigeria (SEPCiN) [43]. A revised version of this document was made available to UNEP in January 2011. As the document only came into force recently, the SPDC sites assessed by UNEP were not managed according to the RMS and no direct comparisons between the previous and new system have therefore been possible. However, the document is reviewed here with a view to understanding the key changes and to consider, if the new system were to be implemented, whether past attempts at remediation would have been different and whether the new procedure would improve things in the future.

The following are the key changes from the previous remediation procedure:

- The RMS has set a TPH value of 3,000 mg/kg as the cut-off value for completion of remediation work, as against the former value of 5,000 mg/kg
- An *ex situ* RENA approach has been proposed, making use of a high-density polyethylene (HDPE) membrane to prevent contamination of the location where the *ex situ* remediation is undertaken. The previous document had no provision for *ex situ* RENA and the possibility that hydrocarbons may infiltrate to lower layers was not considered a process risk
- A leachate collection system has been proposed in the *ex situ* RENA process. In the previous system no cognizance was given to the possibility of leaching of hydrocarbons through runoff
- The RMS brings sediments and groundwater into the purview of the materials to be remediated.

It is clear that SPDC has been learning internal lessons regarding clean-up. The changes proposed in the RMS are certainly an improvement on the existing situation. However, they do not meet the local regulatory requirement or international best practices, as elaborated below.

Remediation close-out value. The RMS sets a new remediation intervention value of 3,000 mg/kg TPH to demonstrate commitment to remediation excellence. This compares to the EGASPIN intervention value of 5,000 mg/kg TPH and is presented as the company doing "more than" the legislation requires. However, as elaborated in earlier sections, the use of an 'intervention value' as the 'target value' for remediation close-out is not in line with EGASPIN philosophy and its interpretation by DPR. The proposed SEPCiN value, while certainly an improvement on the previous value, does not represent full compliance. Expert-level discussions are needed between DPR, NOSDRA and the oil companies to arrive at a technologically feasible target value. These discussions should include post-clean-up use of the remediated site (e.g. human use, wildlife site, linkages to wetland) – in other words, a risk-based approach.

***Ex situ* RENA approach.** Conceptually, the *ex situ* RENA approach is an improvement over *in situ* RENA as it recognizes both infiltration and runoff from contaminated soil as issues to be addressed. However, the new approach still has major limitations that are not acknowledged in the document. Since no practical application of the RMS has been observed in Ogoniland, the conformity of provisions in the RMS with situations on the ground could not be verified.

In the *ex situ* RENA approach (Figure 13), a 400-mm thick layer of clean sand (or clay/lateritic layer) is placed over the HDPE liner as a treatment layer (prescribed in a cross-sectional diagram in the RMS document). This layer will invariably become contaminated either through infiltration of leachates or during mixing of the contaminated soil for aeration. It is not evident from the procedure if, at the end of the treatment cycle, this layer will stay in place or be removed and disposed of along with the contaminated soil. If the treatment bed is removed with every cycle (which will be necessary with a sand base), the volume of contaminated material will increase during the treatment process, diluting the actual contaminant and making it possible to achieve the clean-up target value without having achieved full clean-up. On the other hand, if the layer of sand is left in place for multiple cycles, quite how the layer will be treated once the site clean-up is over is not elaborated. In both cases, further refinement and clarifications are needed.

Leachate management. The *ex situ* RENA approach has a leachate collection system, but the approach taken to managing the collected leachate is to put it back on the treatment bed. Since Nigeria experiences heavy rainfall, relying solely on the treatment bed to manage leachate will be hampered by flooding of the treatment area, thus jeopardizing the treatment itself and causing runoff into adjoining areas, and negating the benefit of introducing a leachate collection system. In order to achieve the desired objectives, a separate leachate monitoring, treatment and disposal system integral to the treatment unit is needed.

Management of sediments and groundwater. While the opening part of the RMS mentions that the document covers treatment of sediments and groundwater, these topics are not in fact elaborated.

It clear from the review of the new RMS that SPDC has been trying to address some of the limitations of the previous clean-up system. However, the proposed modifications alone are incapable of fully resolving the limitations of the current approach identified by UNEP. SPDC procedures for oil spill clean-up and remediation need to be fully reviewed and overhauled so as to achieve the desired level of environmental restoration. In addition to procedures and clean-up methods, contracting and supervision also need to be improved.

SPDC operational practice at oil spill sites

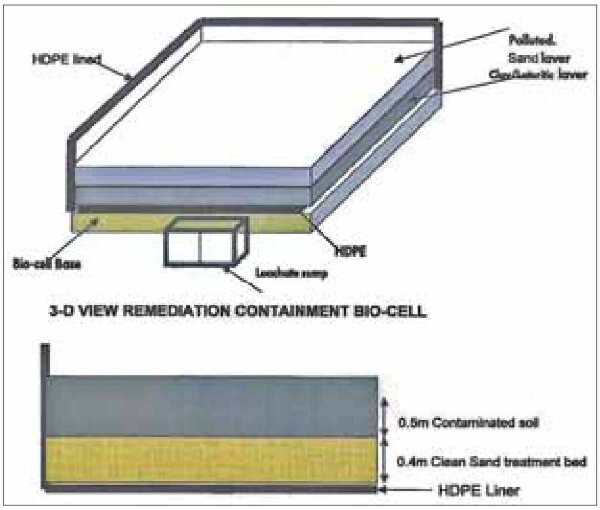
It is evident from the UNEP field assessment that SPDC's post-oil spill clean-up of contamination does not achieve environmental standards according with Nigerian legislation, or indeed with SPDC's own standards. During its reconnaissance survey, UNEP came across dozens of locations where oil spill incidents had occurred in the past. The spills may have happened decades ago or weeks ago, with multiple spills at some locations. Some of these locations had actually been documented by the operator as assessed and cleaned up, while others were still to be cleaned up. The difference between a cleaned-up site and a site awaiting clean-up was not always obvious. Results from the sites that were studied in detail are presented in case studies 1 to 7; however, there are a few general observations that merit attention.

Poor due diligence. An oil spill is one of the possible technical risks anticipated by an oil company. All oil industry operators have systems and resources in place to deal diligently with spills within the shortest possible time. In Nigeria, both SPDC and NNPC have their own dedicated resources to deal with smaller oil spills (referred to by the oil industry as Tier 1). PPMC has its own Pollution Control Centre to deal with bigger spills. Together, the oil industry operators in Nigeria have set up a consortium called 'Clean Nigeria Associates' to deal with larger (Tier 2) oil spills. Truly large (Tier 3) spills will need international assistance from specialized oil spill response agencies.

In summary, there are systems and resources in place in Nigeria to deal with most oil spills, small and large. Even though the oil industry is no longer active in Ogoniland, oil spills continue to happen with alarming regularity. Three minimal operational interventions are absolutely necessary in the event of an oil spill:

1. Ensure that the source of the spillage is shut off by closing the valves on the facility
2. Contain the oil within the spill site to prevent runoff by blocking culverts and digging interceptor gullies
3. Clean up pooled or standing oil which presents a safety hazard

Figure 13. Proposed cross section of a containment bio-cell (Ref SPDC remediation management system) cell [43]



SPDC procedures for oil spill clean-up and remediation need to be fully reviewed and overhauled

A typical spill site within Ogoniland, many of which remain unaddressed for long periods of time

Once these actions have been achieved, contamination of the site should be assessed and the clean-up process initiated.

The UNEP project team visited a number of locations with recent spills. One observation made consistently through the entire survey was that there was always a time-lag between the spillage being observed and dealt with. In the worst case situations, standing oil left on the ground posed an imminent safety hazard and an ongoing environmental hazard. It was not possible at these locations to say how long these pools had been standing. Nor was it possible to ascertain whether the source of the spill had been shut off or was continuing to leak oil. All these factors increase percolation of hydrocarbons into permeable ground surfaces.

Where the oil operator appeared to have taken intervention measures, such as laying a skirt boom or absorbent boom to contain the spill, the equipment used was often observed to be in poor condition, rendering it ineffective. In such cases, pollution continued to spread well past containment points.

The oil industry often cites access restrictions placed by the community as reason for the delay between the reporting of an incident and addressing it. While this may be true in the early days of the spill, the time-lag between the spill event and the site being comprehensively cleaned up shows that issues of access are not the sole cause of delays. In addition, the substandard approach to containment and the unethical action of channelling oil into creeks cannot be laid at the door of community.

Loss of control. Various factors at a spill location, if not properly attended to by the oil operator, can lead to loss of control. Ogoniland has very high rainfall and though there is a so-called rainy season, it rains virtually every month. Any delay in cleaning up an oil spill will lead to oil being washed away by rainwater, traversing communities and farmland and almost always ending up in the creeks. At a number of locations it was evident that fire had broken out following the oil spill. Where oil is standing, it evaporates, creating a flammable mixture that can easily ignite. Standing oil also percolates into soil and kills vegetation, which itself becomes a combustible fuel, further increasing the risk of fire.

Assessment of Vegetation, Aquatic and Public Health Issues

Issues of contamination and ensuing environmental damage are consequences of oil industry operations that are impacting the health, welfare and livelihoods of the Ogoni community
© Mazen Saggar

Assessment of Vegetation, Aquatic and Public Health Issues

Chapter 4 dealt with site-specific land contamination issues where the focus was on soil and groundwater contamination. Sites were assessed on a case-by-case basis, where it was often possible to pinpoint the source of the contamination and identify the operator responsible for clean-up. Soil and groundwater contamination is a regulated issue in Nigeria and operators have procedures in place to manage such incidences.

In this chapter, contamination of non-site specific environmental media, such as air and surface water, is discussed, as is the fate of receptors such as human beings, fish and mangroves, all of which can receive pollution from more than one source. As pollution incidents are diffuse, responsibility cannot be assigned to a single event or single operator. In the specific context of Nigeria, ambient environmental monitoring and compliance are not well regulated. However, issues of contamination and ensuing environmental damage are consequences of oil industry operations that are impacting the health, welfare and livelihoods of the Ogoni community. If sustainable environmental improvement and, indeed, sustainable development of Ogoniland are to become a reality, the issues discussed in this chapter need to be addressed concurrently with clean-up of contaminated sites.

5.1 Impact of oil on tide-dominated delta swamps and mangroves

Mangrove ecosystems, together with seagrasses and coral reefs, are among the world's most productive natural ecosystems. They are characterized by a dynamic equilibrium between flooding, erosion and sediment deposition and are adapted to frequent changes in the shoreline. The mangrove trees and bushes are keystone species of central importance for brackish wetland ecosystems and the terrestrial and aquatic organisms which inhabit them. Consequently, mangroves are not just ecologically significant but are critical to the livelihood and food security of the delta community.

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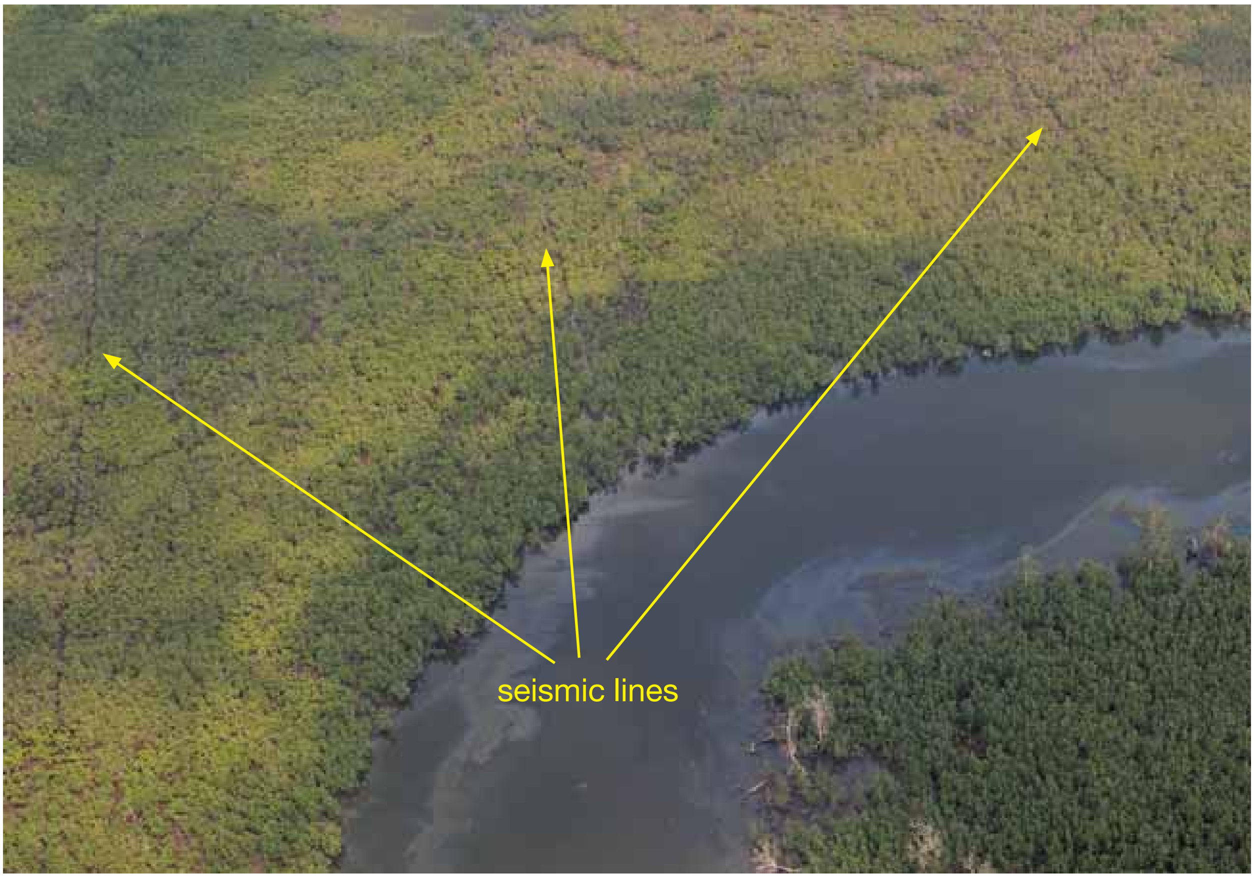
Ogoni people live with contamination of air and surface water every day



Seismic lines at Ogu Bolo, November 2010

In addition to its productive functions, increasingly other ecosystem services of mangroves are being understood. Key among these is protection against storm surges and smaller Tsunami waves. A comprehensive review of the mangroves in Western and Central Africa, including their crucial importance to the livelihood in that region is presented in a recent publication from UNEP [44]. The following sections provide some information relating to Ogoniland.

A number of species typical for mangrove ecosystems found in West Africa occur in Nigeria: *Acrostichum aureum* (an introduced erect, mangrove fern from the neotropics), *Avicennia germinans*, *Conocarpus erectus*, *Laguncularia racemosa*, *Rhizophora mangle*, *Rhizophora harrisonii*, *Rhizophora racemosa* and the mangrove palm *Nypa fruticans*. All were found in Ogoniland during UNEP's fieldwork, with the exception of *C. erectus* and *R. harrisonii*, although in all likelihood both are present. In addition, *Raphia* spp. and *Phoenix reclinata* are present as mangrove associates.

The red mangroves (*Rhizophora* spp.) are by far the most abundant. *R. racemosa* is the most common and tallest of the genus, reaching a height of up to 40 metres in favourable conditions, but often forming shrubby tangles up to 10 metres high, with stilt roots – tall arching roots originating from trunks and branches which supply air to the underlying roots and provide support and stability. It fruits at most seasons and the wood is very hard, suitable for durable construction poles and firewood of high calorific value. *R. racemosa* is a pioneer species and has a high salt tolerance, colonizing the mud on the outermost fringes of vegetation between high and low tide. As the mud dries out closer to land, it disappears.

Lasting impressions of seismic surveys

Oil exploration activities started to have an impact on the Niger Delta vegetation even before a well was drilled or oil produced, and the footprint left by seismic surveys over 50 years can still be seen. Though not extensive in scope or devastating in nature, it is instructive to note that even decades after this disturbance, natural processes have not yet managed to close the gap created by the seismic lines. Some reports state that oil industries continue to keep the seismic lines open for future use [45]. Seismic lines may make the interior of some wetland areas more accessible, potentially leading to further degradation.

Impact of dredging

The large number of meandering water courses makes access to oil exploration and production sites difficult in delatic region. The development of oilfield infrastructure in the mangrove zones therefore requires dredging and/or vegetation clearance and the creation of canals to open navigable routes. During dredging, soil, sediments and vegetation along the access route of the proposed site are removed and typically disposed of over banks, in most cases upon fringing mangroves, and then abandoned (Map 17). The abandonment of the resulting dredged material has a number of environmental impacts. These include smothering of fringing mangroves, alteration of surface topography and hydrology, acidification, accumulation of heavy metals and water contamination, which together in the Niger Delta have resulted in damage to vegetation and killing of fish [45]. Importantly, hydrological changes, such as increased salinity or lack of regular influx of freshwater to mangrove communities, may lead to degradation and ultimaltely destruction of the mangrove community [46].

While no dredging was seen to be taking place in the creeks around Ogoniland during the UNEP assessment period, evidence of dredging can be seen from satellite images. Channels that have been dredged or widened and the resulting spoil are all clearly evident in satellite images even now, decades after the dredging operation.

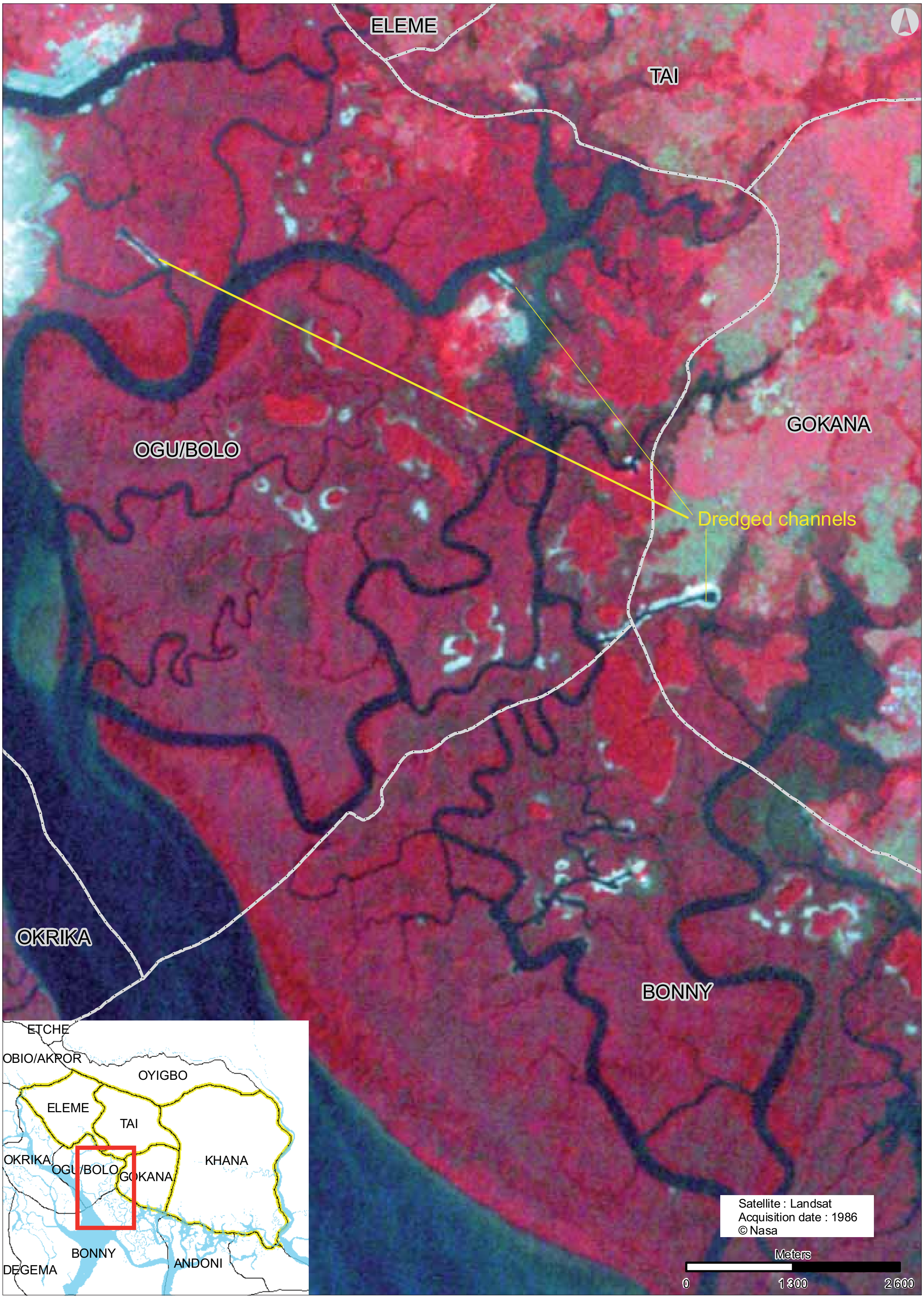
Without proper rehabilitation, former mangrove areas have been converted to bare ground which eventually may become colonized by invasive species such as nipa palm. The impacts of dredging on mangroves are far reaching because it affects almost all components of the ecosystem, including the mangrove vegetation itself, benthic invertebrates, fisheries, plankton, wildlife, soil, sediment and water quality – and ultimately the local communities who depend directly on the rich mangrove ecosystem for their subsistence [47, 48].

Impact due to physical disturbance

Mangroves in the creeks around Ogoniland have been very badly affected by physical disturbance, both through increasing use of the mangrove

A right of way more than 30 metres wide cut through mangroves

Map 17. Satellite image showing dregdging (Bodo West, Bonny LGA)



forests by a growing human population in the coastal zone and in particular from oil exploration and production activities. When the pipeline for carrying product from Bodo West flow station was laid, for example, it was partly routed through mangroves. A right of way 30 metres wide was cut and was observed during the UNEP study to be still clear of vegetation. The edges of the right of way appear to have been dredged, allowing floating oil to spread over the soil along the entire right of way, gradually destroying the fringing mangroves and contaminating land (Map 18).

Impact due to oil pollution

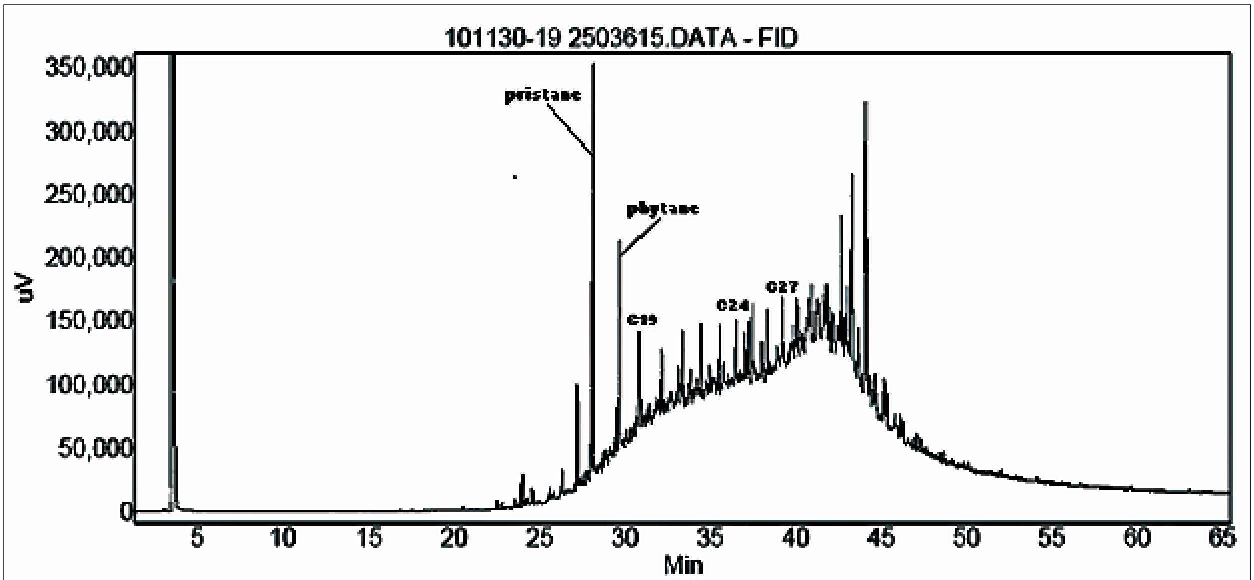
The impact of oil on mangrove vegetation in Ogoniland has been disastrous, as was evident to the UNEP team during an early reconnaissance mission along the creeks. Impacts vary from extreme stress to total destruction. In the most impacted areas, only the roots of the mangroves remains, with no stems or leaves. The roots are completely coated in oil, sometimes with a 1 cm or more thick layer of bituminous substance. The pollution has accumulated over a very long period, perhaps over decades.

Mangroves coated with oil will probably die

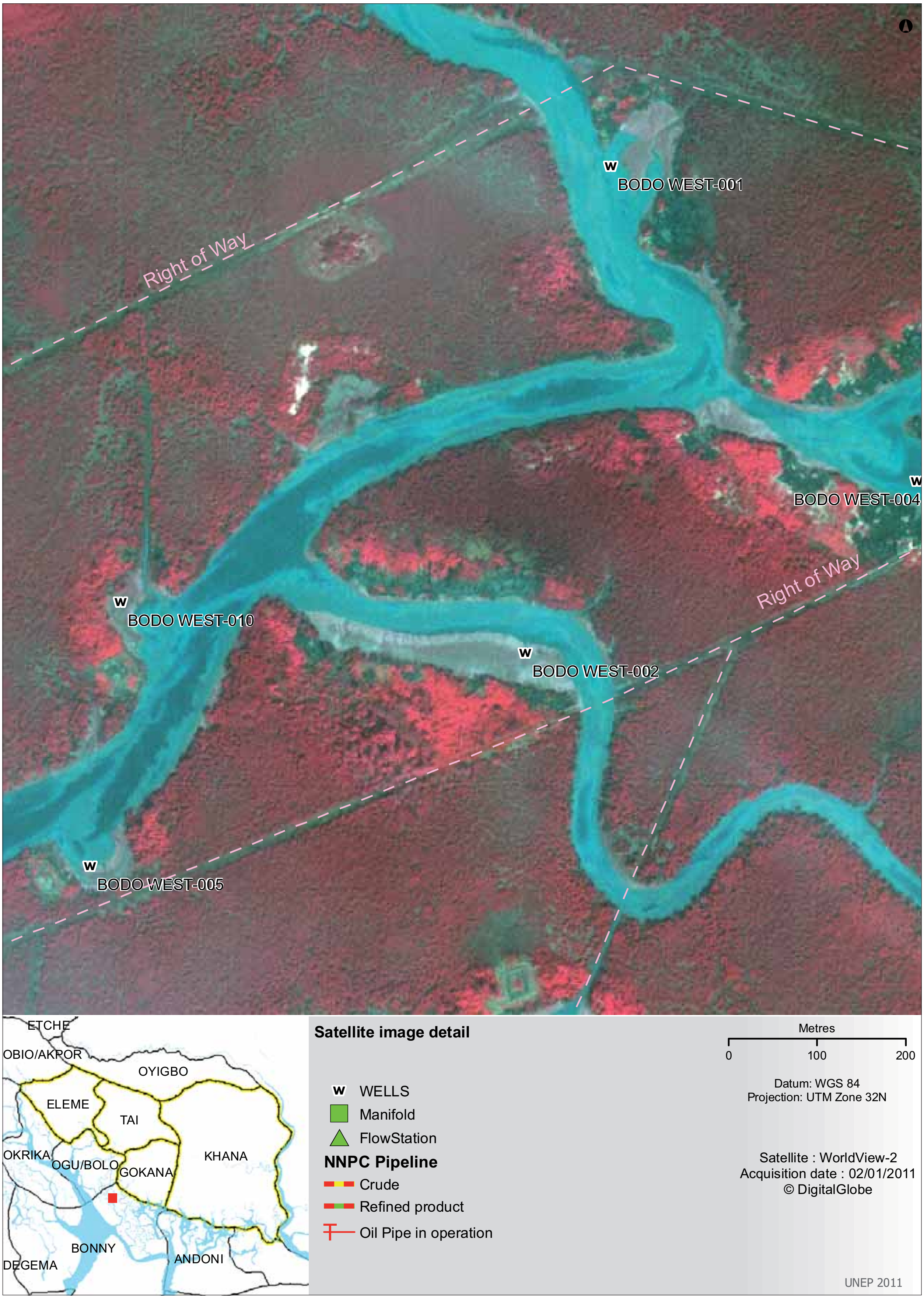
From a typical GC fingerprint of the hydrocarbon coating the mangrove roots (Figure 14), it can be seen that the hydrocarbon is highly degraded with extensive depletion of low molecular mass alkanes (saturated hydrocarbons) and dominance of pristine/phytane isoprenoids (naturally occurring organic chemicals). In practical terms this means that the material sticking to the vegetation is highly bituminous, and will not biodegrade or dissolve in water, even if the water is in constant contact with the hydrocarbon.

Mangroves roots heavily coated by a thick layer of bituminous material (Bodo West, Bonny LGA)

Figure 14. GC fingerprint of highly weathered oil covering mangrove roots



Map 18. A satellite image showing a right of way in mangroves, (Bodo West, Bonny LGA)



Nipa palm competing with native mangrove (Imo River, Khana LGA)

In estuarine areas where the water is calmer and where there is regular inflow of freshwater and nutritious silt, nipa palm, an invasive alien mangrove species from the Asia-Pacific region, becomes more abundant. The plant has a horizontal trunk which grows beneath the ground, the leaves and flower stalk growing upwards above the surface to a height of up to 9 metres. The plant's habit of growing from underground stems results in almost pure stands of nipa palm. It can tolerate infrequent inundation as long as the soil does not dry out for too long.

Any disturbance of the mangrove ecosystem favours this opportunistic plant, which propagates itself prodigiously, either by vegetative reproduction or through floating seeds. Red and white mangroves are progressively being outcompeted and replaced by nipa and monospecific stands can be found inland as far as the tide can deposit seeds, which may even germinate as they float. The area around Bonny and the shoreline of the Imo estuary (up to 25 km upstream from the open sea) are particularly infested [49], thereby drastically changing the physiognomy of the mangrove forest. Nipa was introduced into eastern Nigeria in 1906 and has since invaded extensive intertidal areas in the four coastal states, including Rivers State, where more than 200 square kilometres (over 10 per cent) of the mangrove zone have been taken over by nipa palm [50].

Nipa is not utilized by local communities in Nigeria [44] and is regarded as a "nuisance palm" because it lacks economic potential. Visual observations at multiple locations indicated that the plant is more resilient to hydrocarbon pollution than native mangrove species. If measures are not taken to stem the severe oil pollution, nipa has the capacity to overwhelm the native vegetation, thus making entire wetland areas economically less useful to local communities.

Case study 8 Artisanal refining of crude oil at 020-001 Bodo West oilfield, flow station and manifold

There are hundreds of locations in the Ogoniland creeks where people undertake illegal refining of crude oil every day, as shown by the thick black smoke that emanates from the refinery sites. Since the practice is illegal, on-the-ground observations were impractical within the security constraints governing the UNEP study. However, it was decided to investigate one location – adjacent to the SPDC Bodo West flow station – in order to gain a more exact understanding of the environmental impact of this activity.

This site was chosen because (i) it was accessible, (ii) the open nature of the site meant that it could be surveyed effectively, (iii) there was more than one escape route from the site in the event that evacuation became necessary on security grounds, and (iv) observations of aspects other than the practice of artisanal refining could be made.

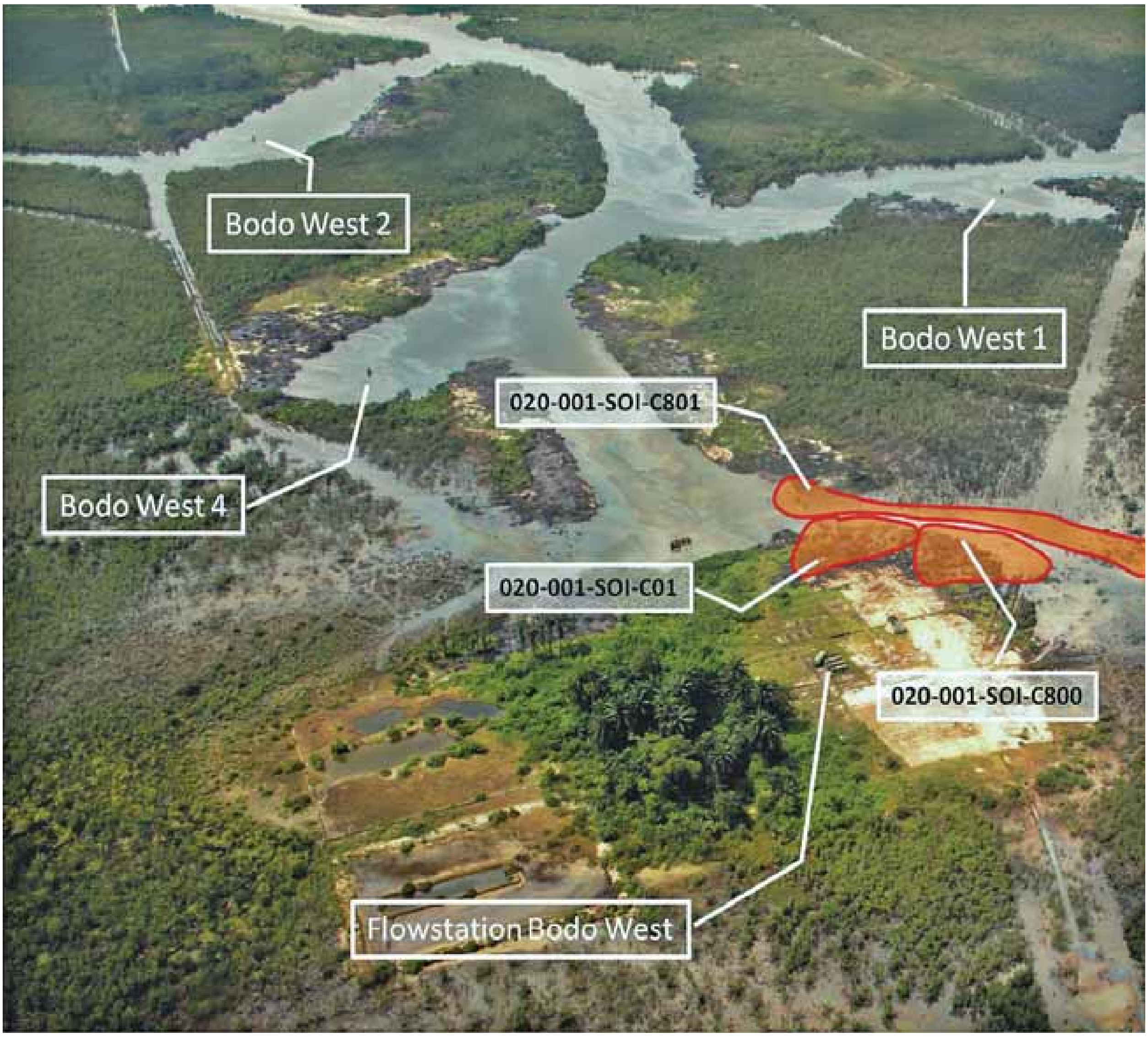
Arranging a field visit to Bodo West was logistically complex, requiring permission and support from the local police as well as the navy. The team that entered the site had to be vigilant and in constant radio contact with a support team at Bodo Jetty should additional assistance have been required.

Site description. There are 12 wells (in water) and a flow station (on land) at Bodo West. A pipeline connecting to a trunk line was laid to carry crude oil from the site. Remnants of the flow station building, an abandoned landing jetty and a small number of vessels are all still present. Although the facility had been abandoned, the site did not appear to be fully decommissioned. The site is entirely open, with a concrete pad (possibly the remains of an old building), which probably explains why the site is a popular location for artisanal refining.

Spill history. Oil spills in this area were not reported to UNEP by SPDC, either on the land on which the flow station and the manifold are situated, or around any of the 12 wellheads.

Visual observations on site. Photographs below show the Bodo West oilfield near the former flow station area. Brown oil slicks and oily sheens can be seen on the water.

Bodo West oilfield: artisanal refineries are indicated by arrows



Bodo West artisanal refining location showing UNEP investigated area

The area was visited for soil sampling on 24 November 2010. Most of the surface area within the intertidal zone – the area exposed to the atmosphere during low tide and covered by water at high tide – was covered by oil slicks. In the main area of investigation, traces of artisanal refining could be seen and, weeks after the close-down of these activities, crude oil was found stored in a collection pit (Figure 62).

On higher ground, an area of approximately 3,000 square metres had been prepared for what appeared to be (enhanced) bioremediation of the uppermost layer of soil. Windrows with a height difference of approximately 0.4 metres (i.e. 0.2-0.3 metres effective depth) had been formed. Uncontaminated sand showed a whitish-grey colour, whereas heavily contaminated areas were dark brown. Within the intertidal zone floating oil formed a surface layer and a small trench had been excavated to channel the oil directly into the creeks. While this appeared to be SPDC contract activity, the context of the remediation work was not clear to UNEP.

Three groundwater wells were found on the site, all of which were successfully sampled via small openings in each of the covers, into which a bailer was inserted to extract the water sample.

The area of artisanal refining bore the typical footprint of the practice: a pit for storing the crude oil and a fire pit with mounds of raised soil on either side over which the still for refining the crude is placed. The third component of artisanal refining – the drums or tanks in which the refined product is stored – was absent.

Sample analyses. Four borehole samples and three composite samples of soil were taken from the area in and around the refining location. The composite samples were from the following locations:

- The area where refining was actually undertaken – typically above the high-tide mark (C01)
- The area adjacent to the refining area where the waste oil flowed out – this area was intertidal and thus frequently inundated by water (C800)
- The channel adjacent to the refining area – which was flushed daily by tidal activity (C801)

In addition, samples were collected from the crude oil storage pit.

Table 34 gives a summary of UNEP's soil and groundwater investigations at Bodo West.

Table 34. Summary of soil and groundwater investigations at the Bodo West artisanal refinery site

UNEP site code	**qc_020-001**
Site name	**Bodo West**
LGA	Bonny
Site description	Artisanal refining
Number of soil samples	16
Number of ground water samples	3
Deepest investigation (m)	3.30
Maximum soil TPH (mg/kg)	33,200
Number of soil measurements greater than EGASPIN intervention value	6
Deepest sample greater than EGASPIN intervention value (m)	3.00
Maximum water TPH (µg/l) (CL samples)	399
Presence of hydrocarbons in surface water (CL)	yes
Number of soil measurements below 1 m	13
Number of soil measurements below 1 m greater than EGASPIN intervention value	4

Remnants of the artisanal refinery (Bodo West, Bonny LGA). The locations at which artisanal refining has been carried out present a picture of total environmental devastation

The following observations can be made from the analysis of the composite samples:

- In the refining area itself, which is restricted to the shore area above the high-tide mark, the contamination is variable. While a pit full of crude oil and a high concentration of 32,300 mg/kg TPH was observed within this area, the average concentration was only 8,480 mg/kg TPH. Thus, the area is contaminated heavily but not uniformly
- In the area periodically washed by the tide, the spread of pollution is more uniform and heavy. A value of 33,200 mg/kg TPH was observed in this area. This number gains significance with the realization that thousands of hectares of land in the intertidal area appear to be similarly contaminated, at least on the surface
- The soil sample taken from the channel regularly flushed by tidal water contained 481 mg/kg of hydrocarbons. Natural washing of the soil is at play here and this partially explains the ever-present layer of hydrocarbon on the water surface.

General conclusions. The locations at which artisanal refining is – or has been – carried out present a picture of total environmental devastation. With fresh crude oil stored on land in sandy pits, hydrocarbon can migrate in all directions. Damage to the soil at the refinery site itself is but a small portion of the overall environmental footprint caused by the refinery. The oil which escapes from the refining process, during transport, storage or runoff, flows into open water. Given the Bodo West oilfield's position in a flat, tidally influenced area, spilled oil can spread across many square kilometres, depositing oil slicks over downstream mudflats and mangrove swamps on an ebbing tide, and picking up and distributing oil slicks upstream on an incoming tide.

Proliferation of artisanal refining in Bodo West

During the remote sensing analyses of the Ogoniland undertaken concurrent to the field work, it was observed that there is a very rapid proliferation of the refining activity in Ogoniland in the past two years. In order to understand the extend of this activity, a detailed remote sensing analyses of the area around the Bodo West oil field was undertaken. It must be stated in advance that the observations made for this area is typical of the nearby area (beyond the oilfield itself) and limiting the study boundary to Bodo West was based primarily on the availability of the satellite images needed to undertake such an assessment.

For purpose of illustrating the damage a rectangular area enclosing all the oil wells in Bodo West was selected (total area of 506 hectares). The land use classes are described in Table 35.

Map 19 shows the land use changes in this area between 2007 and 2011. Two changes stand out;

1. Appearance of a new land use classification "artisanal refining". Such locations are always on the edge of the water body

Table 35. Land use classification for satellite image analyses

Classification	Description
Mangrove	In mangrove and was mangrove
Mangrove, open	Natural areas with open mangrove canopies (on very slightly higher ground which are distinctive and have not changed
Mangrove, dead	Vegetation, or part of, still in place, but no photosynthetic activity
Mangrove, degraded	What was mangrove but now degraded
Vegetation on dredged soil	Vegetation the slightly raised areas of dredged soil
Bare soil, dry	The very bright slightly raised areas, both dredged spoils not covered by vegetation and roads
Bare soil/mud falt, moist	The darket soils with generally no or little vegetation, this includes rights of ways and areas which were previously mangroves
Artisanal refineries	The burnt/black areas, previously vegetation on raised and dredged spoils
Industrial	Areas cleared by oil industry for its facilities such as flow stations

Table 36. Change in various land use classed between 2007 and 2011 for Bodo West (Bonny LGA)

Landuse Class	Area 2007 (m^2)	Area 2011 (m^2)	Change
Artisan refining	0	110,503	110,503
Bare soil	47,442	49,199	1,757
Bare soil / mud flat, moist	31,829	31,829	0
Coast / water interface	38,411	46,690	8,279
Industrial	18,157	18,157	0
Mangrove	3,658,938	3,347,663	-311,274
Mangrove degraded	381	307,762	307,381
Mangrove, open	74,999	40,327	-34,672
Mud flat / dead mangrove	6,743	25,671	18,928
Vegetation on dredged soil	272,108	171,206	-100,902
Water	914,559	914,559	0

2. Substantial increase in the classification "degraded mangroves"

The quantitative statistics are provided in Table 36.

It can be seen that there is a 10 per cent reduction in the area of healthy mangroves within a period of four years (and as noted in section 4.2, much of this change has happened since 2009). If left unchecked, this may lead to irreversible loss of the mangrove habitat in the area.

Loss of mangroves not only has economic impacts, for instance loss of timber production, it also has serious environmental consequences. Dead or dying mangroves coated with oil no longer provide a healthy habitat for fish or other aquatic life, causing catastrophic collapse of aquatic food chains and marine biodiversity. As fishing is a major livelihood activity in Ogoniland (and Niger Delta in general), destruction of mangroves will lead to collapse of fisheries.

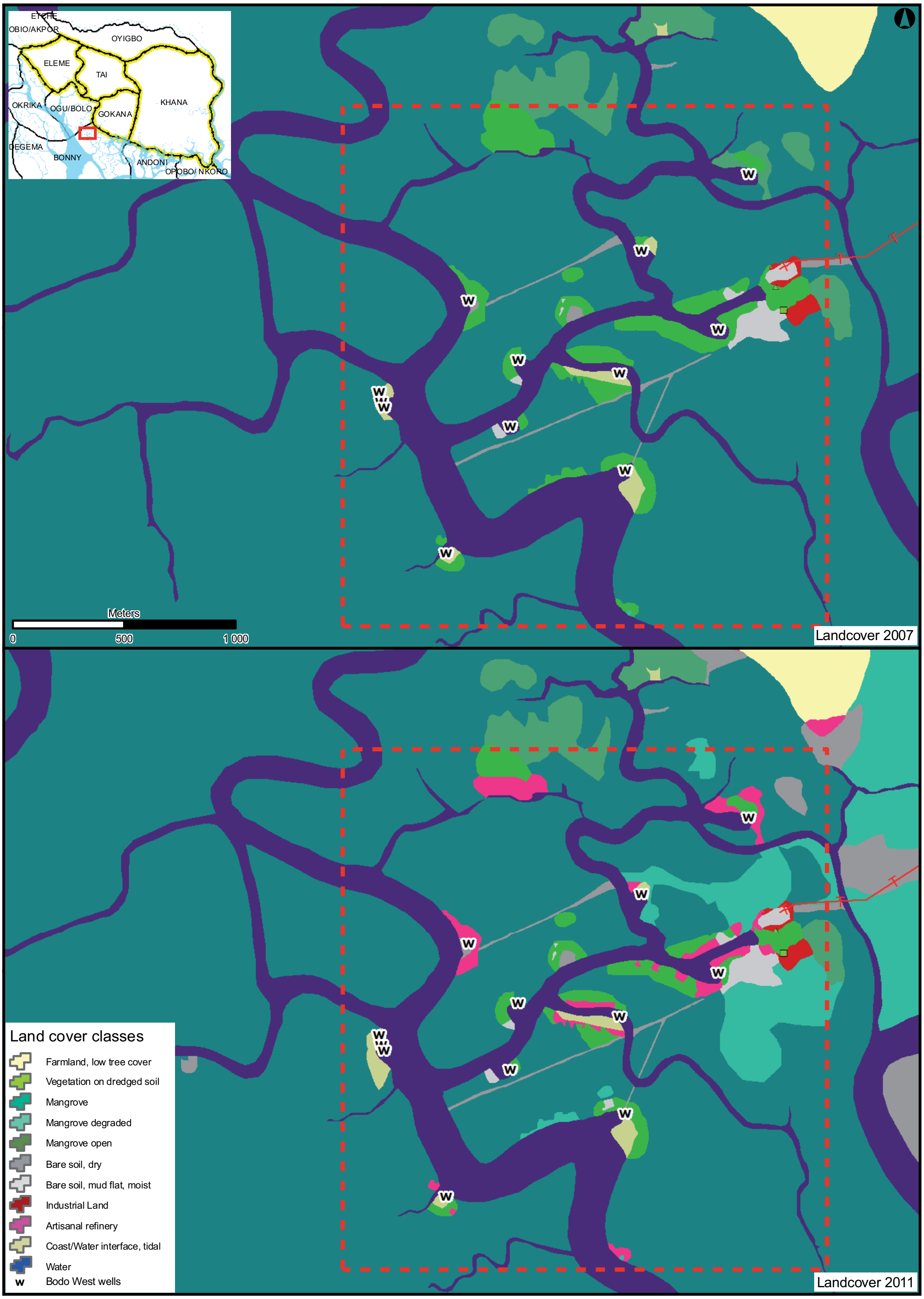
In addition, as mangroves die back and their roots decay, their binding effect is lost and sediment is exposed to erosion leading to receding shorelines [11, 50]. Other effects are changes to navigable channels and changes to the hydrology of an entire area.

If this trend has to be reversed, the practice of artisanal refining must be brought to a swift end. Artisanal refining of crude oil is now a large-scale activity across the Niger Delta and its mass of interconnected creeks. Closing down one or all of these refineries in Ogoniland will not leave the creek waters free from oil.

Visible hydrocarbon pollution on surface water in Bodo West, November 2010

Artisanal refining is the outcome of a complex social, economic and security situation and any initiative to curtail the activity has to deal with all of the above issues. It is not clear if those who undertake artisanal refining are indeed from Ogoniland itself. So, only by a comprehensive plan which cover the entire Niger Delta, this issue can be addressed.

Map 19. Proliferation of artisanal refining and degradation of mangroves (Bodo West, Bonny LGA)



5.2 Impact of oil on land-based vegetation

As evident from Chapter 4, oil spills are frequent events in Ogoniland. When a spill occurs on land, various scenarios can arise, among them:

- No remedial action is taken, leaving the contamination in place and exposed to the elements
- Fires break out, killing vegetation and creating a crust over the land, making remediation or revegetation difficult
- Remediation by natural attenuation is attempted at the site before fires occur

When spills have occurred on land but no remedial action is taken, the oil seeps to the ground and flows to low lying areas. This spread is exacerbated by rainfall, which enables oil to run off into nearby farms, ponds, swamps or creeks. When oil reaches the root zone, plants begin to experience stress and, in extreme cases, death follows. This is observed routinely in Ogoniland, for example within swamp vegetation. Any crops in the area directly impacted will also be damaged, and root crops, such as cassava, will become unusable. However, in due course, even when no remedial action is initiated, thick layers of oil will eventually wash off from the soil, making it possible for more tolerant plant species to re-establish, giving the area an appearance of having returned to healthy stage. When farming recommences, plants generally show signs of stress and yields are reportedly lower than in non-impacted areas. This naturally has an impact on the livelihood of the community though statistical information on this issue was not available. Also farming in soil which is contaminated also exposes the community to dermal contact with hydrocarbons.

Fire on a pipeline right of way (Deebon community, Bodo, Gokana LGA) June 2011

Table 37. Incidences of fire at oil facilities in Ogoniland, 2001-2011 (source: SPDC)*

Date	Location of fire incident
9 March 2001	Bomu flow station 10-inch delivery line to Bomu manifold
16 June 2001	24-Inch Nkpoku-Bomu Trans-Niger Pipeline at Sime
24 August 2001	28-Inch Bomu–Bonny Trans-Niger Pipeline at K-Dere near Bomu manifold
30 May 2002	24-Inch Trans-Niger Pipeline at Bara-Ale Community
18 September 2003	28-Inch Nkpoku–Bomu Trans-Niger Pipeline at Gio
23 May 2004	36-inch Trans-Niger Pipeline at Nkpoku
January 2005	Bomu Well 2
January 2005	Bomu Well 18
February 2005	Korokoro W 3
February 2005	24-inch Bomu trunk line
14 August 2006	Yorla Well 13
31 October 2006	Bomu Well 15
30 November 2006	Bomu Well 12
17 December 2006	Bomu flow station and Well 6
3 January 2007	Bomu flow station and Wells 41 and 50
April 2007	Yorla Well 16
May 2007	Yorla Well 16
18 June 2007	28-inch Trans-Niger Pipeline at K-Dere and Bodo
19 June 2007	24-inch Trans-Niger Pipeline at K-Dere
19 June 2007	24-inch Trans-Niger Pipeline Nkpoku–Bomu at Bera
21 October 2007	28-inch Ebubu-Bomu Trans-Niger Pipeline at Eteo
June 2008	Bomu Well 8
December 2008	24-inch Bomu trunk line
April 2009	Bodo 28-inch pipeline
April 2009	Yorla Well 16
March 2010	Bomu Well 44
April 2010	24-Inch Bomby–Bonny trunk line
May 2010	24-inch Bera trunk line
March 2011	24- and 28-inch MOGHOR Trans-Niger Pipeline
March 2011	24-inch K-Dere Trans-Niger Pipeline

*This listing is as complete as available information permits, as at May 2011, but may not include all fire incidents occurring at Ogoniland oil facilities during the period in question.

In a number of cases, especially following major oil spill events, SPDC initiated remedial action through enhanced natural attenuation (RENA). Initiation of this process precludes farming or regrowth of natural vegetation while clean-up actions are ongoing. However, as discussed in Chapter 4, the location continues to remain a source of pollution through rainwater runoff to neighbouring areas. Current clean-up standards require soil contamination to be less than 5,000 mg/kg TPH. However, even when remediation is achieved to this level, a residual impact on vegetation will persist.

When not attended to immediately, many pipeline spills or ruptures result in fires that can cover large areas, sometime even visible from satellite images and kill extensive tracts of vegetation as indicated by Table 37. Fires also leave behind a thick, burnt crust of bituminous substances fused with topsoil. Until such time as the crust is broken down, the affected area will remain unsuitable for vegetation/crop growth.

While most oil pipeline fires are short-lived, fires in oil wells can burn for extended periods, sometime for months. Such fires are more intense as they are continually supplied with crude from the well and can generate extremely high temperatures around the wellhead, killing off surrounding vegetation and severely damaging vegetation beyond the kill zone. Moreover, smoke from fires can travel long distances, depositing partly burnt hydrocarbons on vegetation far beyond. Such deposits on healthy leaves can adversely affect their photosynthetic ability, eventually killing the plant.

While oil well fires are not uncommon in Ogoniland (Table 35), none occurred during the period of UNEP's fieldwork, probably due to SPDC's ongoing programme of capping all wells. UNEP was therefore unable to take any measurements concerning the impact of fires on vegetation.

5.3 Contamination of surface water, sediments and fish

Assessment of contamination of surface water was conducted in two phases. In the first phase, reconnaissance observations were made on the ground, from boats and from the air. In the second phase, monitoring and sampling of water, fish and sediments were undertaken. The key observations are presented below.

Presence of oil

Floating layers of oil in the creeks in Ogoniland were present right through the 14-month fieldwork period of the UNEP assessment. These layers varied from thick black oil (which was often found along the coastline in places where the water was more stagnant) to thinner, silvery or rainbow-coloured sheens in the faster-flowing parts of the Imo River (Map 20). The field observations in Ogoniland clearly indicated ongoing entry of oil into the creeks from many sources, and no single clear and continuous source of spilled oil was observed or reported during UNEP's site visits.

Water quality

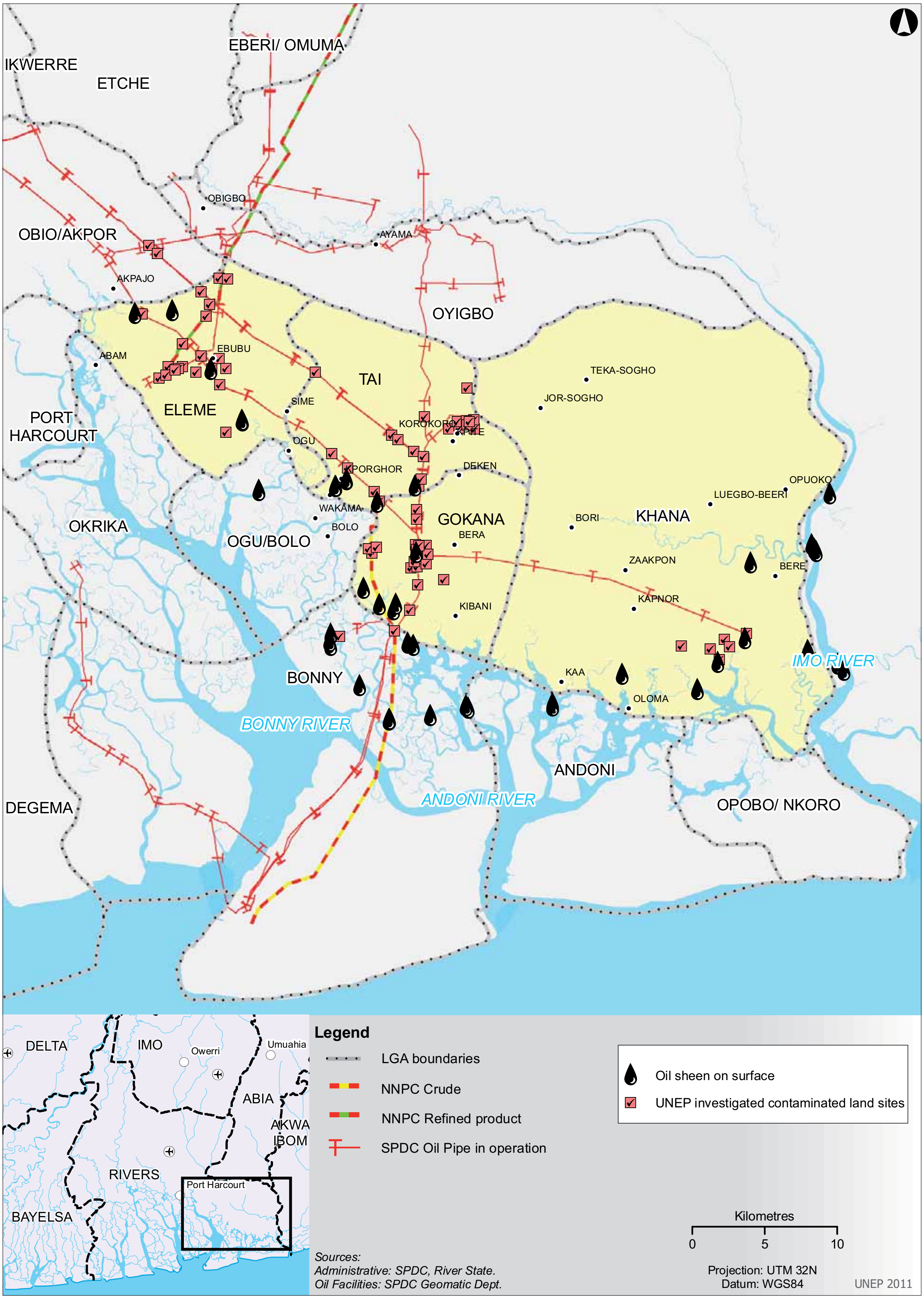
In addition to visual observations in the creeks, scientific monitoring of water, sediments and fish was also undertaken along the Imo River and the creeks in the Bodo area. The results are presented below.

Water temperature was consistently measured at 25-30°C in the creeks, the exact temperature being dependent on the time of day and the quantity of sunlight absorbed, especially in the shallower, slow-flowing streams. Mangrove sites may have somewhat elevated temperatures, owing to the extra time it takes to heat and cool a larger body of water flowing in from the ocean.

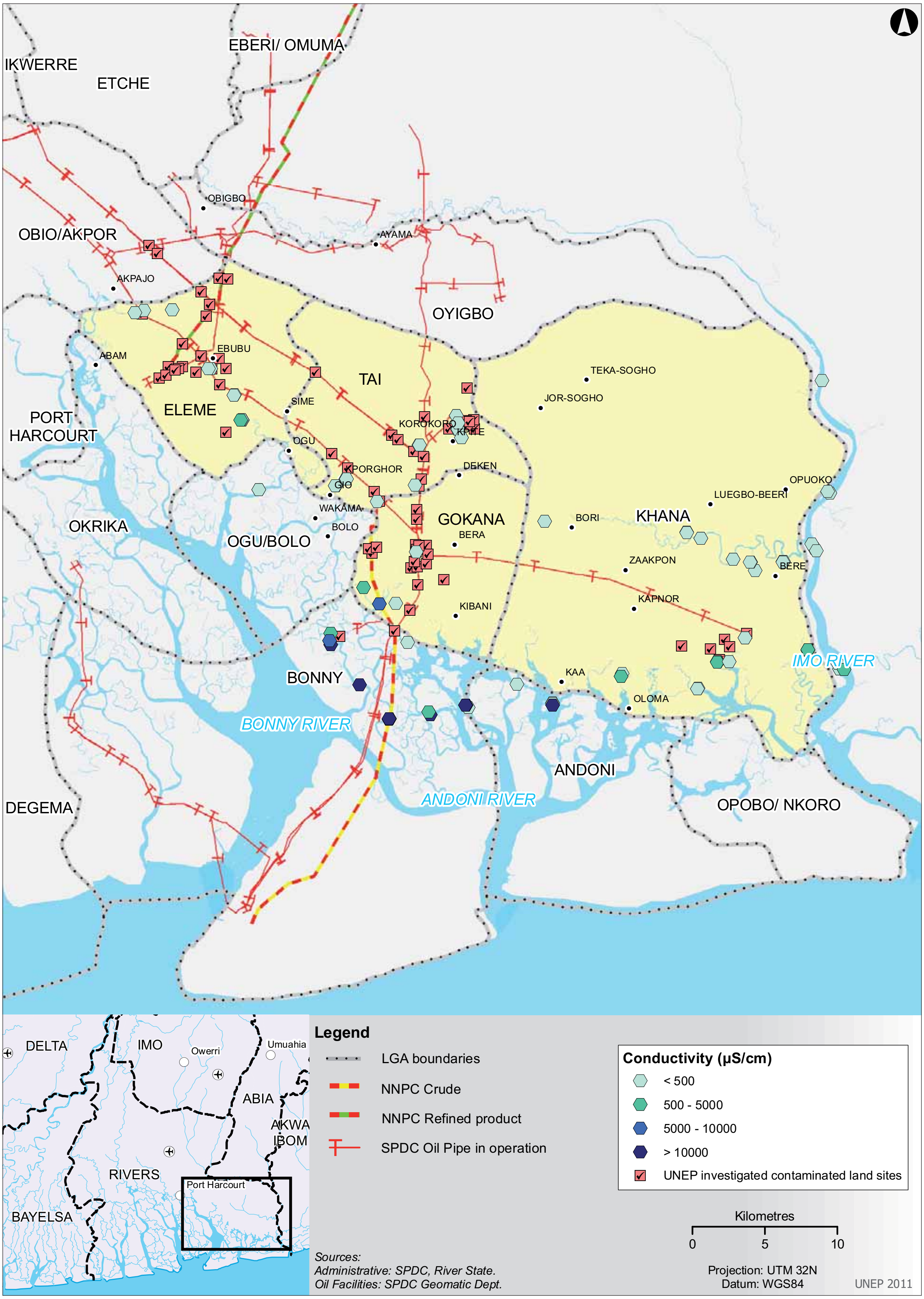
Salinity, as measured as conductivity, showed low readings as expected (Map 21), except for mangrove stations affected by the tidal flow of the Gulf of Guinea water through the Bonny and Andoni Rivers.

An aerial view of the pollution within the creeks

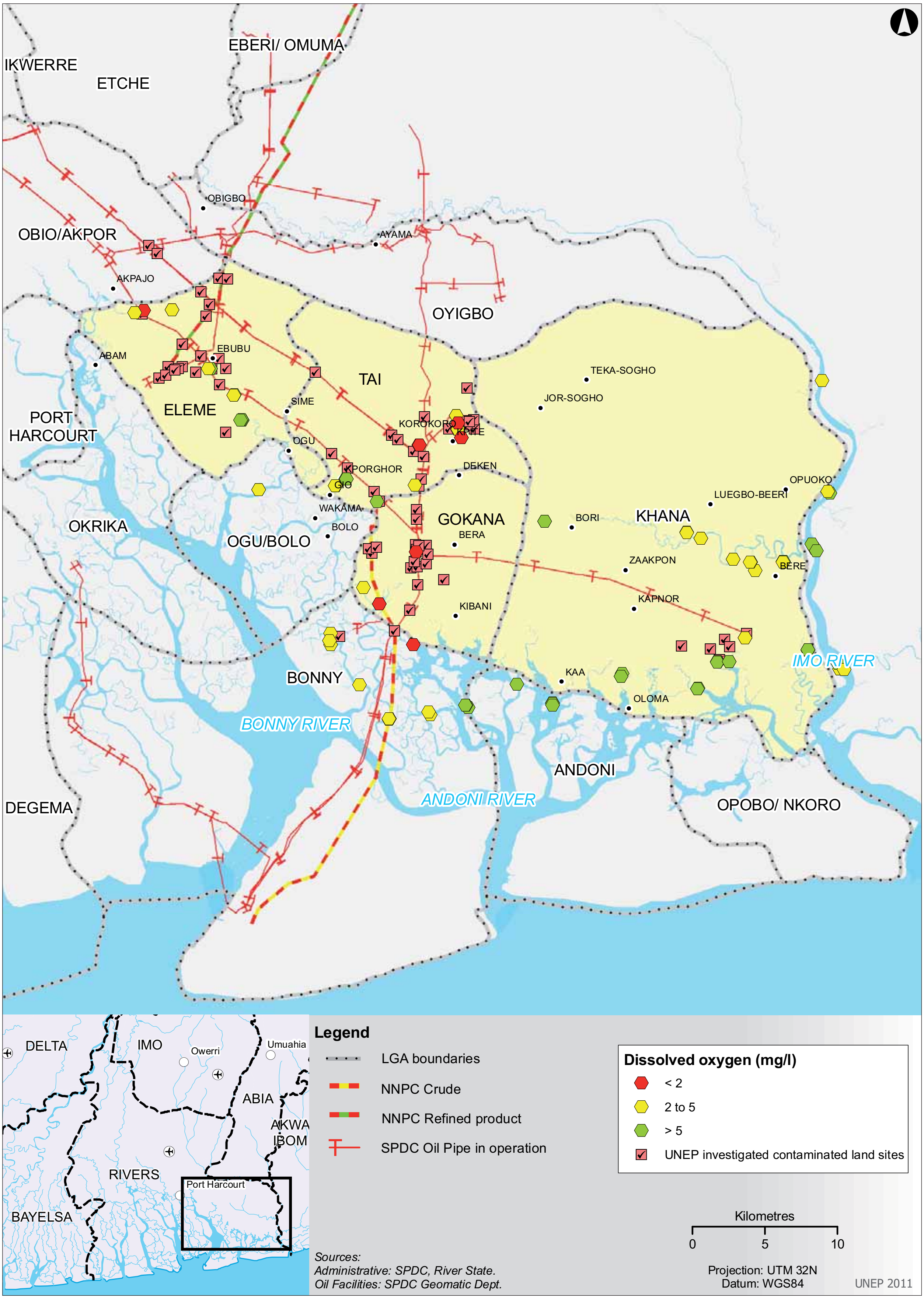
Map 20. Observed surface water sheen in surface water in and around Ogoniland



Map 21. Conductivity (µS/cm) readings within the Ogoniland water bodies



Map 22. Dissolved oxygen readings in the Ogoniland bodies



Oxygen levels were within normal levels at many stations (Map 22), though at some stations low concentrations were observed. At 25°C 8.4 mg/l oxygen can theoretically be dissolved in water, falling to around 8.1 mg/l at 28°C. Levels of dissolved oxygen below 5 mg/l start to cause stress in fish and at levels below 2 mg/l fish kill could happen. Dissolved oxygen is a transient parameter and several factors influence the levels of oxygen in the water, such as the amounts of decomposing organic matter, including of hydrocarbons in the water or at the seabed, the turbulence of the water (turbulent flow increases oxygen levels), and oxygen input from aquatic plants during daylight hours. As field monitoring of dissolved oxygen presents analytical challenges, it is important to measure this parameter regularly and to take necessary corrective actions. If dissolved oxygen at location is monitored below 5 mg/l regularly, further investigation as to the reason should be undertaken and remedial action will be needed to the health of the water body.

Petroleum hydrocarbons in water

The presence of a hydrocarbon sheen on the water in the creeks has already been mentioned. Hydrocarbons may reach the creeks from a spill on land – at an SPDC facility or NNPC pipeline – which either flows into, or is carried by runoff water into, a creek, from vessels carrying oil, or from illegal artisanal refining. Tidal influences also mean that spilled oil can be carried upstream as well as downstream of a given spill location. Concentrations at the monitored locations are given in Table 38.

Internationally there are no specific quantitative guidelines regarding the presence of total hydrocarbons in surface water. WHO Guidelines for safe recreational water environment, object to the presence of hydrocarbons on water bodies on three grounds, aesthetic impact on sight, smell and possibility of dermal absorption during contact recreational activity such as bathing.

Table 38. Concentrations of TPH detected in surface water

Sampling location reference	Community	Number of samples	TPH CWG (μg/l)
001-001	Ejama	3	218
009-010	Bara	1	716
100-001	Ebubu	3	74
101-001	Agbonchia	3	132
101-002	Aleto	3	267
103-002	Korokoro	3	148
103-003	Korokoro/Kpite	3	112
104-002	Ataba	3	963
104-003	Ataba-Otokroma 2	3	7,420
104-004	Ataba	3	2,880
105-002	-	3	28
105-003	Ikot Abasi	4	46
107-001	Eyaa-Onne	3	338
109-001	Kporghor	3	121
110-001	Kporghor	3	12
114-001	Botem-Tai	3	131
115-001	Luyor Gwara	3	239
116-001	Kwawa	3	1,070
117-001	Luegbo-Beeri	2	135
118-001	Kozo	2	1,350
119-001	Bodo	1	11
119-002	Bodo	1	13
120-001	Kpador-Bodo	2	13
120-003	Bodo	1	15
124-001	Yeghe	2	27
125-001	Bodo	1	2,030
130-001	Kolgba	1	2,350

A hydrocarbon sheen on the water surface of the creeks was an everyday reality during the period of UNEP's fieldwork

Two provisions of Nigerian legislation are also important in this context. Section VIII, 2.11.3 of the EGASPIN, dealing with clean-up and monitoring of oil spills, states: "Any operator or owner of a facility that is responsible for a spill that results to impact of the environment shall be required to monitor the impacted environment alongside the restorative activities."

In sub-section (i) it further states: "For all waters, there shall be no visible sheen after the first 30 days of the occurrence of the spill no matter the extent of the spill."

And sub-section (ii) states: "For swamp areas, there shall not be any sign of oil stain within the first 60 days of the occurrence of the incident."

Over the course of more than a year of fieldwork in Ogoniland, the presence of a hydrocarbon sheen was an everyday reality and it is clear that the above provision is not enforced. One reason for this is that according to both the regulator and the oil industry the majority of this oil comes from illegal operations and therefore nobody took action to clean it up. However, this alone cannot explain the lack of action, as Section VIII 4.0 of the EGASPIN addresses such situations.

Section 4.1 states: "An operator shall be responsible for the containment and recovery of any spill discovered within his operational area whether or not its source is known. The operator shall take prompt and adequate steps to contain, remove and dispose of the spill. Where it is proven beyond doubts that an operator has incurred costs in cleaning up a spill for which he is not responsible, the operator shall be reasonably compensated, up to the extent of recovering all expenses incurred, including reimbursement of any payment for any damage caused by the spill, through funds established by the Government or the oil industry for that purpose."

It is not clear whether a fund was actually established as implied in the EGASPIN. But it is evident that there are provisions for the clean-up of such spills and removal of floating hydrocarbons from the environment. There are multiple technical resources available in Nigeria to respond to oil spills, but these resources have not been put to use.

An oily sheen is ever-present on the water surface of the creeks around Ogoniland. This same water is used by local communities for fishing, bathing and in some cases for drinking. Information should be made available to local people about locations that are dangerous for drinking, fishing or bathing due to the presence of hydrocarbons. Effective action is needed to clean up the existing contamination and to prevent further release of hydrocarbons into the environment.

Impacts of oil on sediments

Although oil exploration and extraction have continued for decades in Ogoniland, and clean-up of contaminated land has been undertaken at hundreds of locations, clean-up of wetland sediments has not yet been attempted. Such work has, however, been undertaken in other parts of the world and is key to restoring aquatic ecosystems to health. Lack of proper clean-up can prevent the re-establishment of benthic activity, which affects ecosystem functioning and productivity. Anaerobic degradation of hydrocarbons can release foul-smelling gases. Contaminated sediments can also act as reservoirs of pollution, releasing hydrocarbons when disturbed (e.g. by the propeller action of a motorboat) into the aquatic environment long after the original source of pollution has been removed.

Petroleum hydrocarbons in sediments. In all, sediment samples from 37 locations in the four LGAs were analysed. Table 39 presents the observed concentrations of hydrocarbons where they exceeded EGASPIN values.

Table 39. TPH concentrations in sediments exceeding EGASPIN values

Sampling location reference	Community	TPH (mg/kg)
001-001	Ejama	12,100
009-010	Biara	19,600
104-004	Ataba	8,630
119-001	Bodo West	15,100
120-001	Kpador-Bodo	12,100
120-002	Bodo	6,570
121-001	Sugi-Bodo	12,100
122-001	K and B Dere	12,000
123-001	K-Dere	16,500
130-001	Kolgba	17,900

The locations where aquatic sediments were above the EGASPIN values are presented in Map 23.

There are many studies of petroleum hydrocarbon concentrations in freshwater and marine sediments. The results for the marine environment have been summarized by the US National Research Council [51] and show that concentrations of total petroleum hydrocarbons in sediments far from urbanized coastal areas are often in the range of 20-50 mg/kg. Concentrations in the range 50 to several hundred mg/kg are frequently found in coastal sediments where anthropogenic activities are intensive. In busy shipping channels and near marinas, levels often show concentrations of several hundred mg/kg. Close to direct point sources of oil contamination, such as water-cooled oil refineries and oil terminals, TPH concentrations may be 1,000 to several thousand mg/kg. From a toxicological standpoint it is generally considered that biological effects start to occur among more sensitive organisms at levels in the range of 50-100 mg/kg. More resistant organisms can tolerate concentrations of 1,000 to a few thousand mg/kg.

With regard to the EGASPIN, the intervention value for hydrocarbons in sediments is 5,000 mg/kg, against a target value of 50 mg/kg. There are 10 samples above the intervention value, most substantially so (Table 39).

Impacts of oil on fisheries

The aquatic resources of Ogoniland constitute a significant cultural heritage of the Ogoni people, representing an all-important aspect of their history and identity. They play a major role in determining settlement patterns, in particular the location of fishing communities along the estuaries. Aquatic resources are also a source of employment generation. A sample survey of the communities undertaken concurrently with the UNEP survey indicated that while agriculture remains the major occupation, in some areas fishing could be the main occupation (Figures 15 a and 15 b).

Map 23. Average TPH readings in sediments in Ogoniland

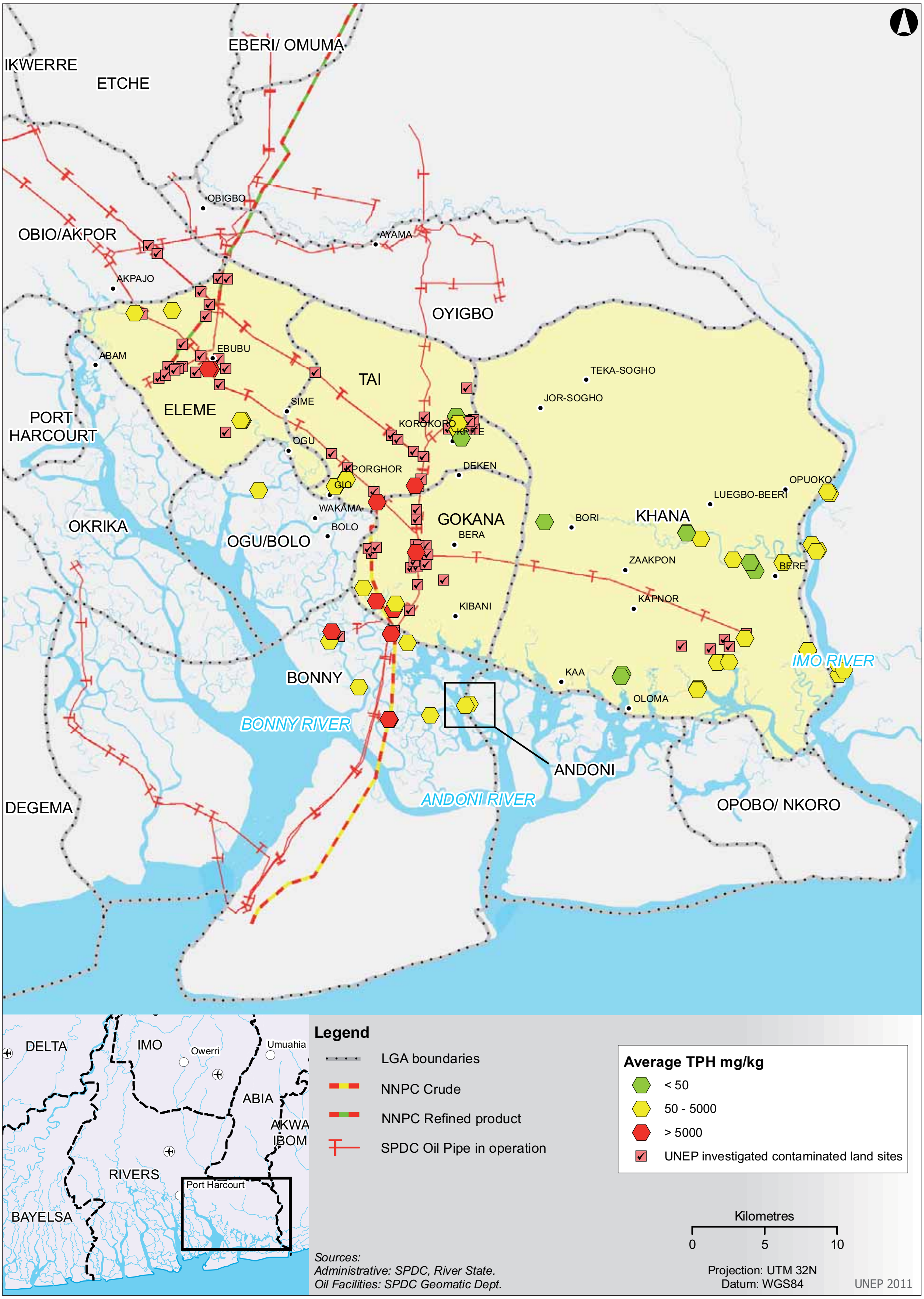


Figure 15a. Occupation of the head of household in all sampled areas of Ogoniland

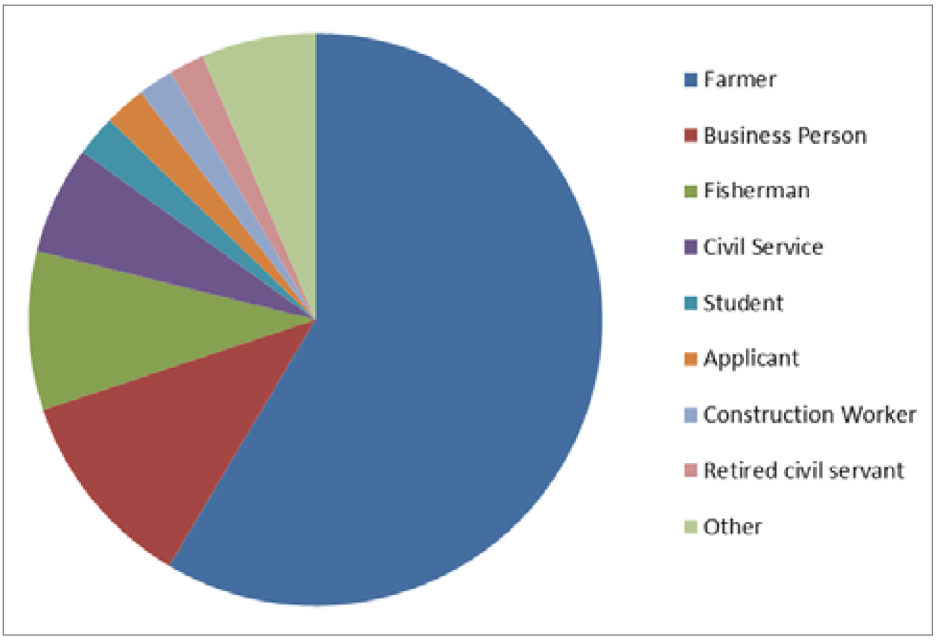
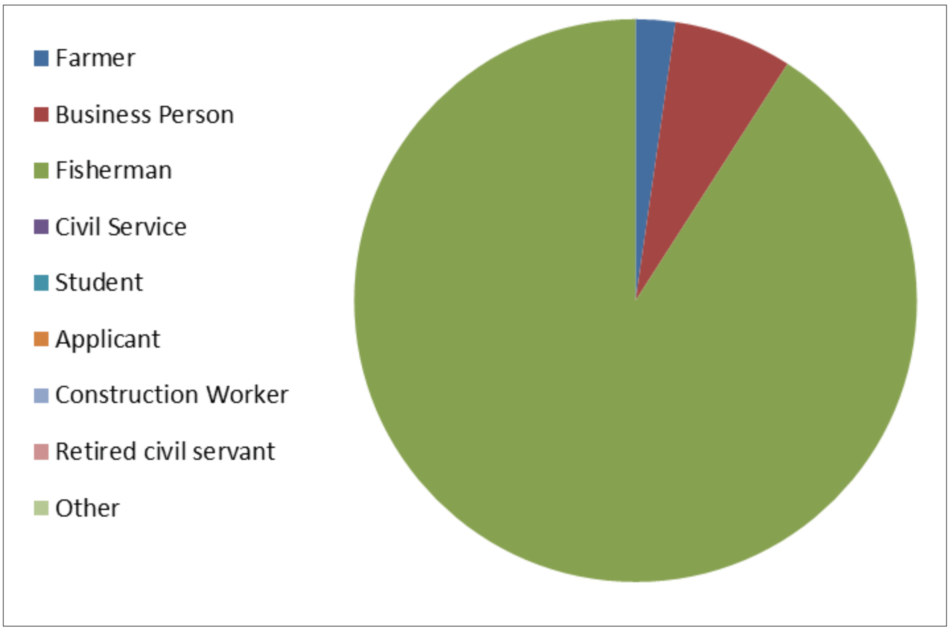


Figure 15b. Occupation of the head of household in Kaa, Khana LGA



Transfer of land ownership within Ogoniland is by inheritance, donation, purchase or, in the past, by conquest. Land can be owned by an individual, a family or the entire community. Community lands include fishing ports/rights and designated portions of the water body. Fishing ports and locations are commonly owned by communities but are generally bestowed by the local chief. Although individuals can own fishing ponds in their family swamps, permission is usually granted by the owner to anyone who wishes to fish in the swampland. Such swamps can also be leased on a seasonal basis.

At fishing ports, markets and in local communities the UNEP assessment team met with artisanal fishermen who earn their living from fishing, commercial fishmongers and subsistence fishermen/women.

Artisanal fishermen are involved directly in fishing activities as a means of livelihood and either own or occupy surface-water fishing grounds. There are small subsectors specialized in estuarine and inshore canoe fishery. Fishing is carried out by the use of small, open craft which may or may not be motorized.

Fishmongers may or may not own or occupy fishing grounds, or be involved directly in fishing activities, but they act as intermediaries between the fishermen and the end consumer. This category is made up predominantly of women.

The final category is comprised of fishermen or women who undertake fishing activities on a very small scale, either for subsistence or leisure.

Since fishing grounds and ports are the backbone of the fishing industry (as farmland is to agriculture), almost all fishing families and communities tend to acquire their own fishing location(s) and establish prerogative rights over them. This accounts for the abundance of fishing locations in Ogoniland.

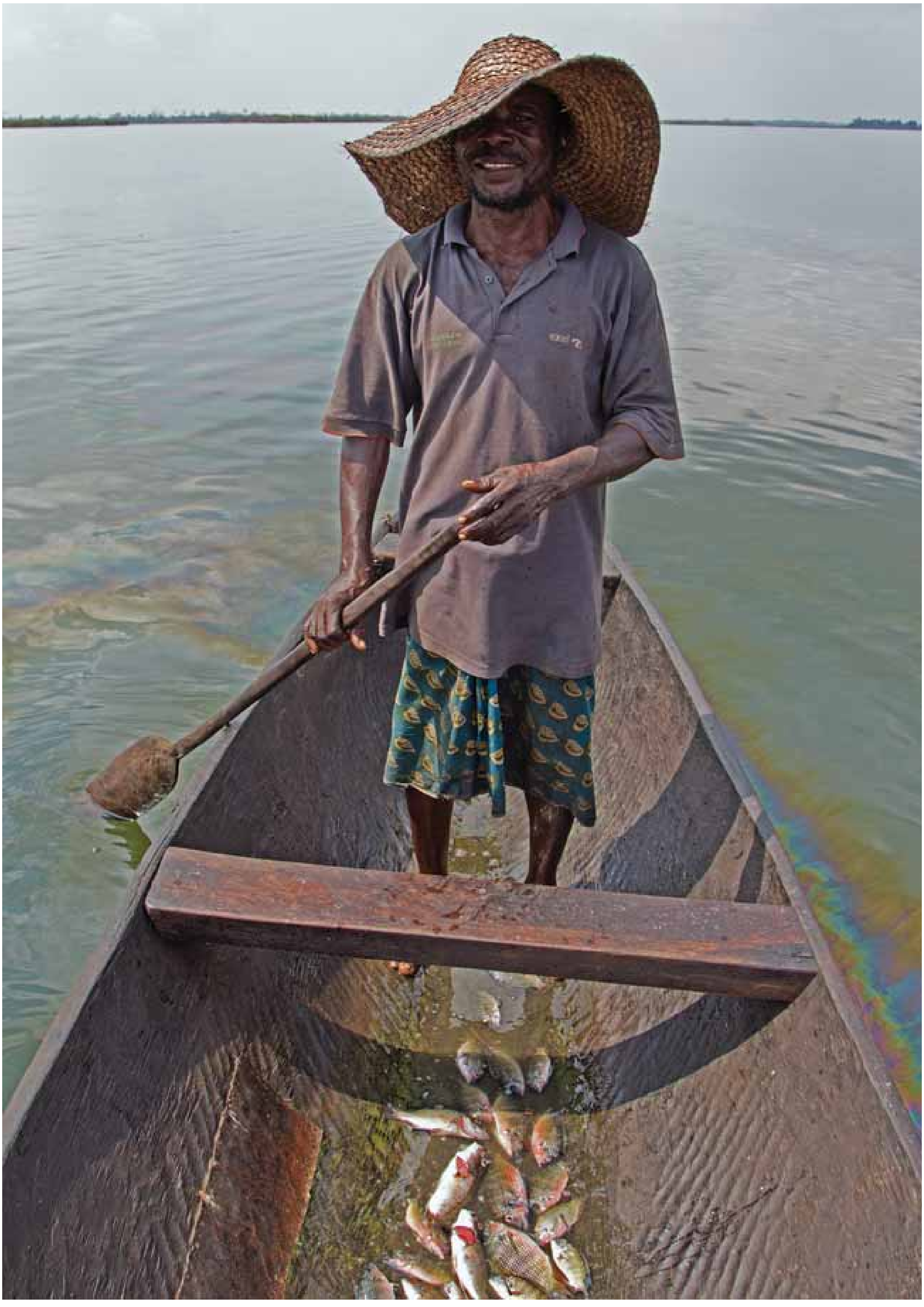
Destruction of fish habitat

Given the socio-economic status of Ogoniland, and surrounded as it is by extensive creeks, fishing should be an integral part of the community's livelihood. While fishing was indeed once a prime activity, it was evident from local community feedback and field observations that it has essentially ceased in areas polluted by oil, especially where physical impacts are evident. When encountered in known polluted areas, fishermen reported that they were going to fishing grounds further upstream or downstream.

Where a number of entrepreneurs had previously set up fish farms in or close to the creeks, they reported that their farms and businesses had now been ruined by the ever-present layer of floating oil.

No scientific assessments of the fishing pressure in Ogoniland are available. However, judging from the fact that large portions of the catch are made up of juvenile and sub-adult fish, it is reasonable to conclude that overfishing is a major problem affecting the fisheries in Ogoniland.

An Ogoni woman selling periwinkles at a local market, Kozo, Gokana



Local fisherman with his catch (note the sheen in the water, Bonny River)

A fish farm with significant oil sheen (Bodo West, Bonny LGA)

Fish consumption

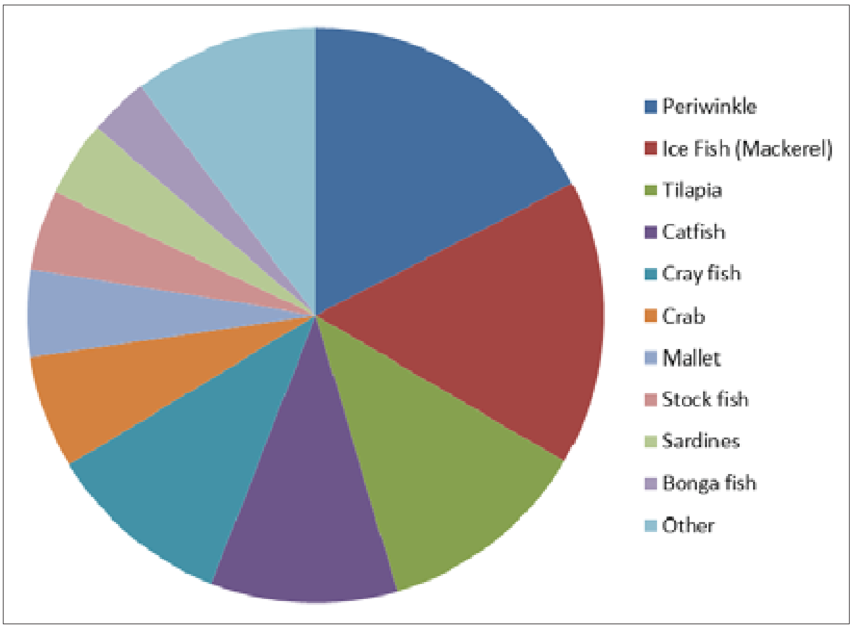
Figure 16 summarizes reported fish consumption in Ogoniland by species. Among all communities, periwinkle, ice fish, tilapia, catfish and crayfish are consumed most frequently. However, the importance of species varies considerably. In some communities, such as in the fishing village of Kaa, no one species dominates. Among those who reported consuming a variety of different types of fish, the species reportedly most consumed (i.e. number of meals per unit time) across all communities were crayfish, periwinkle and ice fish. Combined with chemical concentration data, this information could be used to estimate the level of petroleum hydrocarbons ingested by fish consumers.

Analytical results

There is recurring concern among local communities that accumulations of hydrocarbons could be building up within the fish tissues that they consume. Fish tissue analyses were conducted to determine if this is indeed the case.

Concentrations of 16 PAHs in fish, oysters and mussels from the four Ogoniland LGAs are given in Figure 17a-c. The concentrations of PAHs in biota were low in all samples. In fresh fish and seafood, concentrations were below the detection limit for most of the different PAHs. In a few cases, measurable but low levels were found.

Figure 16. Figures for fish consumption



It is worth noting that smoked fish purchased in local markets showed elevated levels of PAHs. WHO recommends a maximum intake of 20 µg/kg (human) body weight. Hypothetically, assuming a human body weight of 75 kg and the concentrations of PAH's in smoked fish found in the present investigation, a person could eat up to half-a-kilo of smoked fish per day and still be below the WHO recommended maximum daily intake. Thus, fish consumption in Ogoniland, either of those caught locally or purchased from markets, including smoked fish, was shown not to pose a health risk to the community.

Total PAH concentrations in bivalves after oil spills and in chronically polluted areas often show concentrations in the range 10-50 mg/kg. Following the *Exxon Valdez* oil spill in Alaska in 1989, the concentration of PAHs in mussels was found to be in the range 0.002-6 mg/kg [52]. Mussels from the North Sea show concentrations of 0.05-1 mg/kg and up to 4 mg/kg near an aluminium smelter in Scotland [53]. After an oil spill in Laguna de Terminos, Mexico, oysters were found to contain 2-42 mg/kg [54]. In Galveston Bay, Texas, concentrations in oysters were up to or above 9 mg/kg [55]. An analysis of mussels along the north-west Mediterranean coast of France and Italy showed average concentrations of around 0.05 mg/kg, with generally higher concentrations near large harbours [56].

The fisheries sector is suffering

The possible presence of hydrocarbons in fish was a matter of serious concern for the Ogoni community. This investigation showed that the accumulation of hydrocarbons in fish tissue is not a serious health risk in Ogoniland. However, the fisheries sector itself is suffering due to the destruction of fish habitat in the mangrove zone and highly persistent contamination of many creeks, making them unsuitable for fishing.

Figure 17a. Total PAHs in fish from fishermen

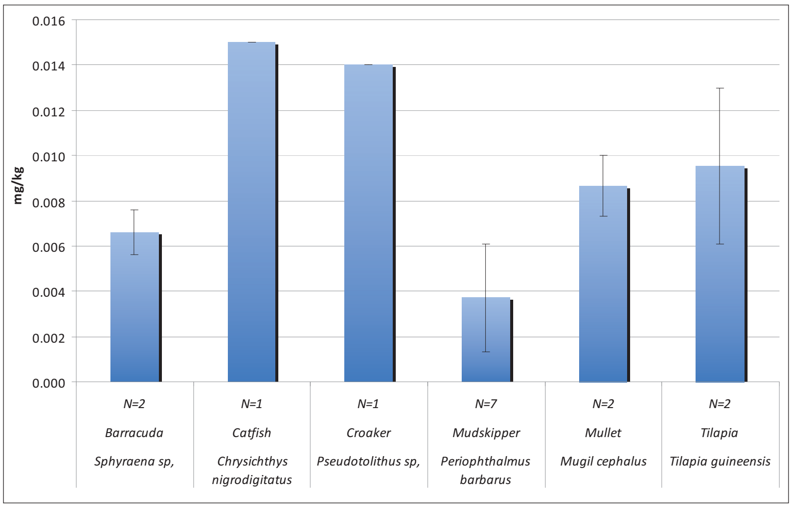


Figure 17b. Total PAHs in mollusks from fishermen

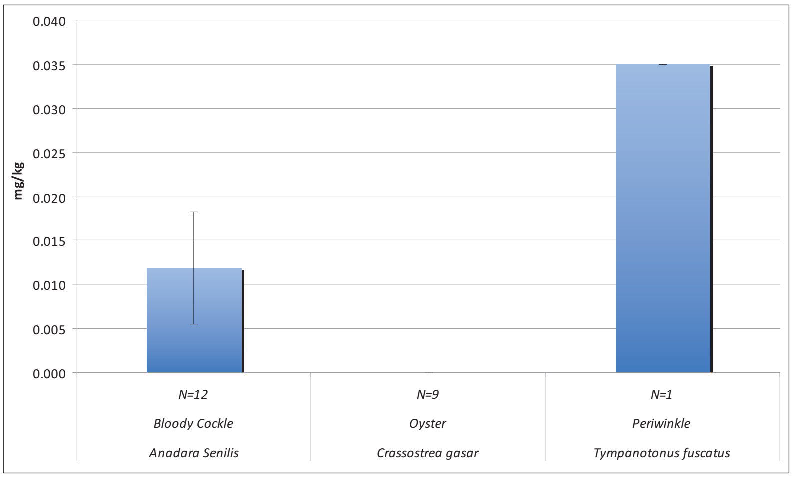
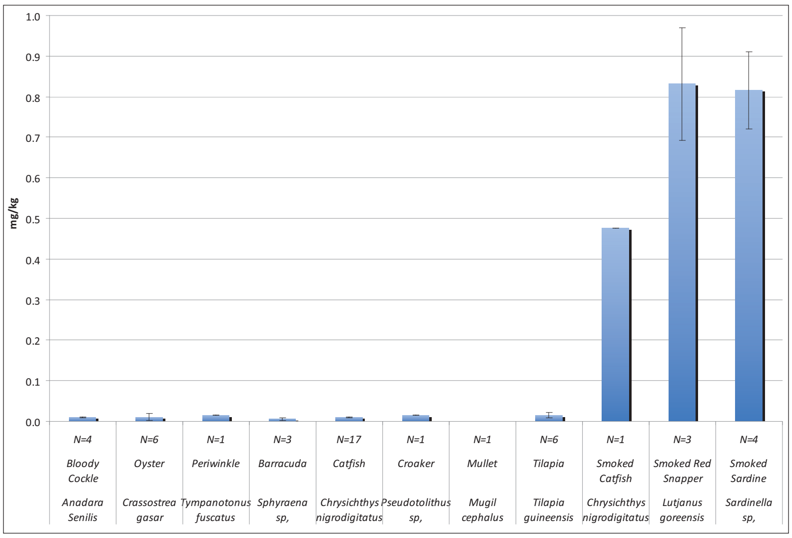


Figure 17c. Total PAHs in Fish and mollusks fought from fishermen and markets



5.4 Impacts of oil on public health

Exposure and health questionnaires

The design of the exposure and health questionnaire meant that responses from those communities selected to complete it were reflective of the general population, although some selection bias is possible given that participation was voluntary.

A total of 881 questionnaires were completed by 474 male and 401 female heads of household, with the gender of respondents unclear in six questionnaires. Most respondents were between 25 and 55 years of age. The number of questionnaires circulated among each community was proportional to the population of that community, with a goal of interviewing 20-25 per cent of each community. Table 40 summarizes the number of questionnaires completed in each community.

As noted in section 5.3, agriculture is the dominant occupation across Ogoniland while fishing is locally significant. Those involved in agricultural work may be exposed to petroleum hydrocarbons present in soils, through oral, dermal and even inhalation exposure. Fishermen may be exposed to petroleum hydrocarbons present in sediments and surface water, as well as via oral, dermal and inhalation exposure routes.

Table 40. Number of completed questionnaires in each community

Community	Completed questionnaires
Agbonchia	88
Bera	38
Bodo	103
Dere	51
Ebubu	181
Kaa	41
Korokoro	70
Kpean	64
Kpite	94
Kwawa	66
Okwale	85
Total	881

Oil spills represent one of numerous sources of exposure to petroleum hydrocarbons. Others are commercial refineries, petrochemical plants, vehicle emissions, generator exhausts, bush burning, trash burning on the side of the road, food processing (e.g. gari processing, abattoirs), gas flaring from oil production in nearby LGAs, artisanal refining, burning of domestic waste, cigarette smoking and cooking fuels. The questionnaire asked respondents to specify sources to which they might be exposed. While this section was generally left blank, questions regarding smoking and home cooking practices were answered.

The UNEP team consulting community members on health issues in Eleme LGA

Table 41. Summary of questionnaire responses on cooking practices

All communities	Percentage reporting use of cooking fuel type				
	Wood	Petrol	Kerosene	Cooking gas	Stove
Indoor cooking (n=522)	83	4.2	15	4.8	4.4
Outdoor cooking (n=348)	93	2.9	6.6	0	0.3

Smoking. Smoking of cigarettes, cigars and other substances, which result in exposure to benzene and some PAHs, turned out to be relatively rare, with approximately 85 per cent of all respondents reporting that they had never smoked. Those who smoked reported using cigarettes, cigars and Indian hemp.

Cooking location and fuel. More than half of all respondents (522 of 881) reported cooking indoors and, of these, 83 per cent relied on wood for fuel, followed by kerosene (14.6 per cent), cooking gas (4.8 per cent) and petrol (4.2 per cent) (Table 41). Fewer respondents (348 of 881) reported cooking outdoors and, of these, 93 per cent relied on wood for fuel, followed by kerosene (6.6 per cent) and petrol (2.9 per cent). The responses are summarized in Table 39. (Note: These percentages total more than 100 per cent because some respondents reported using more than one fuel type.) In consequence, they are likely to be experiencing potentially high indoor exposure to some petroleum hydrocarbons as well as respirable particulates.

Pathways of exposure to petroleum hydrocarbons. Routes of possible exposure to petroleum hydrocarbons originating from oil spills are summarized in Figure 5. In addition to the pathways noted above for agricultural workers and fishermen, other community members might experience oral, dermal and inhalation exposure to petroleum hydrocarbons through drinking water, bathing water and washing water, as well as oral exposure to any foods that are contaminated with petroleum hydrocarbons. Thus, it is important to determine the sources of food and water used by community members and to combine this information with chemical concentration data for these media in order to determine if exposures of concern are occurring.

Drinking water. The most commonly reported sources of drinking water across all communities were, in order of frequency, bore-wells, hand-dug wells and surface water (Figure 18). Use of rainwater was rare relative to the other sources but was reported more frequently for communities in Khana (Kpean, Kwawa, Okwale) than for communities in other LGAs, possibly due to Khana's comparatively rural nature. Less frequently reported sources were bottled water and sachet water (water in plastic bags).

Bathing and washing water. As for drinking water, the most commonly reported sources of bathing and washing water across all communities were, in order of frequency, bore-wells, dug-out wells and surface water (Figure 19). One or more of these three sources were reportedly dominant within individual communities. In Okwale, rainwater was reported to be more important for bathing and washing than for drinking. Use of sachet water was the least frequently reported source, with bottled water not used at all.

Health-care services. On the question of health care, some respondents indicated that they used more than one location (Figure 20). As well as primary health-care centres, many people also visit local pharmacists. The reported frequency of use of private clinics, primary health-care centres and general hospitals varied among communities. Bodo respondents, for example, most often sought health care at a general hospital, while respondents in Kpite and Kwawa were more likely to use primary health-care centres. Some reported visiting traditional healers but less frequently than other sources of health care. These responses confirmed what was learned through interviews with community members and health-care professionals, namely that people seek help from pharmacists as a first resort, followed by care at various medical facilities, the choice depending on factors such as accessibility, cost and quality of care.

Rainwater

A recurrent complaint from the Ogoni community during the reconnaissance phase concerned rainwater contamination, reported at times to be black and the cause of skin irritation. Since a number of communities use rainwater as a source of drinking water, it was important for UNEP to include rainwater in its investigations. Given the unpredictability of rainfall, however, this was not an easy task, so samples had to be collected from households which had a rainwater collection system. Some opportunistic samples were also collected while it was raining. Table 42 provides information on the basic parameters and observations on rainwater samples.

Figure 18. Sources of drinking water

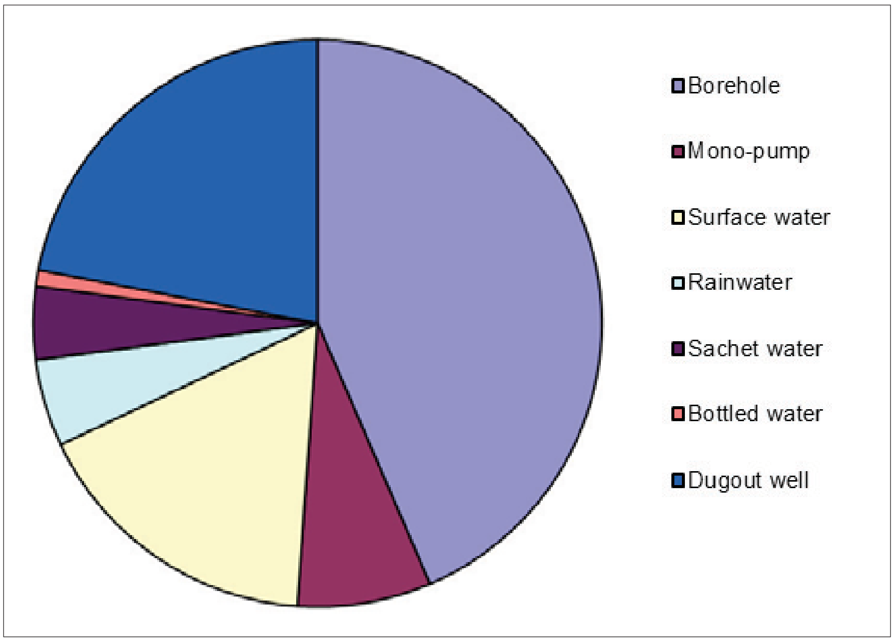


Figure 19. Sources of bathing and washing water

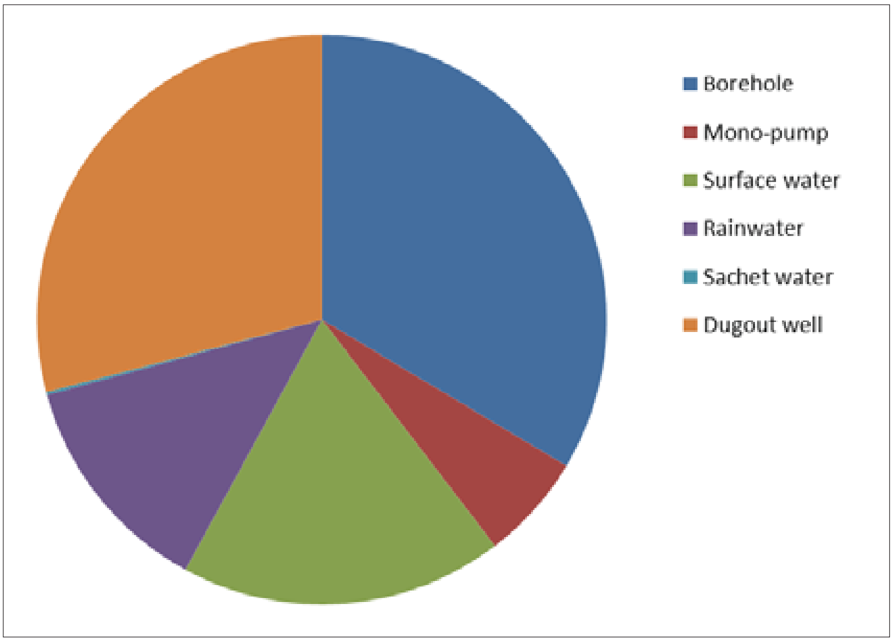


Figure 20. Primary health-care providers for the community

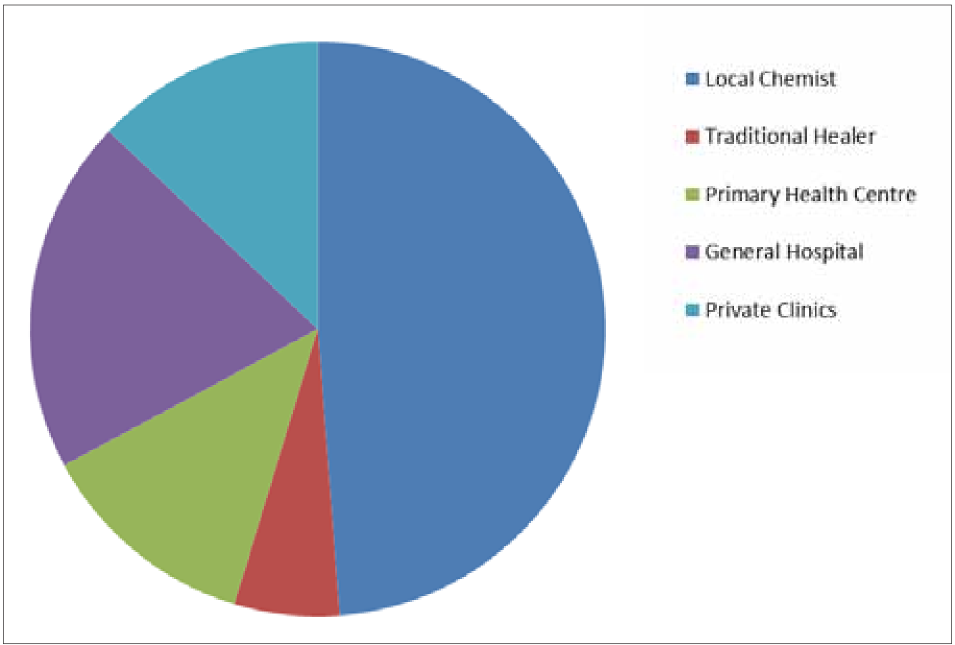


Table 42. Basic parameters and observations on rainwater samples

Community	Electrical conductivity [µS/cm]	pH	Temp (deg C)	Colour	Odour	Method of collection / remarks
Kwawa	10.32	6.62	26.1	None	None	Roof while it was raining
Agbonchia	30.7	7.13	24.5	Blackish	None	Rainwater harvesting container; black sooty substance in water
Okwale	69.6	7.73	25.9	None	None	Rainwater harvesting container; black sooty substance in water.
Okwale	30.1	7.13	25.9	None	None	Rainwater harvesting container
Okwale	25.7	6.91	27.8	None	None	Rainwater harvesting container
Korokoro	57.5	8.01	27.6	None	None	Rainwater harvesting container
Korokoro	32.7	8.96	34.8	Greenish	Slight	Rainwater harvesting container; rain collected from a thatched roof house used as kitchen
Korokoro	31.01	6.85	29	None	None	Rainwater harvesting container
Korokoro	120.5	5.43	32.3	None	None	Rainwater harvesting container
K-Dere	27.7	6.92	25.9	None	None	House very close to spill site
K-Dere	13.71	7.13	25.3	None	None	Rainwater harvesting container
Norkpo	10.7	6.99	29.9	None	None	Rainwater harvesting container
Norkpo	32.1	7.18	23.7	None	None	Rainwater harvesting container
Norkpo	47.3	7.43	45.2	None	None	Rainwater harvesting container
Ebubu-Ejamah	58.2	8.19	31.8	None	None	Rainwater harvesting container
Ebubu-Ejamah	26.7	6.97	28.1	None	None	Rainwater harvesting container
Ebubu-Ejamah	35.8	7.18	28	None	None	Rainwater harvesting container
Obajioken-Ogale	317	4	27.5	None	None	Previous night rainfall harvested with a container
Obajioken-Ogale	12.88	5.2	27.2	None	None	Rainwater harvesting container
Obajioken-Ogale	25.3	7.91	30	None	None	Rainwater harvesting container
Agbi-Ogale	23.7	6.3	29.8	None	None	Rainwater harvesting container
Agbi-Ogale	26.1	5.53	27.5	None	None	Rainwater harvesting container
Kpite	16.06	5.91	26.1	None	None	Aluminium roof top system
Kpite	7.6	6.21	26.4	None	None	Rainwater harvesting container
Kpite	10.39	6.48	30.1	None	None	Rainwater harvesting container
Kpite	47.4	7.12	31.4	None	None	Rainwater harvesting container
Aabue-Korokoro	17.76	8.4	23.7	None	None	Rainwater harvesting container
Aabue-Korokoro	29.5	6.85	24.1	None	None	Rainwater harvesting container
Aabue-Korokoro	20.4	6.85	24	None	None	Rainwater harvesting container
Aabue-Korokoro	17.13	6.85	24.3	None	None	Rainwater harvesting container
Korokoro	52.92	2.39	26.5	None	None	Thatched roof system
Korokoro	15.4	5.76	26.6	None	None	Rainwater harvesting container
Kpean	28.3	5.18	28.8	None	None	Premises of a Church
Kpean	11.6	5.84	25.7	None	None	Rainwater harvesting container
Kpean	15.73	6.19	28.5	None	None	Rainwater harvesting container
Kpean	8.65	5.79	8.65	None	None	Rainwater harvesting container
Akpajo	26.1	5.69	23.2	None	None	Directly sampled in open air
Akpajo	25.4	5.72	25.4	None	None	Directly sampled in open air
Akpajo	26.2	6	22.7	None	None	Directly sampled in open air

Table 43. TPH concentration in rainwater samples

LGA	Sample ID	qc_label	TPH (µg/l)
Eleme	004-006-RW-103	water: community rainwater samples	52
Tai	008-002-RW-102	water: community rainwater samples	189
Tai	008-002-HW-110	water: community rainwater samples	68
Tai	013-002-RW-103	water: community rainwater samples	1,520
Tai	013-002-RW-102	water: community rainwater samples	3,250
Tai	013-002-RW-101	water: community rainwater samples	98

Table 42 lists pH measured in rainwater and drinking water samples collected by the UNEP Public Health Team. WHO (2008) describes rainwater as "slightly acidic and very low in dissolved minerals; as such, it is relatively aggressive [and] can dissolve metals and other impurities from materials of the catchment and storage tank" [59]. Of the 35 rainwater samples collected from harvesting vessels, 22 had pH measurements in the range 6.5-8.5 required by Nigerian drinking water quality standards [36]. Of the 13 samples with pH measurements outside this range, 12 had pH levels ranging from 2.4 to 6.3 and one had a pH of approximately 9. The rainwater sample with a pH of 2.4 was described as 'colloidal' but was reportedly used for washing and other domestic purposes. The sample with a pH of about 9 was reportedly greenish in colour with a slight odour and had been collected over a relatively long period. Rainwater samples collected directly from the atmosphere had pH measurements ranging from 5.6 to 6, below the 6.5-8.5 range. These pH levels might reflect relatively clean rainwater, but they could also reflect some effect from nearby industrial activity and vehicular emissions. As with the rainwater samples collected directly from the atmosphere, drinking water samples had pH measurements below 6.5, ranging from 5.1 to 5.7.

WHO has noted the difficulty in determining links between human health and the pH of drinking water because pH is so closely associated with other aspects of water quality. Furthermore, foods with low pH, such as lemon juice (pH about 2.4) and orange juice (pH about 3.5), are commonly consumed. However, pH measurements outside the 6.5-8.5 range might influence public health indirectly if they resulted from the leaching of metals into the water from the rainwater conveyance and harvesting system.

Table 43 shows the results from analysis of TPH levels in rainwater samples from Ogoniland. The presence of hydrocarbons was noted in six of the 46 samples. The Nigerian drinking water standard for hydrocarbons is 3 µg/l. These TPH concentrations detected may have come from chemicals scoured from the atmosphere by rainfall or from rainwater catchment systems and harvesting vessels. However, as the community use the water from harvesting vessels, the observed concentrations represent the actual risk to the community. Only three rainwater samples were collected directly from the atmosphere by the UNEP team; none had detectable concentrations of TPH. Because rainwater samples were collected from the area where concern had been expressed about its quality, these findings are encouraging, particularly given that questionnaire respondents reported use of rainwater for drinking, as well as for bathing and washing.

Two further observations regarding hydrocarbons in rainwater are worth noting:

- The observed hydrocarbons may have come from a non-SPDC source in Ogoniland (such as the refinery) or a non-Ogoniland source (such as flares from neighbouring LGAs)
- The presence of TPH in rainwater is highest during local incidents of fire. While such incidents are not uncommon in Ogoniland, no fires occurred during UNEP's assessment

While contamination of rainwater by hydrocarbons appears not to be serious across Ogoniland, given the prevalence of the use of rainwater for drinking and the possibility of increased pollution during localized fires, the community should be assisted in creating a safer approach to rainwater harvesting in order to prevent hydrocarbon and non-hydrocarbon contamination.

Drinking water from wells

Two types of well are constructed in Ogoniland: dug-out wells (i.e. wells dug by hand) and bore-wells (i.e. boreholes). Anecdotal information suggested that dug-out wells are shallow and typically less than 10 metres in depth, while bore-wells may reach a depth of 50 metres. However, all such wells essentially exploit the same aquifer. Drinking water wells were sampled by both the Public Health (PH) Team and the Contaminated Land (CL) Team.

A summary of hydrocarbon contamination in the wells is presented in Table 44. In every case, TPH values exceed the Nigerian standard for drinking water of 3 µg/l.

In addition, some of these samples exhibited strong petroleum odours, again in violation of the national standard, which requires drinking water odour to be "unobjectionable" [37]. The respective communities were aware of both the pollution and the inherent dangers but explained that they continue to use the water for bathing, washing and cooking because they have no alternative.

One important point must be noted here. The drinking water survey was neither a comprehensive survey analysing every drinking water well in Ogoniland, nor a sample survey in which the locations of the wells were selected in a systematic manner to reflect overall drinking water contamination in Ogoniland. Rather, the values given above are an indication that in many locations petroleum hydrocarbon has migrated to the groundwater. In practice, it is likely that every well within the vicinity of a contaminated well is either already contaminated or at risk of becoming contaminated.

Table 44. Summary of community wells where TPH values were detected

Samples by	Sample ID number	LGA	Well type	TPH (ug/l)
CL	001-005-MED-101	Eleme	water: bore-well (community)	19,900
CL	001-005-BH-02	Eleme	water: bore-well (community)	4,280
CL	001-005-BH-04	Eleme	water: bore-well (community)	317
CL	001-005-GW-104	Eleme	water: hand-dug well (community)	20,300
CL	001-009-HW-01	Eleme	water: hand-dug well (community)	12
CL	019-014-GW-100	Gokana	water: hand-dug well (community)	63
CL	019-014-GW-102	Gokana	water: hand-dug well (community)	11,500
CL	019-035-HW-104	Gokana	water: hand-dug well (community)	12
CL	019-035-HW-12	Gokana	water: hand-dug well (community)	21
CL	019-020-HW-15	Gokana	water: hand-dug well (community)	4,240
CL	019-007-HW-101	Gokana	water: hand-dug well (community)	15
CL	008-002-HW-01	Tai	water: hand-dug well (community)	14
CL	008-002-HW-03	Tai	water: hand-dug well (community)	12
CL	008-002-HW-04	Tai	water: hand-dug well (community)	12
CL	008-002-HW-11	Tai	water: hand-dug well (community)	11
CL	008-002-HW-12	Tai	water: hand-dug well (community)	11
CL	008-002-HW-13	Tai	water: hand-dug well (community)	13
CL	005-009-HW-04	Tai	water: hand-dug well (community)	53
PH	001-005-HW-100	Eleme	water: hand-dug well (community)	39.3
PH	001-005-BH-103	Eleme	water: bore-well (community)	1320
PH	001-005-BH-104	Eleme	water: bore-well (community)	233
PH	001-005-BW-100	Eleme	water: bore-well (community)	42,200
PH	001-005-BH-102	Eleme	water: bore-well (community)	20,200
PH	004-006-BH-105	Eleme	water: bore-well (community)	299
PH	001-002-BH-102	Eleme	water: bore-well (community)	642
PH	009-003-HW-101	Tai	water: hand-dug well (community)	54.7
PH	009-003-HW-102	Tai	water: hand-dug well (community)	154
PH	008-002-HW-100	Tai	water: hand-dug well (community)	59.4

Case study 9 Groundwater pollution at Nsisioken Ogale, Eleme LGA

While groundwater in Ogoniland is contaminated in a number of areas and some community wells have been impacted, the most serious contamination was observed in Nsisioken-Ogale, in Eleme LGA. The site in question lies adjacent to an abandoned NNPC pipeline operated by PPMC. It was anecdotal information provided by the local community about hydrocarbon odour in water drawn from wells at this location that caused UNEP to investigate.

Close inspection revealed a section of pipeline from which a substantial quantity of refined oil must have leaked to the ground. Although the spill was reported to be over six years old and the pipeline itself was abandoned in 2008, UNEP located 8 cm of floating pure product on the groundwater surface at the point of contamination.

The results of sampling by UNEP of a number of dug-out wells and bore-wells in the area are presented in Table 45.

Nigerian drinking water standards do not have a specific provision for benzene (a known carcinogen) but WHO guidelines are 10 µg/l. Water from five of the wells around the NNPC pipeline contained levels higher than the WHO recommendation, four considerably so, meaning that anyone consuming water from these wells will have been exposed to unacceptable levels of the pollutant.

The sampled wells are most probably not the only community wells with high levels of contamination, meaning that there is a high risk to the community of benzene poisoning from water taken from the wells for drinking. It is also important to note that pollution is present in both dug-out wells and bore-wells. While the community believes that drilling deeper wells is the solution – and some families that can afford it are doing just this – the geological profile of the area (see Figure 8 on page 106) clearly indicates that there is only a single aquifer. Drilling deeper wells only serves to increase the rate at which contamination is spread vertically. There is no guarantee therefore that deeper wells mean cleaner water.

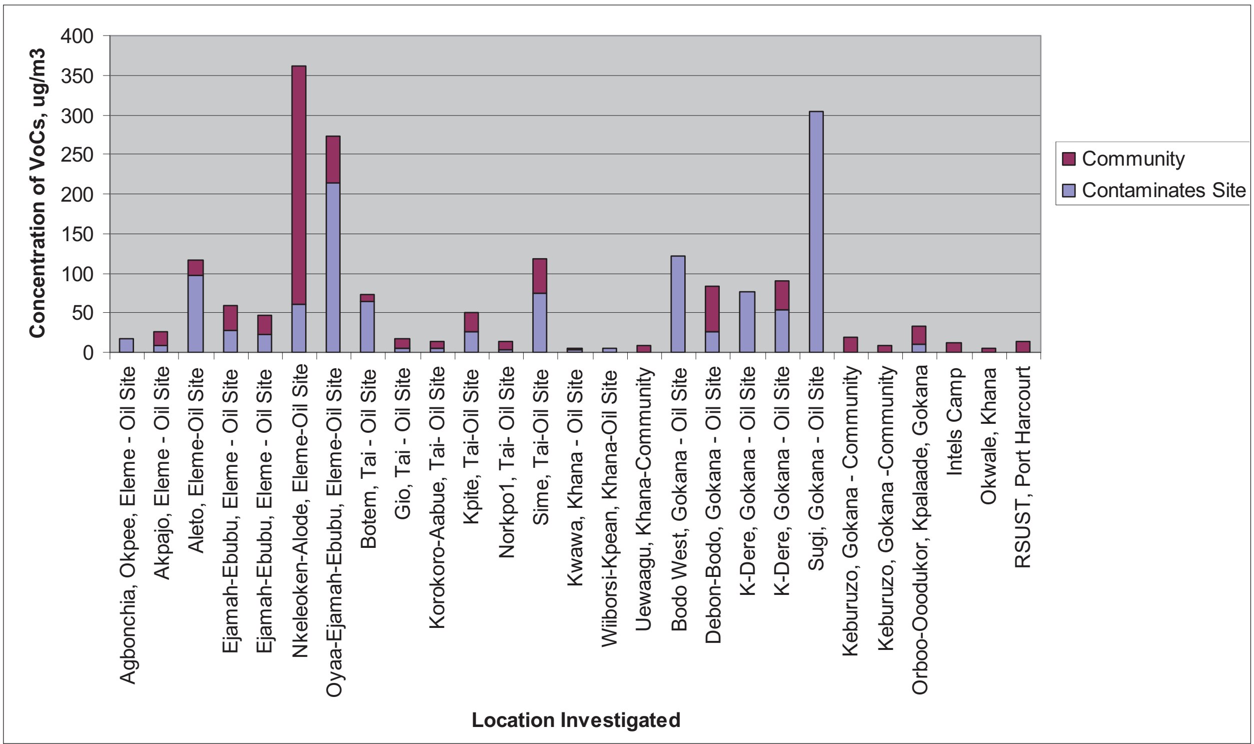
As the situation warranted immediate attention, UNEP communicated this information to the Government of Nigeria in December 2010 once laboratory results had been confirmed, along with the following recommendations:

1. Provide households whose water supply is contaminated by benzene with an alternative source of safe drinking water
2. Delineate the distance over which contamination of groundwater by benzene has spread
3. Remove the contamination from both soil and groundwater
4. Investigate whether there are other locations with signs of benzene contamination along the entire 80-km pipeline from Port Harcourt to Umu Nwa Nwa
5. Undertake follow-up monitoring, including health surveillance of the communities in the affected areas

Table 45. Benzene concentration in contaminated wells in Nsisioken Ogale

Sampled well	Benzene (µg/l)
001-005-BH-102	9,280
001-005-BH-103	161
001-005-BW-100	7,090
001-005-MED-101	8,370
001-005-GW-104	7,140

Figure 21. Sum of VOCs in air in Ogoniland



Outdoor air

Volatile organic compounds. Figure 21 shows the sum of VOC concentrations at locations where air sampling was carried out. Where communities were adjacent to known contaminated sites, sampling results are presented together.

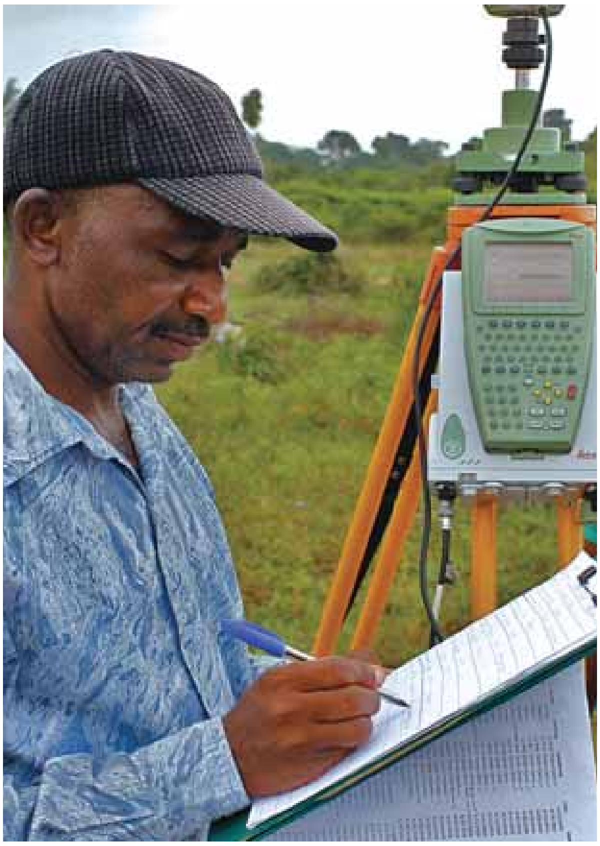
Concentrations of VOCs in air were generally higher near oil spill locations with larger quantities of relatively unweathered product on the ground than at spill locations with weathered or combusted oil. This was to be expected given that these VOCs are among the petroleum hydrocarbons that volatilize and weather most rapidly.

There was no clear pattern as to whether the measured VOCs were higher at the spill site or in the nearby community; the concentration of VOCs in many community samples was similar to or even higher than the corresponding oil spill samples. However, this generally occurred at spill sites with either weathered product or only a small amount of product on the ground surface.

At many sampling sites the community samples were very close, sometimes immediately adjacent to spill sites and, arguably, did not necessarily represent a different location. Community samples were also likely to reflect more non-oil spill sources of petroleum (e.g. vehicle exhaust; fuel sold on the side of the road; presence of petroleum transport vehicles, as at Nkeleoken-Alode, Eleme, where the community sample was far higher than the spill site sample). Moreover, concentrations detected below approximately 2 $\mu g/m^3$ are close to laboratory detection limits and must therefore be viewed with greater uncertainty than higher detected concentrations. These factors made it difficult to accurately apportion the VOCs detected in the atmosphere to specific oil spills and other petroleum sources. However, the air concentrations did indicate some influence of oil spills on air quality.

Figure 21 also shows air concentrations in the Okwale reference community and in two urban reference samples in Port Harcourt. Concentrations of VOCs were generally low in these samples and similar to oil spill locations with limited and/or weathered oil contamination on the ground surface.

Significance of benzene concentrations. While the survey measured concentrations of individual VOCs at sampling locations across Ogoniland,



Member of the UNEP project team monitoring air quality

only benzene values are reported here (Figure 22). This is because benzene is a known carcinogen and was detected in both soil and groundwater investigations in Ogoniland.

WHO has developed indoor air quality guidelines for benzene [37]. It notes that toxicity from inhaled benzene and other indoor air contaminants "would be the same whether the exposure were indoors or outdoors. Thus there is no reason that the guidelines for indoor air should differ from ambient air guidelines".

Benzene was detected in all samples at concentrations ranging from 0.155 to 48.2 μg/m^3. WHO concluded that no safe concentration of benzene in air can be recommended because it is a genotoxic carcinogen. Instead, WHO – and USEPA – have reported concentrations of benzene in air that correspond to different levels of excess lifetime cancer risk (Table 46).

Note that USEPA's estimates are ranges, acknowledging the uncertainty involved in estimating these concentrations. Approximately 10 per cent of detected benzene concentrations in

Figure 22. Benzene concentrations across Ogoniland

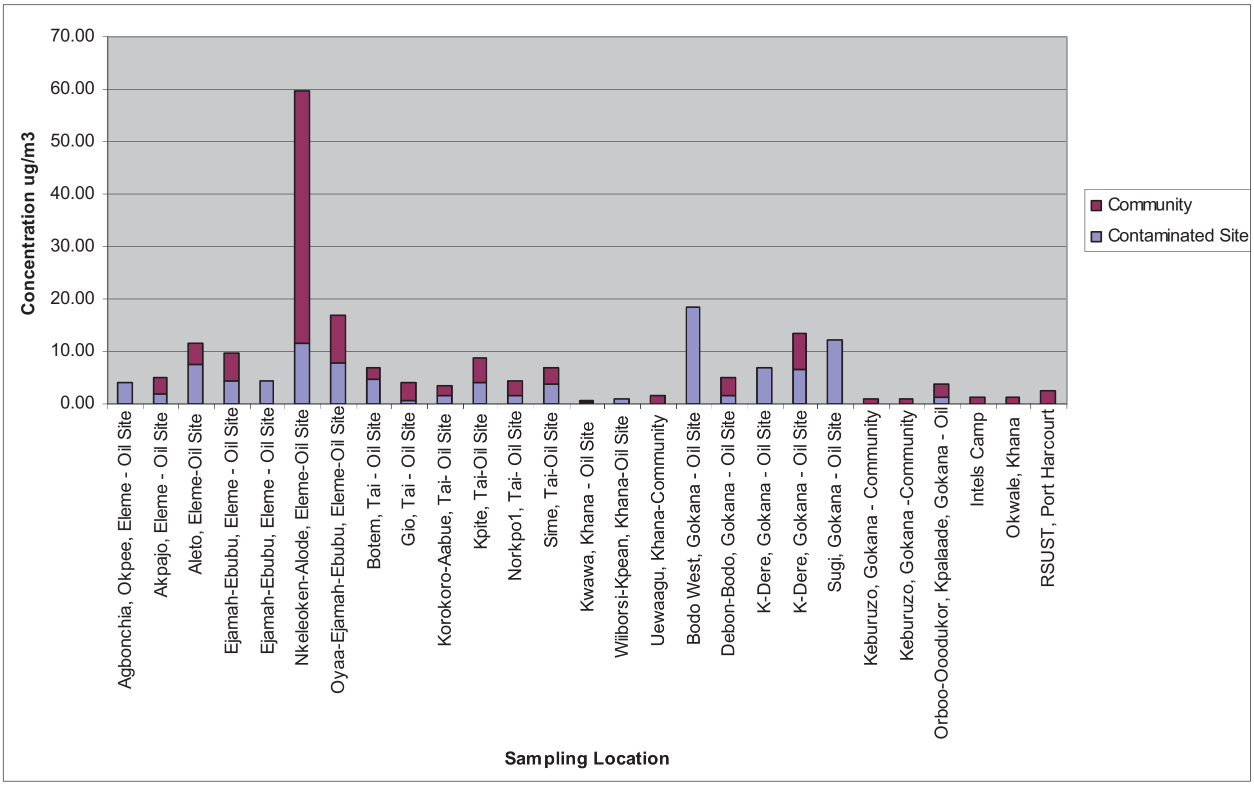


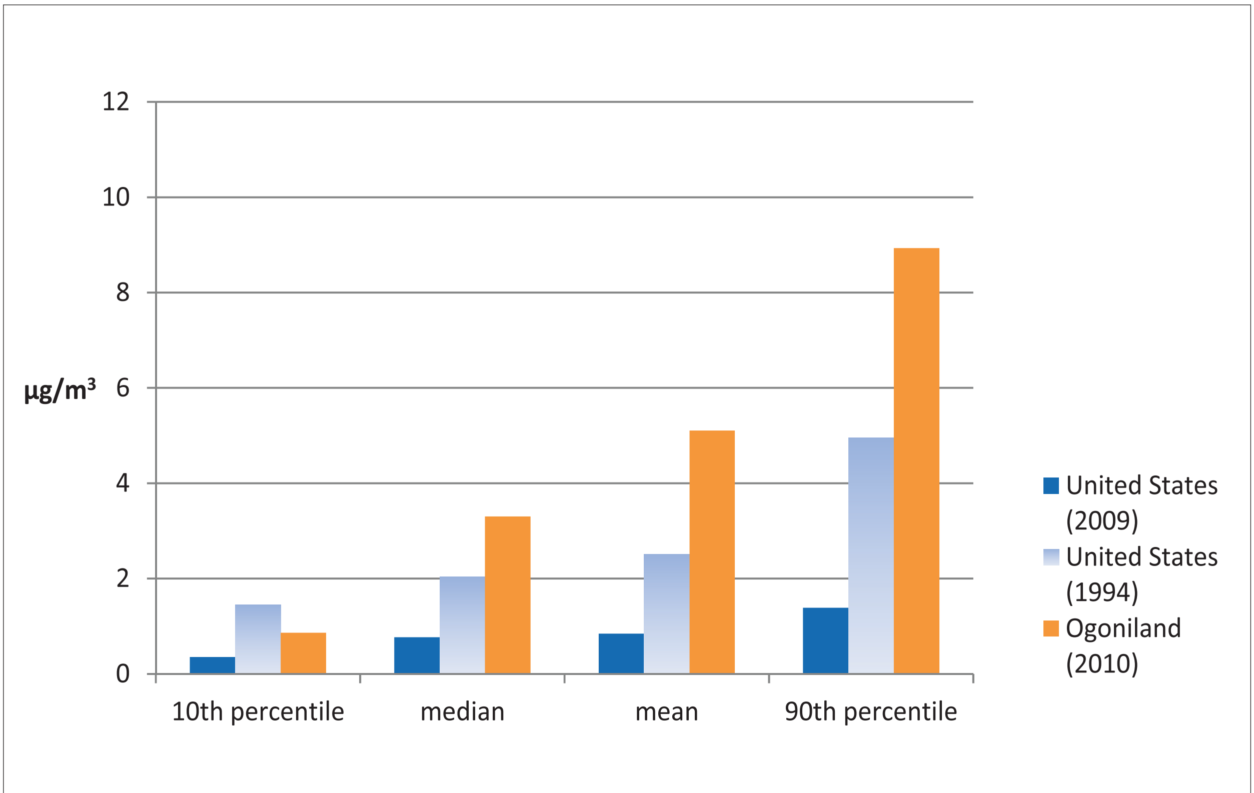
Table 46. Concentrations of benzene in air that correspond to different levels of excess lifetime cancer risk, reported by WHO and USEPA

Excess lifetime cancer risk	Corresponding concentration of benzene in air (µg/m³)	
	WHO (2010)	USEPA (2011)
1 in 10,000	17	13 to 45
1 in 100,000	1.7	1.3 to 4.5
1 in 1,000,000	0.17	0.13 to 0.45

Ogoniland were higher than the concentrations WHO and USEPA report as corresponding to a 1 in 10,000 cancer risk, and nearly all were higher than the concentrations corresponding to a 1 in 1,000,000 cancer risk. However, it is important to recognize that many of the benzene concentrations detected in Ogoniland were similar to those measured elsewhere in the world, given the prevalence of fuel use and other sources of benzene. Nevertheless, Figure 23 clearly shows that some benzene concentrations in Ogoniland were higher than those being measured in more economically developed regions, such as the US, where benzene concentrations are declining because of efforts to reduce benzene exposure.

Exposure to multiple petroleum hydrocarbons in air. The chemical-by-chemical comparison to guidelines represents only a partial evaluation of risk to human health. It is possible that these chemicals, acting in combination, can cause adverse effects on human health. In addition, the VOCs included in this study are indicators of petroleum release to the atmosphere, but the concentration data do not provide full quantification of all petroleum hydrocarbons in the air near oil spill sites. Crude oil – and the petroleum products derived from it – contain hundreds to thousands of individual petroleum hydrocarbons. In addition, there are sulphur compounds that also have health impacts. If air samples had been analysed for petroleum fractions and individual PAHs, many would have been detected based on the composition of crude oil. Also, at some sites a distinct petroleum odour was apparent despite individual VOC concentrations being below odour thresholds, suggesting that other petroleum hydrocarbons were evaporating.

Figure 23. Concentration of benzene in outdoor air in Ogoniland and in urban areas of the United States



Respirable particulate matter. Exposure to respirable particulates has been linked to significant health problems, such as aggravated asthma and premature death in people with heart and lung disease. While not a consequence of oil spills as such, these particles can be generated when oil burns.

In establishing its guidelines for respirable particulate matter [58], WHO endeavoured to set the lowest concentration possible given uncertainty about threshold concentrations below which adverse health effects are not expected.

$PM_{2.5}$ and PM_{10} correspond to particle size fractions that include particles with an aerodynamic diameter smaller than 2.5 µm and 10 µm respectively. Figures 24a and 24b compare the approximately one-hour average $PM_{2.5}$ and PM_{10} concentrations measured in Ogoniland with the WHO 24-hour average guidelines. It is important to note the difference in averaging periods; if Ogoniland measurements continued for 24 hours, the comparison might differ from that shown in these figures. However, sampling for this length of time was not possible given logistical and security constraints at the

Figure 24a. One-hour mean concentration of particulate matter (PM2.5) in Ogoniland

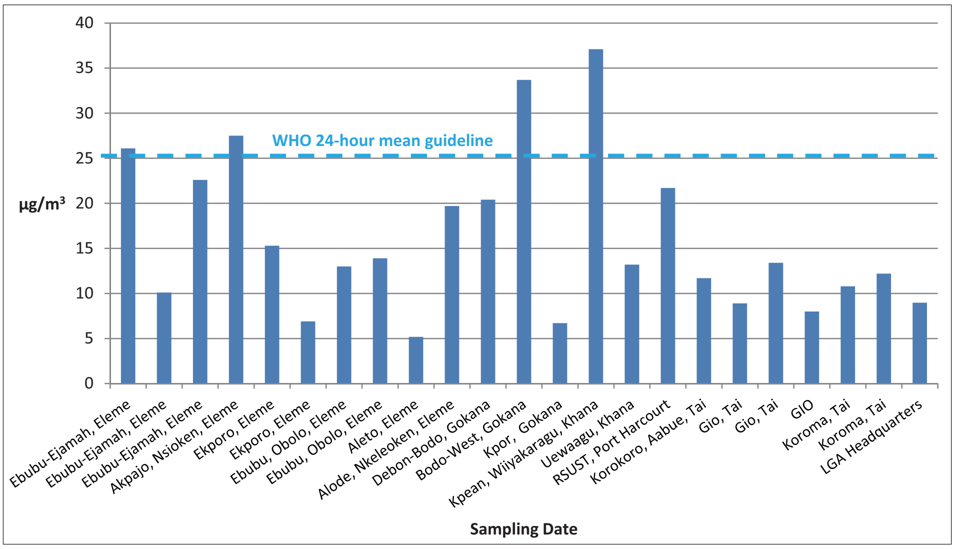
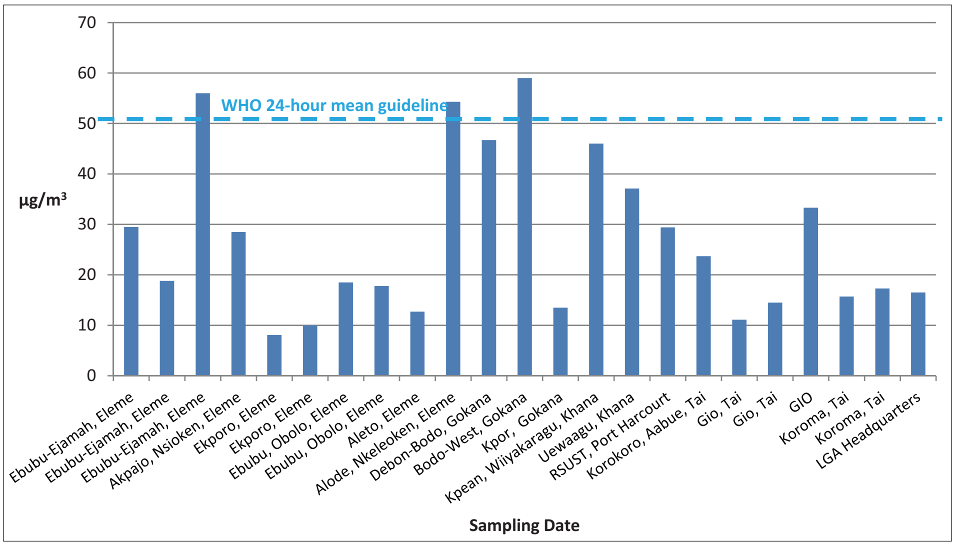


Figure 24b. One-hour concentration of particulate matter (PM10) in Ogoniland



locations visited. Nevertheless, the comparison indicates that few locations exceeded the WHO guideline, and PM concentrations in general were in the range of those measured elsewhere in the world, including both developed and developing regions [59].

Concentrations of particulate matter in Ogoniland

Use of solid fuels such as wood for indoor cooking increases the concentration of PM in indoor environments and, consequently, the risk of acute respiratory effects and even mortality among adults and children. In responses to the exposure and health questionnaire, discussed in more detail below, many respondents reported using wood to cook food indoors. While UNEP did not measure PM concentrations in any indoor environments, it is reasonable to suggest that PM concentrations might exceed the WHO 24-hour average guidelines. Future studies could be carried out to confirm this suspicion. However, even without additional study, it is clear that use of solid fuel for indoor cooking should be discouraged to protect public health.

Medical records. Approximately 5,000 individual medical records were collected from primary health-centres in four affected communities and one reference community. The information was entered into a database and analysed. Nigerian colleagues from RSUST provided extensive support in both collecting records and the interpretation of information that required local knowledge. Before analysing the data, database entries were checked by double-entering a subset of records to ensure accuracy of data entry. This step was especially important given the challenge of interpreting handwritten records that were often very difficult to read and sometimes illegible.

The Public Health Team developed a system for categorizing individual reported symptoms in consultation with a primary care physician. Figures 25a to 25e show the most frequently reported symptom categories at each centre, segregated by age group. The types of symptoms reported at each primary health-care centre are generally consistent with other recent health studies in Nigeria that include Ogoniland [34, 60, 61, 62, 63]. However, quantitative comparisons could not be made because insufficient information was available to ensure comparability of the data sets.

Members of UNEP's project team during a community visit

Figure 25a. Frequency of health symptoms in Ogoniland

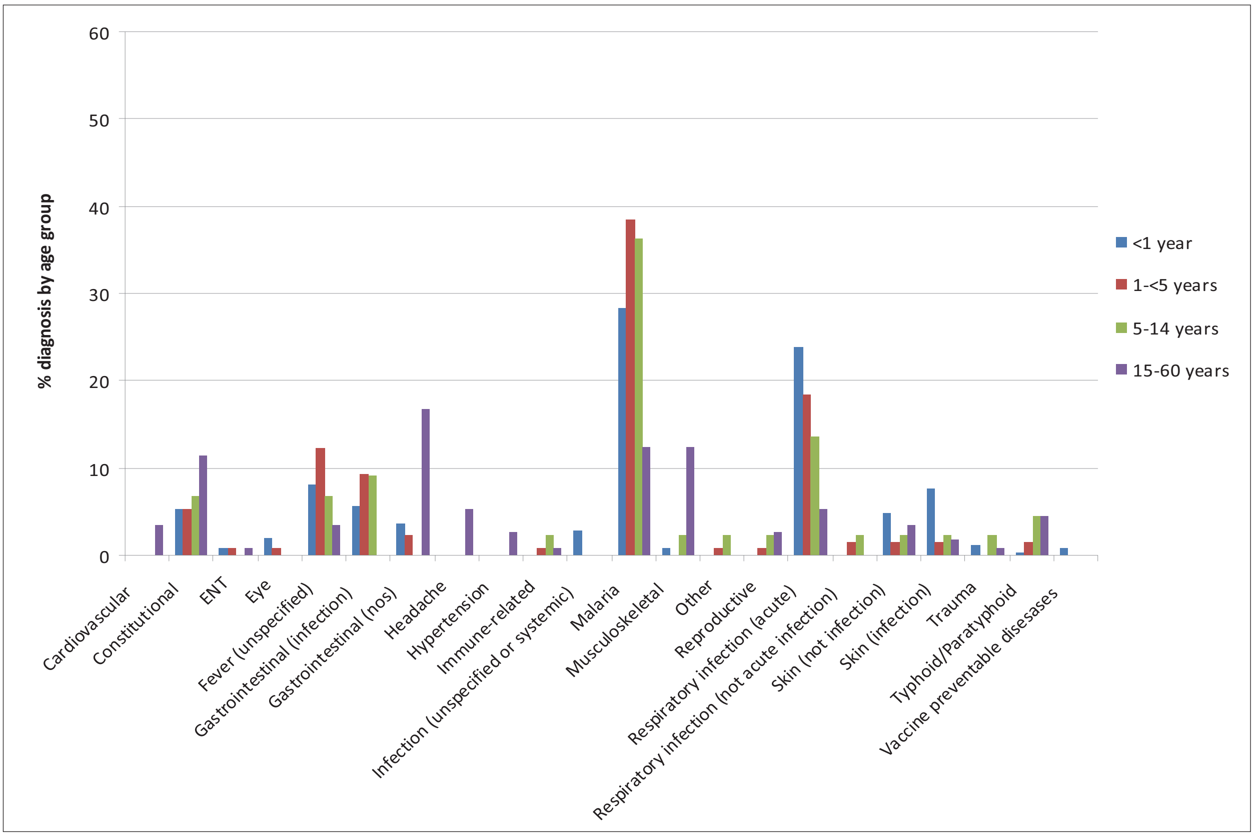


Figure 25b. Frequency of health symptoms in Ogoniland

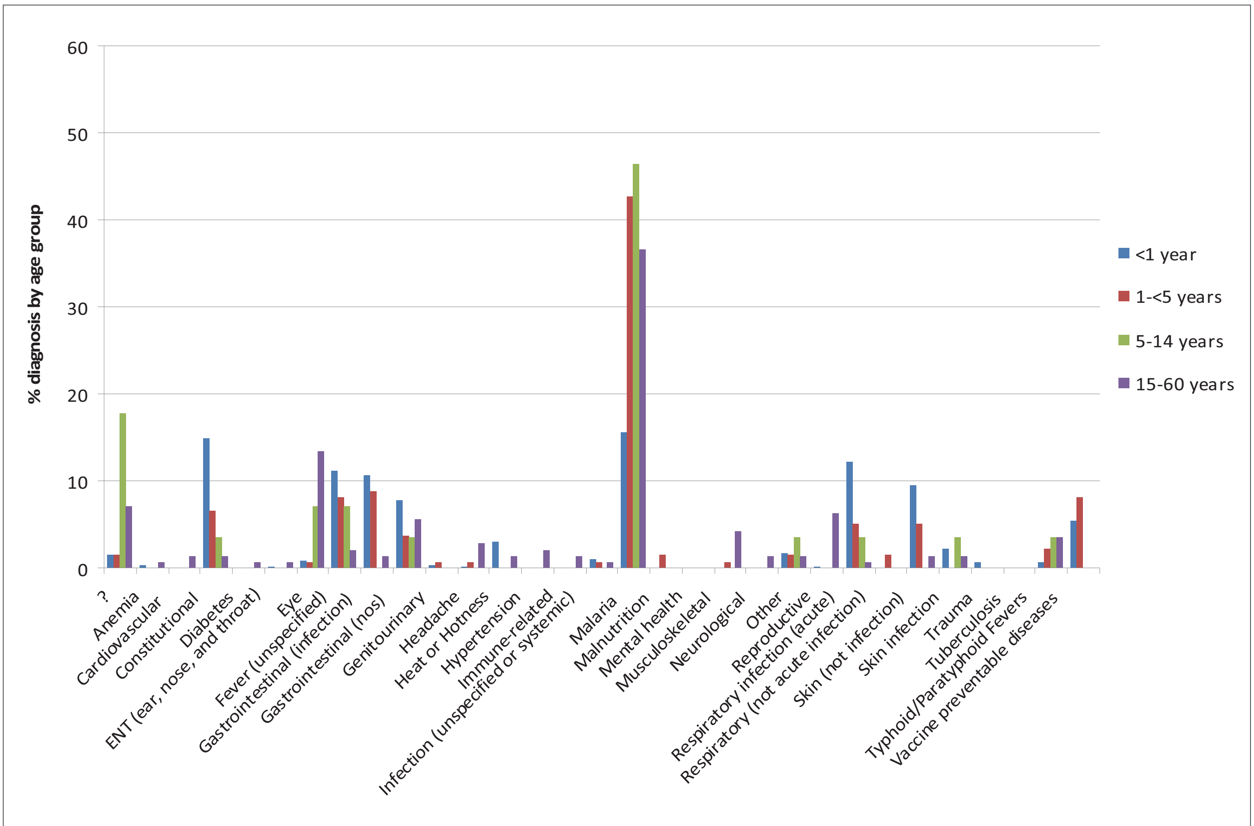


Figure 25c. Frequency of health symptoms in Ogoniland

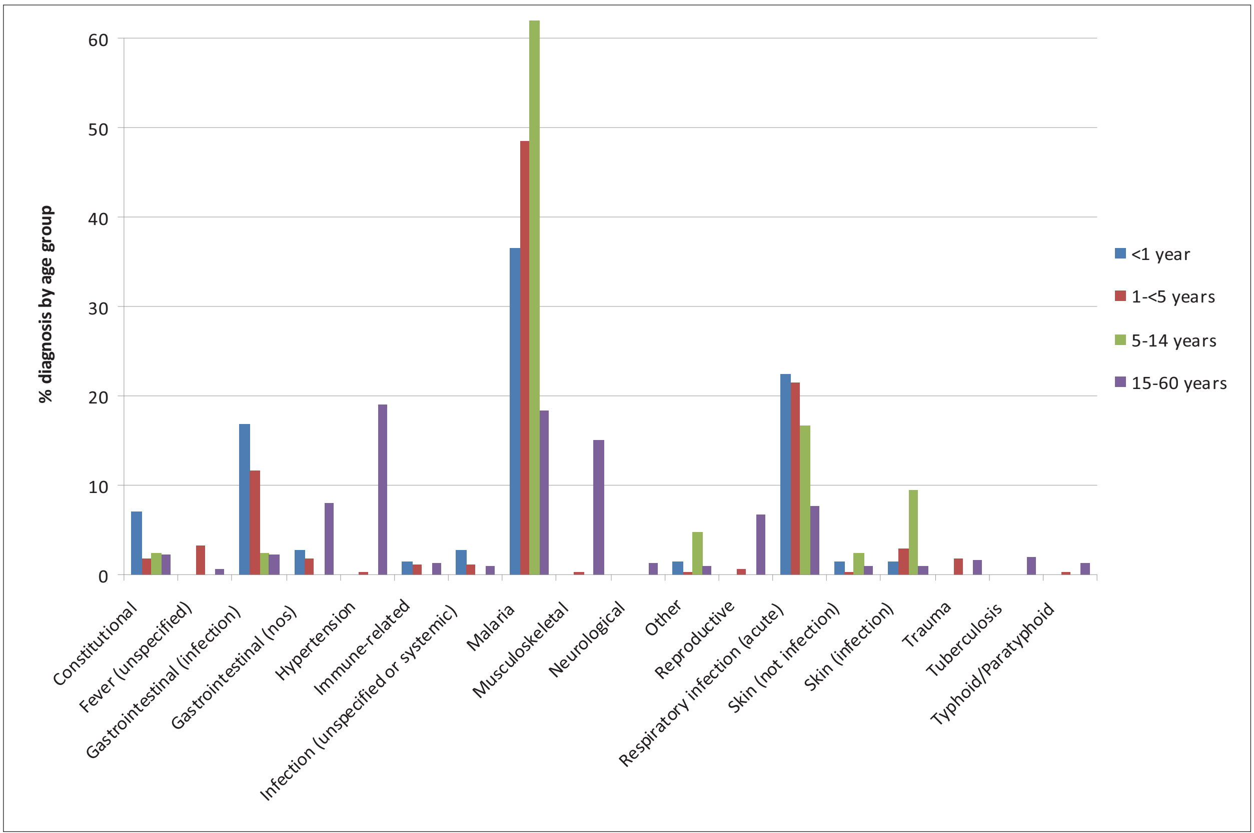


Figure 25d. Frequency of health symptoms in Ogoniland

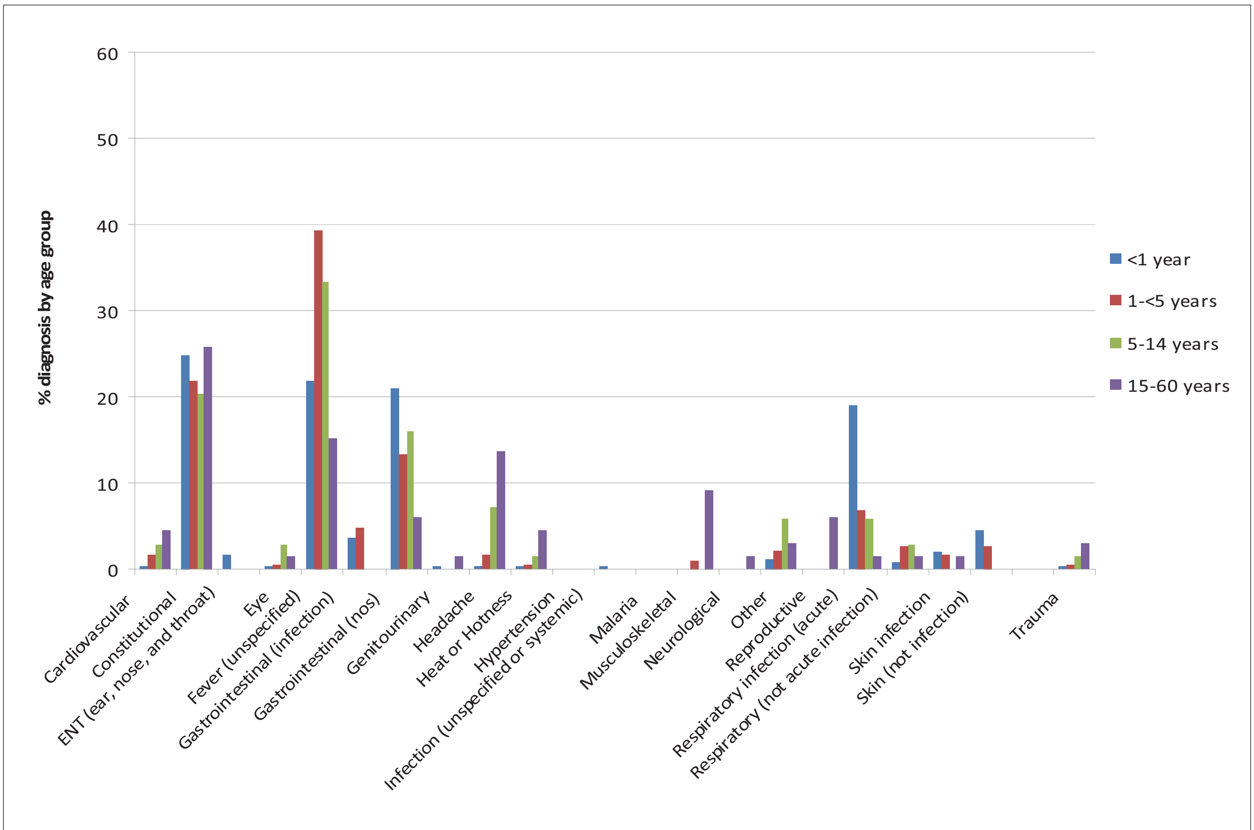
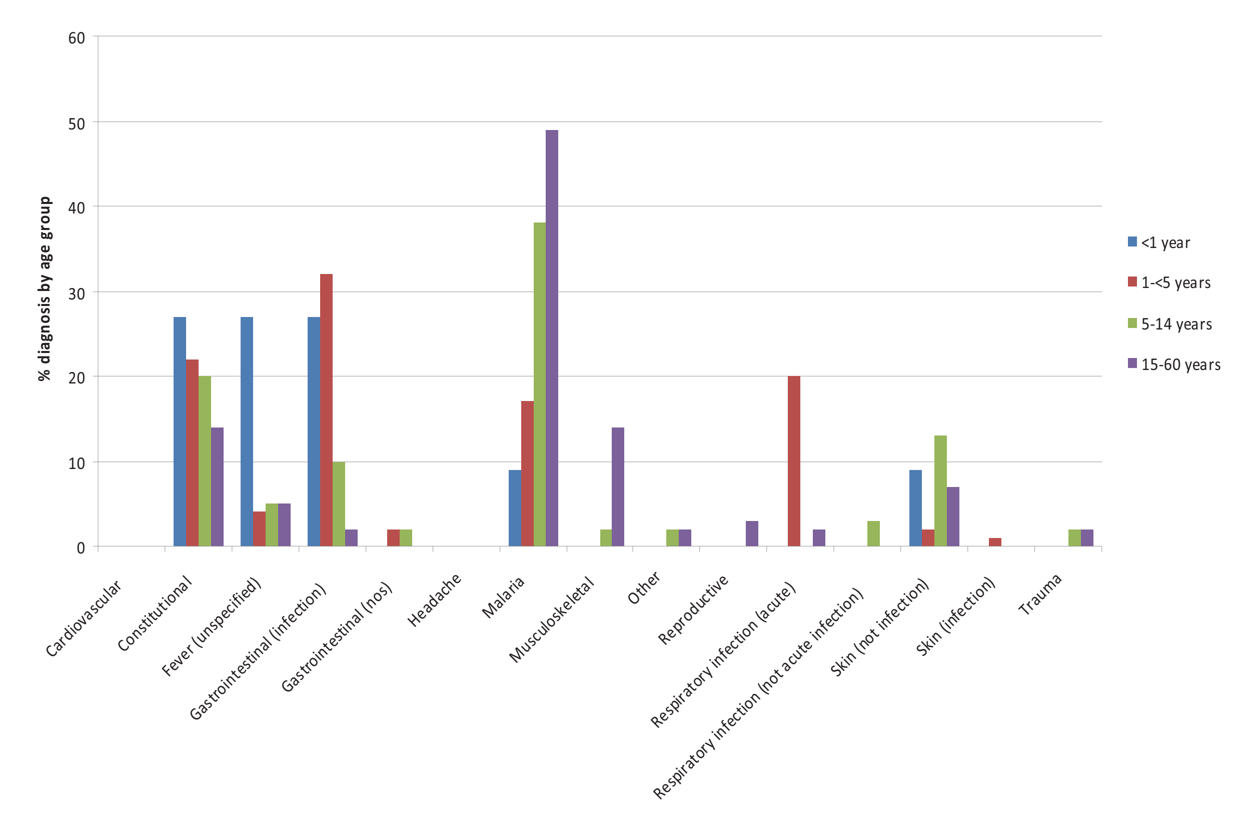


Figure 25e. Frequency of health symptoms in the reference primary health-care centre in Okwale



The frequencies of symptoms recorded at each of the four primary health-care centres serving communities affected by large oil spills were compared with frequencies reported at the reference primary health-care centre in Okwale, using the Cochran-Mantel-Haenszel test for repeated tests of independence. Table 47 shows the results of these comparisons in the form of odds ratios. An odds ratio significantly greater than one suggests that the frequency of symptoms reported at two primary health-care centres differs. The values in parentheses following each odds ratio value are its confidence intervals. No significant differences are apparent among primary health-care centres with odds ratios mostly lower than one, except possibly for the 'GI (not infection)' symptom category. It is possible that this category is related to petroleum exposure but no definitive conclusion is possible given the non-specific nature of symptoms in this category.

The proportion of malaria cases varied considerably among the communities. This variation is likely an artifact of multiple factors. For example, some individuals in the region might refer to malaria as "fever" and report it as such, while others report "malaria" or "plasmodiasis." However, reports of "fever" were not combined with reports of "malaria," and this approach might have underestimated the proportion of malaria where medical staff members are more likely to report suspected malaria as "fever." This issue with variable malaria proportions highlights an important limitation of the medical record review: all "diagnoses" are subject to considerable uncertainty given the variability in reporting practices among primary health care centres and the fact that medical testing is not conducted to confirm diagnoses. The lack of confirmed diagnoses and relatively small sample sizes generally limit UNEP's ability to reach firm conclusions from the medical record data. Also, single individuals sometimes appear multiple times in the database, sometimes with different symptoms and sometimes with the same symptoms. Additional analyses of these data could be performed in the future to check the influence of multiple entries for single individuals.

Table 47. Cochran-Mantel-Haenszel Chi-square statistics comparing major symptoms reported at four primary health-care centres and one reference health-care centre

	Constitutional	Fever/malaria	GI (infection)	GI (not infection)	GI (total)	Respiratory infection (acute)	Skin (not infection)
Okwale (reference)	N = 36	N = 102	N = 44	N = 5	N = 49	N = 84	N = 17
Agbonchia	N = 35 X2 = 8.26 P = 0.004 Df = 1 OR = 0.49 (0.30, 0.80)	N = 189 X2 = 0.02 P = 0.8819 Df = 1 OR = 0.98 (0.72, 1.32)	N = 30 X2 = 16.93 P = < 0.0001 Df = 1 OR = 0.37 (0.23, 0.60)	N = 30 X2 = 8.52 P = 0.0035 Df = 1 OR = 3.80 (1.46, 9.90)	N = 60 X2 = 3.05 P = 0.0809 Df = 1 OR = 0.70 (0.46, 1.45)	N = 24 X2 = 99.39 P = <0.0001 Df = 1 OR = 0.11 (0.07, 0.19)	N = 27 X2 = 0.004 P = 0.95 Df = 1 OR = 1.02 (0.55, 1.90)
K'Dere	N = 128 X2 = 0.51 P = 0.48 Df = 1 OR = 0.87 (0.58, 1.29)	N = 360 X2 = 2.11 P = 0.15 Df = 1 OR = 0.82 (0.62, 1.07)	N = 95 X2 = 13.46 P = 0.0002 Df = 1 OR = 0.49 (0.34, 0.72)	N = 78 X2 = 10.72 P = 0.001 Df = 1 OR = 4.10 (1.65, 10.23)	N = 173 X2 = 0.8079 P = 0.3688 Df = 1 OR = 0.85 (0.60, 1.21)	N = 101 X2 = 87.12 P = <0.0001 Df = 1 OR = 0.23 (0.17, 0.32)	N = 81 X2 = 0.83 P = 0.36 Df = 1 OR = 1.28 (0.75, 2.20)
Kpite	N = 18 X2 = 39.61 P = <0.0001 Df = 1 OR = 0.18 (0.10, 0.33)	N = 242 X2 = 0.14 P = 0.71 Df = 1 OR = 0.95 (0.71, 1.26)	N = 52 X2 = 14.80 P = 0.0001 Df = 1 OR = 0.44 (0.29, 0.68)	N = 32 X2 = 4.44 P = 0.04 Df = 1 OR = 2.68 (1.03, 6.95)	N = 84 X2 = 4.69 P = 0.03 Df = 1 OR = 0.66 (0.45, 0.96)	N = 106 X2 = 26.79 P = <0.0001 Df = 1 OR = 0.43 (0.31, 0.60)	N = 6 X2 = 21.15 P = <0.0001 Df = 1 OR = 0.15 (0.06, 0.38)
Kwawa	N = 229 X2 = 18.01 P = <0.0001 Df = 1 OR = 2.24 (1.53, 3.28)	N = 180 X2 = 33.79 P = <0.0001 Df = 1 OR = 0.43 (0.32, 0.57)	N = 22 X2 = 17.28 P = <0.0001 Df = 1 OR = 0.23 (0.11, 0.49)	N = 138 X2 = 35.65 P = <0.0001 Df = 1 OR = 9.69 (3.93, 23.89)	N = 160 X2 = 0.0017 P = 0.9674 Df = 1 OR = 0.99 (0.70, 1.41)	N = 59 X2 = 113.54 P = <0.0001 Df = 1 OR = 0.16 (0.11, 0.23)	N = 14 X2 = 15.71 P = <0.0001 Df = 1 OR = 0.26 (0.13, 0.53)

* 'Cardiovascular/hypertension' and 'respiratory (not infection)' were excluded due to too few cases (n <5) in the Okwale reference centre

When interpreting medical records from primary health-care centres, it is important to recognize that these data are representative for only a fraction of the population because many people consult local pharmacists, traditional healers, private clinics and general hospitals for medical care. This reality is evident from the responses to the exposure and health questionnaire. In fact, most people living in the reference community of Okwale reported that they go to local pharmacists for health care. Moreover, primary health-care centre records do not provide confirmed diagnoses. Many effects associated with exposure to petroleum are non-specific, making them difficult to discern even with perfect medical records. Nevertheless, a review of primary health-care centre records is a reasonable first step in examining associations between oil exposures and health effects. Future studies should focus on specific exposed communities and follow them over time, with careful documentation of exposures and health effects, to improve the chance of confirming any adverse effects that might be occurring.

The public health studies undertaken in Ogoniland have led to the following conclusions, based on the information gathered by the Public Health Team as well as other segments of the UNEP study:

- People are exposed to petroleum hydrocarbons, sometimes at very elevated concentrations, in outdoor air and drinking water. They are also exposed through dermal contacts from soil, sediments and surface water

- It is possible that human health has been adversely affected by exposure to hydrocarbons through multiple routes. The situation could be particularly acute where high levels of benzene were detected in drinking water

- The medical records available do not provide the detail required to link symptoms with petroleum specifically. In fact, many of the non-specific symptoms resulting from petroleum exposure are likely to be treated by pharmacists who keep no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A villager standing in contaminated water. The Ogoni people are exposed to petroleum hydrocarbons through dermal contacts from soil, sediments and surface water patient records. This situation is not unlike that encountered when conducting similar studies in more developed countries. One solution is to improve medical record-keeping protocols; however, there can be significant institutional and resource constraints to implementing such changes. A more promising alternative is to conduct a prospective epidemiological study with a carefully selected cohort, where exposures and effects can be documented over time

- From an epidemiological analysis point of view, this study should be seen as a preliminary investigation. Information from this study could be used to design exposure monitoring and medical record-keeping protocols such that future studies have more power to detect effects of petroleum exposure on human health

Specific recommendations concerning public health are given in Chapter 6.3.

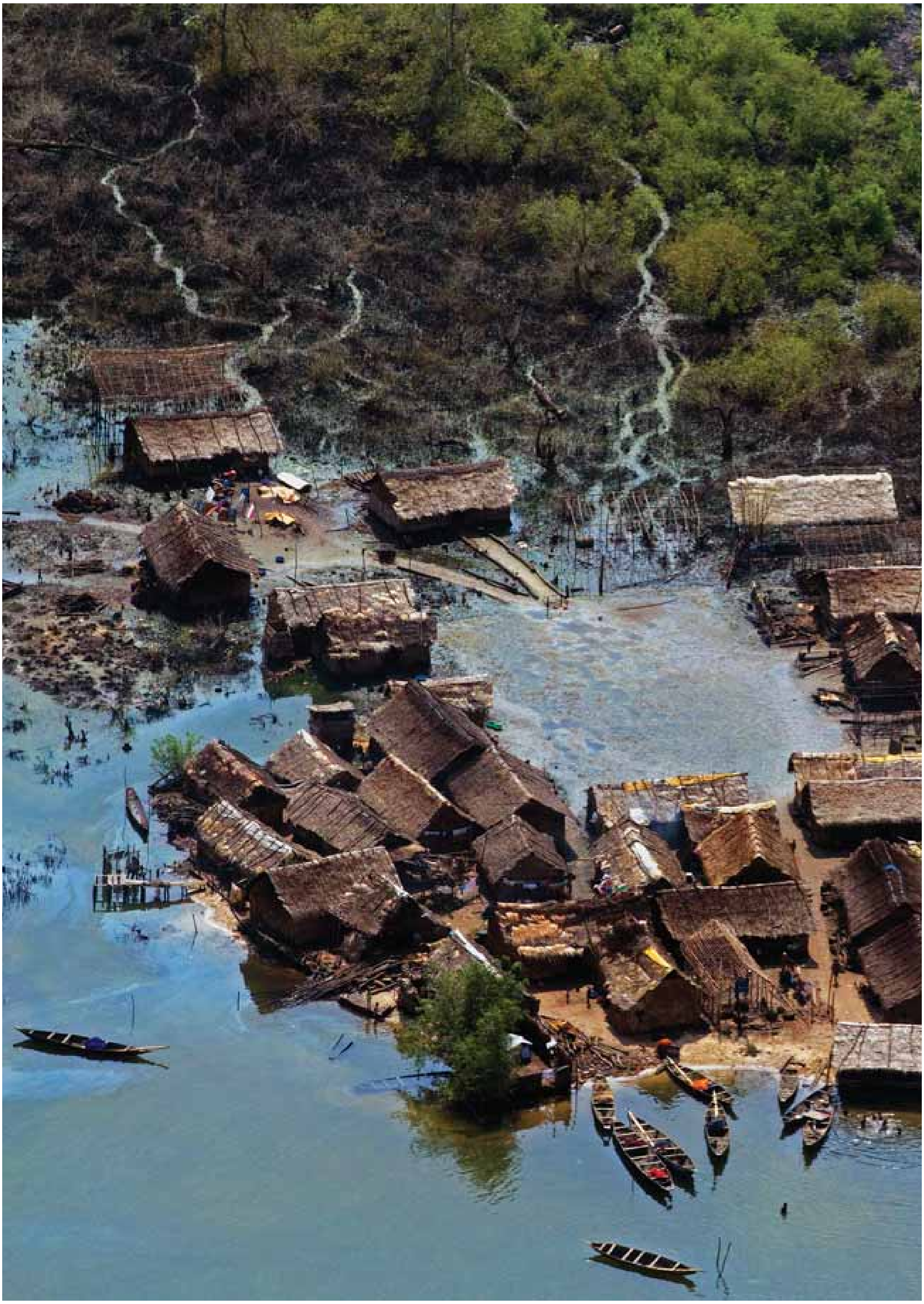
Ogoniland is not an island

The geographical scope of the UNEP study was limited to Ogoniland and the surrounding creeks. However, contamination entering creeks can travel downstream and have adverse effects on communities outside Ogoniland. Nothing demonstrates this fact better than the village of Andoni (map 25), a small community of fewer than 50 houses whose inhabitants mainly make their living from fishing. The village is situated on the water's edge and villagers travel by boat to other areas for schooling, health care and other everyday needs.

Aerial photography clearly shows that the water around the village is polluted with an ever-present layer of floating hydrocarbons – a situation also observed on the ground. It is clear that Andoni is seriously impacted by hydrocarbon pollution, and since the village is permanently surrounded by water, its inhabitants are probably even more exposed to oil contaminants than nearby land-based communities.

Andoni may not be alone in suffering the effects of contaminant migration. There may be many more communities upstream and downstream of Ogoniland that are also suffering the consequences of oil spillage.

An Andoni LGA community member (right) assisting during a field trip to creeks in Khana and Andoni LGAs, August 2010



An aerial view of a community encircled by oil pollution (Andoni LGA)

Recommendations

For most members of the current Ogoniland community, chronic oil pollution has been a fact of life
© Mazen Saggar

Recommendations

It is clear from UNEP's field observations and scientific investigations that oil contamination in Ogoniland is widespread and severely impacting many components of the environment. The Ogoni people live with this pollution every minute of every day, 365 days a year. Since average life expectancy in Nigeria is less than 50 years, it is a fair assumption that most members of the current Ogoniland community have lived with chronic oil pollution throughout their lives. Children born in Ogoniland soon sense oil pollution as the odour of hydrocarbons pervades the air day in, day out. Oil continues to spill from periodic pipeline fractures and the illegal practice of artisanal refining, contaminating creeks and soil, staining and killing vegetation and seeping metres deep into ground, polluting water tables. Smoke from artisanal refining is a daily presence and fire close to inhabited areas is a constant threat from pools of oil which gather after a spill due to corrosion or bunkering or where artisanal refining of crude oil takes place.

A multiplicity of technical and non-technical reasons lie behind this tragic situation. UNEP is aware that not all spills in Ogoniland are caused by corrosion of oilfield equipment. Illegal extraction of oil, locally referred to as bunkering, is also a cause of spills and the ensuing environmental damage. It was not within UNEP's scope to indentify the cause of the individual spills, nor is it scientifically possible to detect the original cause of spills after an unknown time period. From an environmental impact perspective, mangroves would be no less damaged by oil spilled from a pipeline leak due to lack of maintenance than from a pipeline tapped for bunkering. Technical solutions for the clean-up of contamination are also not impacted by the original cause of the spill. However, when it comes to finding lasting solutions to improve the environmental situation in Ogoniland, all root causes need to be addressed.

Smoke from artisanal refining is a common sight in Ogoniland

At the technical level, measures have to be taken to clean up the contamination and restore the environment. And at a more strategic level, action is needed to prevent a repeat of this tragedy in Ogoniland. UNEP's recommendations are therefore divided into two parts.

In this chapter we present recommendations that, once implemented, will have an immediate positive impact on Ogoniland. They are not of equal priority. In fact some can only be carried out after others have been fully implemented.

In Chapter 7 we give recommendations that have longer timelines and which, when implemented, are a path to sustainability that will bring lasting improvements for Ogoniland and for Nigeria as a whole.

While the overall environmental situation in Ogoniland needs urgent and focused attention, the assessment has indicated a number of segments where there is an immediate danger to public health.

Emergency Measures

1. Ensure that all drinking water wells where hydrocarbons were detected are marked and that people are informed of the danger
2. Provide adequate sources of drinking water to those households whose drinking water supply is impacted
3. People in Nsisioken Ogale who have been consuming water with benzene over 900 times the WHO guideline are recorded on a medical registry and their health status assessed and followed up
4. Initiate a survey of all drinking water wells around those wells where hydrocarbons were observed and arrange measures (1-3) as appropriate based on the results
5. Post signs around all the sites identified as having contamination exceeding intervention values warning the community not to walk through or engage in any other activities at these sites
6. Post signs in areas where hydrocarbons were observed on surface water warning people not to fish, swim or bathe in these areas
7. Inform all families whose rainwater samples tested positive for hydrocarbons and advise them not to consume the water, and
8. Mount a public awareness campaign to warn the individuals who are undertaking artisanal refining that such activities are damaging their health.

From a duty of care point of view, these need to be acted upon immediately. The following is a list of such emergency measures needed to be initiated.

6.1 Operational recommendations

Before cleaning up the existing oil pollution and restoring the environment, there are a number of other measures which should be taken to achieve both environmental improvement and prevention of further oil spills.

Maintenance of oilfield facilities

SPDC should conduct a comprehensive review of its assets in Ogoniland, including a thorough test of the integrity of current oilfield infrastructure. Following the review, SPDC should develop an 'Asset Integrity Management Plan for Ogoniland' as well as a comprehensive decommissioning plan. For the assets that SPDC would like to retain, the plan should specify risk levels, inspection routines and maintenance schedules. These plans should be communicated to the Ogoni people.

Decommissioning of oilfield facilities

Prior to decommissioning, an environmental due diligence assessment of the plan should be undertaken, to include feedback from the Ogoni people. Based on the decommissioning plan, prepared as part of the asset integrity assessment, SPDC should initiate decommissioning of those facilities that the company will no longer use.

Prevention of illegal activities

A campaign to bring to an end illegal oil-related activities (tapping into oil wells/pipelines, transportation of crude, artisanal refining) should be conducted across Ogoniland. The campaign should be a joint initiative between the Government of Nigeria, the oil companies, Rivers State and local community authorities. The campaign should include an awareness component highlighting the disproportionate environmental footprint (borne by all sections of the community) of artisanal refining in relation to the marginal benefits derived. The campaign could also spell out training, employment and livelihood incentives that will encourage people away from participating in illegal activities.

The products derived from illegal refining can be seen at roadside stalls

Oil spill response

While a National Oil Spill Contingency Plan exists in Ogoniland and NOSDRA has a clear legislative role, the situation on-the-ground indicates that spills are not being dealt with in an adequate or timely manner. In order to ensure that all oil spills, regardless of the cause, are dealt with within the shortest possible time, an Oil Spill Contingency Plan (OSCP) for Ogoniland, covering both land areas and water bodies, should be prepared. The plan should be communicated to the community, with particular emphasis on how any delay in reporting or responding to a spill will have disproportionate environmental consequences.

When an oil spill occurs, adequate resources should then be deployed to put the plan into operation. Practice drills should be carried out periodically to ensure rapid responses to future oil spill incidents. Results of drills and OSCP improvements should be communicated to the Ogoni people in public meetings. Better still, as key stakeholders the communities themselves should take part in drills, with training provided and roles assigned. In this way the communities will come to understand the response process and learn to work with the oil response agencies and vice versa, instead of using the spill site as an 'environmental hostage'.

Ongoing remediation of contaminated sites

The current approach by SPDC to clean-up contaminated sites through remediation by enhanced natural attenuation (RENA) should be discontinued. Even SPDC's revised Remediation Management System does not address the issues observed in UNEP's assessment.

Instead, procedures should be put in place for any new spills to be assessed within the shortest possible time and heavily contaminated soil excavated and sent to the centralized facility (see under 'Technical recommendations', below) for treatment and disposal. The final clean-up standards and ongoing monitoring plans should be discussed and agreed with the relevant government agencies.

6.2 Technical recommendations for environmental restoration

Environmental degradation in Ogoniland impacts soil, water and biota. Achieving environmental restoration demands more than simple technological intervention. Sustainable recovery will only be possible when technological interventions for clean up of contaminated land and water bodies is backed up by practical action at the regulatory, operational and monitoring levels [9]. Specific recommendations in each of these areas are given below.

Prior to discussing clean-up options, one issue needs to be clarified. It is often stated that unless ongoing pollution is stopped, any clean-up undertaken is futile. However, this statement is only partially valid. In the case of land contamination, the locations of pollution sources and the extent of contamination emanating from them are relatively clearly defined and can be cleaned up independently from spills in other areas. The potential for future spillages, either from operational accidents or illegal activities, should not preclude the decision to initiate clean-up action where the source and extent of contamination are known.

The situation concerning pollution of water bodies is somewhat different because the physical extent of pollution is much less clearly defined or limited than in the case of land-based pollution. So long as any inflow of oil into any part of the creeks is continuing, all interconnected creeks are in danger of contamination. Therefore, clean-up activities of the mangroves and soil should not be initiated before all possible measures are taken to stop ongoing pollution from reaching the creeks. However, in the case of creeks which do not flush naturally, the floating hydrocarbon should be removed.

Clean-up of contaminated soil and sediments

Pollution of soil by petroleum hydrocarbons is widespread in Ogoniland – in land areas, in sediments and in swampland – and has occurred both in recent times and over a period of decades. Most of the contamination is from crude oil, though contamination by refined products was found at three locations. The decision to clean up individual sites has to be done based on detailed site-by-site risk assessments which must include consultation with the community and regulators.

The immediate removal of existing floating hydrocarbon from creeks, and on an ongoing basis thereafter, will help to minimize further contamination downstream

Owing to the diverse nature of hydrocarbon pollution, solutions for clean-up will require a combination of approaches. A detailed review of the available technologies is presented in Table 48. The following sections describe the operational philosophy of contaminated soil management.

Establishment of an Integrated Contaminated Soil Management Centre (ICSMC)

The UNEP investigation found oil contaminants exceeding Nigerian intervention values at 42 locations on land and at 10 locations in creeks. In addition, the surface water throughout the creeks contains hydrocarbons. The chemical structure and physical nature of the contamination and the characteristics of the soil all vary according to site. As explained above, site-specific risk assessments will be needed to determine whether clean up will be needed and if yes, what technologies are appropriate. However, based on the observed contamination and risk factors (contamination of pathways and proximity of receptors), it can already be stated with conviction that clean up intervention will be needed at a number of the investigated sites.

It is not feasible, however, either technically or economically, to set up multiple treatment units around Ogoniland for clean-up of contaminated soil. UNEP therefore recommends the establishment of a modern Integrated Contaminated Soil Management Centre in Ogoniland. Such a facility should contain the following technical components:

- **Incinerator.** Using contaminated soil and vegetation as feedstock, this will burn off hydrocarbons from contaminated soil with a high bitumen content. Organic matter (e.g. contaminated shrubs and bushes) will be reduced to ash during this process. Specially suitable for dealing with burnt-out crusts

- **Thermal desorption unit.** Thermal desorption can achieve rapid reduction of hydrocarbons, possibly recover some of the oil and make the treated soil re-usable for backfilling

- **Soil washing unit.** This will be most appropriate for treating contaminated soil with lower fractions of clay particles polluted with light-end hydrocarbons. The cleaned soil may also be used for backfilling excavation trenches

- **Contaminated water treatment unit.** Soil washing will result in large quantities of water being contaminated with hydrocarbons, necessitating the recovery of these hydrocarbons and cleaning of the water prior to discharge into the environment

- **Waste oil treatment centre.** The thermal desorption unit will recover some hydrocarbons but the unit will often be contaminated with other organic and inorganic substances. There will also be waste oil recovered from the contaminated water treatment. The output from these two units will need to be treated in a waste-oil treatment unit in order to recover hydrocarbons, which may be used as fuel in the thermal desorption unit or sold for co-mingling or re-refining with crude oil

- **Containment cells.** Contaminated materials collected in the field (e.g. barium-contaminated soil), as well as materials produced during the treatment process (e.g. incinerated ash), will need to be disposed in properly engineered containment cells

The ICSMC, once established, will be a modern industrial enterprise occupying many hectares of land and employing hundreds of people, offering job opportunities for many in the Ogoni community. The transport of soil, from contaminated sites to the ICSMC and back to the sites after clean-up, alone will require considerable manpower. There will be need for testing and weighbridge facilities and a state-of-the-art management system to document the operations. Once the task of cleaning up Ogoniland is complete, the centre will be able to cater for future spills both inside Ogoniland and in other parts of the Niger Delta. A suitable location for the ICSMC will need to be identified, with construction subject to the results of an integrated environmental and social impact assessment, including community consultations.

Mini treatment centres

In areas where heavy contamination has to be excavated, excavation water will need to be treated before it can be discharged into nearby water courses. In addition, in areas where contamination is below the current EGASPIN intervention values, but above target values or new clean-up targets based on risk assessments, high-technology treatment may not be necessary. In such cases, multiple 'mini treatment centres' for bioremediation of lightly contaminated soil and excavation water are proposed.

Based on the experience in Ogoniland, bioremediation should be done after the contaminated soil is excavated and spread over an impermeable layer protected from rain. These mini treatment centres should be close to the contaminated sites to minimize transportation and facilitate return of the treated soil to the original trenches.

Mini treatment centres should be created based on a common template but scaled to individual site requirements. The centres could be managed by the local community, offering job opportunities for young people, but they would first need to be trained in operation and maintenance of soil remediation and water clean-up. This would contribute to both environmental and social objectives.

These local centres would also act as staging areas for materials passing to and from the ICSMC.

Treatment of contaminated sediments

Decisions on intervention for sediment treatment are more complicated than simply basing them on an intervention value. Issues of erosion, vegetation damage and impact on local aquatic ecosystems as well as potential for natural recovery all need to be part of the decision-making process. Thus, every site at which contaminant concentration in the sediment exceeds the intervention value needs to be assessed on a case-by-case basis. Once a decision on intervention is taken, additional investigations will be needed, including analysis of the sediment for other contaminants and particle size. Only then can a final decision be made on the most appropriate clean-up technology to be used. This could involve, for example, a portable system which can be operated from a barge used for dredging, or transportation of sediments to the ICSMC.

Mini treatment centres for contaminated soil should be created based on a common template

Restoration of contaminated soil in swampy areas

The most extensive area in terms of treatment of contamination will be topsoil from the swamplands. Given that the parameters to be considered are depth of the contamination, the presence of vegetation and frequency of flooding (and therefore difficulty of access), a single approach to clean-up is unfeasible. It must also be noted that a comprehensive clean-up of the contaminated soil all over the creeks is not what is anticipated. There may be areas where no intervention is made and the contamination is overlaid by new sediments which in turn provide healthy substrate for new vegetation. There may be other areas where manual excavation and removal may be most appropriate. All such decisions have to be made based on site-by-site risk assessment. Available options are presented in Table 49.

Moving the soil and sediment to a treatment facility in Ogoniland could be both time-consuming and expensive. A portable facility mounted on a barge which can move through the bigger creeks should be considered. Such a facility could carry the high-technology treatment system (a combination of incineration and soil-washing facilities) and act as a base for the decontamination crew. This would allow a greater degree of flexibility in reaching all or most parts of the swampland.

Decontamination of groundwater

The issue of hydrocarbon contamination in wells needs to be addressed in a comprehensive manner, but clean-up actions must be site-specific. In principle, two forms of contamination need to be dealt with: product spills, in which the contaminants of concern are BTEX and other low molecular weight hydrocarbons, MTBE and other fuel additives; and crude oil spills, in which the whole range of hydrocarbons will need to be treated. In the case of hydrocarbon contamination, centralized treatment will not be possible and on-site treatment units will have to deployed. In making decisions about the clean-up of groundwater, additional factors such as proximity to the community, absorption characteristics of the soil, leaching behaviour of the pollutants, permeability of the soil layer and all possible pathways must be considered.

Topsoil from the swamplands will be the most extensive area in terms of treatment of contamination

Mangrove restoration in Ogoniland will take up to 30 years, once ongoing pollution is stopped

This will required additional data gathering at specific locations. However, in the case of groundwater treatment, based on information gathered so far, it is clear that there will be locations where groundwater treatment will be needed. Contaminated water may be treated after pumping it out from the aquifer or while the water is still *in situ*. The appropriate technologies are described in Table 50.

Rehabilitation of mangroves

As observed in chapter 5, there is significant damage to the mangroves in Ogoniland. Part of the mangroves have died, some of the mangroves are degraded and even those which are currently not showing any stress are constantly under threat. Mangrove rehabilitation is important from both ecological and economic point of view.

There is substantial international experience in restoration of impacted mangroves, including those impacted by oil pollution [64]. The challenge is to decide what exact approaches are appropriate in the context of Ogoniland based on the ecology and hydrology of the area. The following enabling actions should be undertaken prior to initiating mangrove restoration;

- Bringing the ongoing activities of artisanal refining in the entire area (not only in Ogoniland but other areas which are hydraulically linked to Ogoniland) to an end
- Study of the hydrologic regime in the area to see if there are changes in this which could impact the restoration process. In particular, the impact of the recent road construction in the area and its impact on the hydraulic regime should be evaluated
- Reviewing the state of degradation of the various sections and prioritizing areas for intervention.

Table 48. Soil remediation technologies for hydrocarbons

Treatment location	Technology genre	Description	Relevance to Ogoniland context
In situ	Containment (in situ)	Contain the polluted soil in the ground by creating impermeable barriers around it (side/top); barriers on the sides should reach down to a natural impermeable barrier	Inappropriate as the community needs access to the land for their livelihoods
	Natural remediation	No active intervention at site; natural processes, evaporation, dilution, photo-oxidation and biodegradation to reduce pollution	Inappropriate due to proximity of the community to contamination, shallow aquifer and heavy rainfall
	Enhanced natural attenuation	Active intervention at the site to enhance the above processes; primarily periodic tilling of the land and addition of nutrients	Inappropriate due to proximity of the community, shallow aquifer and heavy rainfall
	Fixation	Mix with chemical or physical binding agents to prevent the hydrocarbons from leaching out	Inappropriate as the long-term stability of the binding, as well as the impact of the binding agents, are both unknown
	Soil vapour extraction	Strip off the hydrocarbons from the soil matrix by creating a negative pressure in the subsoil	Appropriate only in the case of highly volatile hydrocarbons; not fit for crude oil which is the main pollutant in Ogoniland; may be applicable at the NNPC product spill sites

Table 49. Restoration approaches for swamp areas

Treatment location	Technology genre	Description	Relevance to Ogoniland context
In situ	Natural attenuation	No active intervention; instead leave the contaminated soil in place and wait for natural processes (e.g.sedimentation, evaporation, flushing by tidal water, biological action) to reduce pollution	Unacceptable given the current social, environmental and health situation, and aesthetics
	Enhancing bioremediation	Minimal intervention apart from spraying nutrients to promote bioremediation	Not possible in areas which are under daily inundation
	Enhancing flushing	Low or high-pressure water jetting of sediments and allowing tidal water to carry away the pollution	High-pressure water jetting may cause extensive disturbance; low-pressure water jetting can be used in conjunction with collection of re-suspended oil
	Absorbent materials	Spread absorbent materials (e.g. sawdust) or mats over contaminated soil to achieve hydrocarbon reduction	Inappropriate for bituminous substances accumulated over periods of a decade or more
	Containment	Cap the polluted area with cleaner material	Oil may still rise to the top
	Revegetation	Plant more hydrocarbon-tolerant vegetation in swamps	Inappropriate as this will alter the marsh ecology
Ex situ	Mechanical intervention	Remove contaminated soil with heavy machinery	Intervention with heavy machinery may leave large environmental footprint
	Manual intervention	Remove contaminated soil by manual labour and remove for clean-up	Least disturbing option

Table 50. Treatment technologies for contaminated groundwater

Treatment location	Technology genre	Description	Relevance to Ogoniland context
In situ	Passive remediation	No active intervention; instead leave the contamination to reduce itself by dilution, diffusion, adsorption and biodegradation	Inappropriate due to proximity of the community and their use of untreated groundwater for drinking
	Enhanced bioremediation	Promote bioremediation of hydrocarbon by pumping in nutrients and oxygen	Inappropriate due to proximity of community and the fact that they use the groundwater for drinking without treatment
	Biosparging	Strip off hydrocarbons in the groundwater by injecting air into the groundwater	Suitable for highly volatile substances only; may be applicable at the NNPC product spill sites
	Recovery of floating hydrocarbons	In cases of severe contamination, recover floating products using submersible pumps	May be appropriate in instances where heavy pollution is observed
Ex situ	Air stripping	Bring up the mixture of groundwater and hydrocarbons and strip off the hydrocarbon in a tank or column	Appropriate only for highly volatile substances and with additional control for air pollution; may be applicable only at NNPC product spill sites
	Phase separation	Bring up the mixture of groundwater and hydrocarbons and separate the two phases by physicochemical processes	Suitable for application; main constraint will be low permeability of the soil
	Trenching and treatment	Create large ponds or trenches in polluted areas where the water level is depressed to enable the draining of hydrocarbons into the area; remove hydrocarbons via 'pump and treat' approach	May be the most appropriate method due to high rainfall, low permeability and presence of large quantity of excavation water

Table 51. Restoration approaches for mangroves

Treatment location	Technology genre	Description	Relevance to Ogoniland context
Cleaning of vegetation	Manual cleaning	Manual cleaning of impacted mangrove stems with absorbent wipes or other wipes	Highly labour-intensive and needs to be done with care, but a possible option
	Low-pressure water jetting	Cleaning of impacted mangrove vegetation using low-pressure water jets	Bituminous substances are recalcitrant and may not be amenable to low-pressure water jetting
	High-pressure water jetting	Cleaning of impacted mangrove vegetation using high-pressure water jets	High-pressure water jetting may damage live plants but is appropriate for dead plants
	Surfactants and vegetation cleaners	Apply surfactants and vegetation cleaners to impacted mangrove vegetation to remove oil	Bituminous substances are recalcitrant and may not be amenable; may have a role in combination with other technologies
Vegetation clearing	Burning	Clear vegetation by burning to create room for new growth	Destruction of mangrove vegetation may accelerate coastline erosion
	Felling	Clear vegetation by cutting away existing plants	This may be attempted once the new plants have taken root to secure the land
Replanting the area	Within the existing root structure	Retain existing vegetation, including the roots of dead mangroves, and undertake replanting	Proven effective elsewhere; key issue is the remaining pollution in substrata
	Within open area	Replant in open areas and remove dead roots if necessary	Proven effective elsewhere; key issue is the remaining pollution in substrata

Public health studies in Ogoniland should continue

- A plan for control and management of alien and invasive species should be developed prior to active intervention in the field

Due to the wide extent of contamination (in Ogoniland and nearby areas) and the varying degrees of degradation, there will not be one single technique appropriate for the entire area. A combination of approaches will therefore need to be considered. This would range from active intervention for cleaning the top soil and replanting mangrove to passive monitoring of natural regeneration. Mangrove restoration in Ogoniland will be a project which will take up to 30 years, once the ongoing pollution is stopped, and an appropriate approach will be to initiate restoration in number of largescale experimental pilot sites (of 10 hectares each) and apply the lessons learnt in each of the locations to rest of the area with similar ecological and hydrological conditions. In locations where the mangrove trees have died, a more active intervention approach which involve clean up of the hydrocarbons on the top soil and bituminous substances on the dead stems followed by artificial replanting should be attempted. A summary of the possible approches are given in Table 51.

6.3 Recommendations for public health

This environmental assessment revealed that in addition to chronic exposure to oil, there are at least three groups of people in the Ogoniland whose health and safety are acutely impacted by the environmental contamination:

- those exposed to hydrocarbon pollution in their drinking water, including one community where benzene concentrations are extremely elevated
- those living on oil pipeline rights of way, and
- those involved in bunkering and artisanal refining.

For each of these groups, reducing the threat that petroleum hydrocarbon poses to their health is an immediate and necessary first step.

Communities exposed to petroleum hydrocarbons in their drinking water

UNEP monitoring showed that there is one community, at Nisisioken Ogale, where families are drinking water highly contaminated with petroleum hydrocarbons, most notably benzene, at concentrations far above the threshold of acceptability according to WHO guidelines. Exposure to such high levels of hydrocarbons is certain to lead to long-term health consequences for community members. This situation warrants the immediate action of stopping people from drinking water from the contaminated wells and providing them with alternative an source of safe water.

The assessment results at Nisisioken Ogale mean that there could well be other households exposed to similar high levels of contamination. All other communities which are impacted, whether in Ogoniland or in surrounding areas, should be identified and provided with alternative access to clean drinking water as a matter of urgency.

The UNEP assessment also found hydrocarbons exceeding Nigerian drinking water standards in 28 drinking water wells used by Ogoni communities. Again, since the assessment was sample based, there could be other households exposed to hydrocarbons through their drinking water. The Government should take appropriate action in cases where Nigerian national standards on drinking water have been exceeded as per the Ministry of Health guidelines. Like the highly contaminated wells in Nisisioken Ogale, some of these wells may warrant immediate action to identify all affected families and to provide them with clean drinking water and medical care. Other wells may require clean-up and ongoing monitoring until such time as the upstream sources of petroleum contamination are eliminated.

It is further recommended that all members of households who have ingested water from hydrocarbon-contaminated sources are registered in a central data base and requested to undergo a **comprehensive medical examination** by medical personnel familiar with adverse health effects arising from contaminated drinking water. In addition, their health should be tracked during ther lifetime as some of the impacts of hydrocarbon exposure, such as cancer, may not manifest, for a very long time.

Communities living on rights of way

From a safety perspective, as well as for the security of oil installations, people living on rights of way should be moved from such locations as soon as possible. However, UNEP is conscious that those affected come from marginalized sections of Nigerian society and that such cases need to be handled with tact and sensitivity. Alternative locations for housing should be found regardless of the legal status of the people involved.

People involved in bunkering and artisanal refining

While bunkering and artisanal refining are criminal activities, the majority of young people who engage in it do so primarily as a means of employment. While it was not possible for UNEP to monitor the health status of those involved in bunkering and artisanal refining, it can be stated with conviction that they are exposing themselves to extreme safety risks (from fire and explosion) as well as health risks (from exposure to crude oil and volatile hydrocarbons). Regardless of the fact that they are working outside the boundaries of the law, it is important that efforts are made to draw them away from such dangerous activities. This may require awareness campaigns on, for example, the disproportionate nature of the short-term financial gain set against the medium to long-term health consequences, both to the individual and to the broader community. Job schemes offering alternative employment opportunities also need to be put in place.

6.4 Recommendations on follow-up monitoring

During and following clean-up operations in Ogoniland, a monitoring programme with three separate objectives should be put in place which will:

- monitor ongoing pollution in all environmental segments
- track the impacts on the health of communities exposed to hydrocarbon pollution, especially those exposed over many years, and
- track the progress of all clean-up projects and provide documentation to support their effectiveness

Monitoring should be prepared and implemented in consultation with the national institutions mandated to deal with specific environmental issues.

Comprehensive preventive surveillance should be undertaken by teams comprising representatives from the oil industry, environmental agencies and local communities

All monitoring activities should be communicated to the community and all results should be made publicly available.

Below, UNEP makes a series of recommendations for monitoring in specific areas. Table 52 summarizes the approaches and frequencies to monitoring in each of the subject areas.

Preventive surveillance

It was clear from the UNEP investigation that there is little, if any, preventive surveillance at oilfield sites in Ogoniland. Polluting activities go unhindered and when an incident occurs there is a (sometimes considerable) time lag between the event and it coming to the notice of the appropriate authority. UNEP recommends that comprehensive preventive surveillance is established, with the following elements:

- Weekly aerial scouting (conditions permitting) of the entire Ogoni oilfield (including the creeks and pipeline rights of way) to identify any new incidents or activities which may result in environmental damage
- Weekly surveillance visits (by boat) to the creeks to check for any indications of pollution and any ongoing incidents or activities which may cause pollution. Surveillance by boat could be directed by aerial observations
- Weekly visits to all oilfield installations, including pipeline rights of way and contaminated sites, to look for signs of any new spills or encroachments, and also to check on progress with remediation where this is taking place.

Preventive surveillance should be undertaken by a team consisting of oil industry representatives and environmental agencies, together with an appointed local community representative as guide and to achieve local ‘buy in’. Daily information reports should be presented to all relevant stakeholders, including the community. However, UNEP recognizes that surveillance activities by boat and on land can only be implemented once the entire security situation within Ogoniland is significantly improved.

Monitoring of groundwater

Hydrocarbons were present in a number of community wells monitored in Ogoniland. UNEP also observed at other contaminated sites that the contamination has reached the groundwater, though it is currently not used for drinking. The following broad approach to groundwater monitoring is therefore recommended:

- In all communities where hydrocarbon was observed in at least one well, carry out a one-off monitoring visit to all households to assess/verify the presence of hydrocarbons in their various drinking water sources. The analytes to be checked should be decided upon based on the likely source of pollution

- In order to protect public health, establish systematic monitoring around all contaminated sites to provide early warning of contaminant migration to groundwater. Monitoring should be carried out monthly and reports made public. The analytes to be checked should be decided upon based on the likely source of pollution.

Monitoring of water bodies, fish and aquatic sediments

A comprehensive monitoring plan focusing on the water bodies, including the Imo River, around Ogoniland should be initiated. It should cover water, fish, sediments and benthic communities and can be used to:

- inform guidelines for zoning of areas where fishing and recreational activities are temporarily suspended owing to excessive pollution

- track improvements in environmental quality as remediation activities are undertaken.

Monitoring of water along established transects should be carried out monthly. Monitoring of sediments and benthic communities should be completed every quarter.

Monitoring of vegetation and fauna

Monitoring of vegetation recovery should be carried out within the creeks and at all oilfield sites. The approach should involve a combination of field transects, undertaken once a year, and analysis of satellite imagery to supplement the field transects, also undertaken once a year.

In due course, as the quality of vegetation and water improve, surveys should include mangrove fauna in order to provide a real indication of habitat restoration.

Air quality monitoring

Comprehensive air quality monitoring across Ogoniland should be initiated to track ongoing pollution, to help establish guidelines for protecting public health and to track improvements at sites where clean-up activities are under way.

Public health monitoring

A public health registry should be established for the entire Ogoniland population in order to track health trends and take proactive action individually and/or collectively where impacts relating to long-term exposure to hydrocarbon pollution are evident.

UNEP observed some communities experiencing extraordinarily high exposures to petroleum. In addition to the recommended health registry, a cohort registry of these exposed individuals would allow for a better and more extensive study than was possible given UNEP's scope of work. Such a cohort registry would list individuals who live in the highly exposed communities and provide the infrastructure to study the health status of cohort members. Ideally, a standardized health service system would be established for the cohort for the purpose of implementing the health status assessments.

6.5 Recommendations for changes to regulatory framework

In this section, UNEP makes specific recommendations to strengthen the legal and institutional weaknesses identified during the environmental assessment of Ogoniland.

Legislative matters

The regulation dealing with the oil industry is the Environmental Guidelines and Standards for Petroleum

A public health registry should be established for the Ogoniland population to track health trends and take action where impacts relating to long-term hydrocarbon pollution exposure are evident

Table 52. Monitoring sectors, approaches and frequencies

Monitoring sector	Monitoring approach	Frequency
Preventive surveillance	Aerial scouting	Weekly
	Surveillance from boats	Weekly
	Surveillance of facilities and incident sites	Weekly
Groundwater	Household visits in impacted communities	One-off
	Wells around impacted sites and facilities	Monthly
Water bodies	Surface water	Monthly
	Sediments	Quarterly
	Fish	Quarterly
	Benthic organisms	Quarterly
Vegetation	Transects in creeks and oilfield sites	Once a year
	Mangrove fauna	Once a year
	Analysis of satellite imagery	Once a year
Air quality	Particulate measurements, hydrocarbons	Monthly
Public health	Cohort registry of highly exposed communities	Yearly
	Public health registry of entire Ogoniland community	Yearly

Industry in Nigeria (EGASPIN). Oversight of the regulation lies with the Department of Petroleum Resources within the Ministry of Petroleum Resources.

1. Transfer oversight of the EGASPIN to the Federal Ministry of Environment, if necessary with appropriate staff or by recruiting and training new staff

2. Make the following operational changes to the regulation:

    (i) Make the provision for social and health impact assessment an integral part of the overall environmental impact assessment (EIA) process for all new oil and gas facilities and upgrades to existing facilities, in line with international best practice

    (ii) Clarify the approach to be taken for clean up of oil spills and other contaminated land, giving clear guidance on remediation criteria and realistic timeframes within which remediation has to be achieved

    (iii) Clarify the present inconsistency between 'intervention value' and 'target value' should such an approach continue to be adopted

    (iv) Include guidance on decommissioning and the environmental due diligence assessment to be undertaken while completing the decommissioning process

    (v) Add new guidance on: (a) surface water quality management; (b) ambient air quality; and (c) mangroves and coastal vegetation

(vi) Ensure all provisions of the regulation are internally consistent with one another

3. Establish guidelines on the circumstances in which recreational and/or commercial fishery closures should be implemented in water bodies subjected to pollution

4. Establish guidelines on the circumstances in which swimming, bathing and other recreational activities should be closed in a water body subjected to pollution

5. Improve public access to information, particularly non-classified information regarding the oil industry, such as EIAs, monitoring reports, spill reports and remediation closure reports

6. Increase access to environmental legislation. The high prices currently charged for legal texts make it difficult for citizens, non-governmental organizations, smaller companies and even governmental institutions to obtain them. Ensure that all legislation related to the oil and gas sector, as well as environmental legislation, is publicly and freely accessible on a single website (comparable to Eur-Lex in the European Union [72]). Legislation should be catalogued and search engines should allow for different inquiries (according to subject, full name of the Act, type of legislation, year of coming into force, etc.). In addition, governmental departments and agencies should make available, though their websites, their respective governing Acts, related legislation, guidelines, standards and procedures.

Institutional arrangements

1. In cases where specific mandates are given to newly formed agencies, EITHER:
   - (i) all existing mandates held by older/other institutions and covering the same subject area should be revoked, OR:
   - (ii) similar mandates of two or more institutions should be revised to clearly delineate the roles and responsibilities of each of the institutions. A clear example is the overlapping mandates of DPR and NOSDRA

2. Review the provisions of the NOSDRA (Establishment) Act, 2006 against NOSDRA's current operational responsibilities. The Act should either be expanded to include responsibility for environmental contamination in general (other than oil spills) or oversight of clean-up should be given to a separate governmental department

3. Clarify the mandates for the regulation and oversight of the following key issues:
   - (i) Water quality in the creeks
   - (ii) Standard setting for various uses of the creeks (e.g. for recreation, fishing), similar to environmental quality objectives and standards developed in other countries
   - (iii) Monitoring of public health
   - (iv) Restoration, management and monitoring of mangroves

4. Lack of resources is a constant theme across many Nigerian institutions (central, state and local). Build the capacity of government and non-governmental agencies to enable them to fulfil their mandates. In particular:
   - (i) increase human resources
   - (ii) increase the availability of material resources (hardware, vehicles, maintenance budgets, etc.), particularly of those agencies that currently depend on the oil industry for logistical support
   - (iii) improve the technical skills of individuals in the various agencies to enable them to deal effectively with the oil industry.

6.6 Recommendations for follow-up

In the field of contaminated site assessment, trade-offs have been made between the amount of money spent on gathering field information versus the amount spent on clean-up activities. This trade-off has given rise to the phased approach to contaminated site assessment. At the end of each phase, the entity who must undertake the clean-up action has to decide whether to initiate a clean-up based on available information or to gather additional information which may assist in better understanding the risk so that the resources can be better directed.

Additional data gathering will be needed even when sufficient information exists about the risk posed by a given site and a decision to remediate it has been made. This will include determining the presence of co-contaminants (such as heavy metals) which may interfere with the possible clean-up technologies and soil characteristics (particle size analyses and permeability, among others).

In this study, systematic information has been gathered for 69 contaminated locations. The observed concentrations of chemical contamination have been compared with Nigerian legislation. Whenever the concentrations have exceeded Nigerian intervention values or drinking water quality standards, recommendations have been made to follow up.

The next logical step in the clean-up and restoration of Ogoniland is to review the available information and set priorities for action. However, two things must precede that:

- Firstly, it is important that the ongoing contamination, from all possible sources, is brought to an end with minimum delay
- Secondly, at each of the individual sites, actions must be taken to prevent them from being secondary sources of ongoing contamination while further risk assessments or investigations are undertaken.

In terms of prioritizing specific locations to be cleaned up, restored or rehabilitated, the following framework is suggested.

Priority 1

All instances where the Ogoni community is known to be at risk. This includes treating contaminated drinking water sources and re-housing families living on or adjacent to contaminated oilfield facilities, such as well pads or rights of way.

Priority 2

Instances where contamination could potentially affect the community (e.g. where groundwater, fishing grounds or agricultural land are impacted).

Priority 3

Instances where a community's livelihood support base is impacted (mangroves, swamps, surface water).

Priority 4

Instances where there is no immediate risk to the community but where there is non-compliance with the law.

It must be emphasised that it is not intended that all priority 1 actions should be completed before initiating priority 2 actions, and so on. As environmental restoration in Ogoniland will be an

Ongoing contamination from all possible sources should be curtailed with minimum delay

While environmental restoration in Ogoniland will take decades, concurrently implementing priority actions will have an immediate and positive impact

activity taking decades, many of these actions will be – indeed must be – implemented in parallel.

Based on the prioritization process, at individual sites additional information gathering will be needed, which may include:

- Details of the geological and hydrogeological properties (e.g. soil type, particle size and hydraulic conductivity/permeability)
- Concentration of metals in the sites: Some metals (Ni and V) are present with crude oil while Pb was added in the past to refined product as an additive. In addition, heavy metals may be present in the soil as natural constituents. Regardless of the orgin, they can interfere with the clean-up and can also cause additional risk.
- Apart from determining the concentration of contaminants in a given site's soils and water component, an important property is the transport behavior of the contaminant when in contact with aqueous solution. This behavior can provide insights into the potential for transfer of contaminants to potential receptors. Hence, a leaching/desorption test is desirable to determine how contaminants partition from the solid phase to the liquid phase. For the groundwater and surface water, an adsorption test is also desirable for the same reason.
- Further speciated analyses of the hydrocarbons, in particular PAHs, may be of interest in detailed risk assessments.

Ogoniland's Path to Sustainability

Achieving long-term sustainability for Ogoniland will require coordinated and collaborative action from all stakeholders
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Ogoniland's Path to Sustainability

Treating the problem of environmental contamination within Ogoniland merely as a technical clean-up exercise would ultimately lead to failure. While the technical recommendations made in this report are essentially aimed at securing environmental improvements throughout Ogoniland, ensuring long-term sustainability is a much bigger challenge – one that will require coordinated and collaborative action from all stakeholders. This can only be achieved when there is sufficient dialogue, confidence and trust between all the parties involved. Clearly, this is not the case at present. Consequently, it is to be hoped that the environmental clean-up of Ogoniland will have multiple effects:

- that it will bring all those involved in the project together in a single concerted cause
- that in doing so it will build confidence and skills within the participating institutions
- that it will involve and provide new opportunities for the Ogoni people and ultimately
- that it will create decent living conditions and secure livelihoods within a clean and healthy environment for the entire Ogoniland community

The recommendations given below address the three key stakeholders in Ogoniland: the three tiers of Government in Nigeria (federal, state and local), the oil companies that have an operational interest in Ogoniland (or may have so in future) and the Ogoniland community (with all the elements therein).

7.1 Recommendations for Government

In this section the term 'Government' represents all three tiers: federal, state and local. Where specific actions are directed towards one tier of government, this is stated explicitly.

Creation of an Ogoniland Environmental Restoration Authority

The sustainable environmental restoration of Ogoniland will take up to 20 years to achieve and will need coordinated efforts on the part of government agencies at all levels. Among the many challenges are inadequate institutional capacity (both technical and financial) and overlapping institutional mandates, procedures and structures which, collectively, prevent effective coordination. Resolving these issues will be a process which itself could take years. Hence, the expectation that effective environmental restoration can be achieved in Ogoniland with the current institutional capacity and framework is simply not realistic. However, stalling the commencement of the clean-up phase until such time that all of these institutional issues are addressed is also not a realistic option due to the seriousness of the environmental situation.

UNEP therefore recommends that the Federal Government of Nigeria establishes an 'Ogoniland Environmental Restoration Authority'. The new authority should have a number of important features, including but not limited to the following:

1. The mandate to follow up and oversee implementation of the recommendations made in this report, as well as any other matters that the Federal Government may wish to assign to the Authority
2. The Authority will have a fixed lifespan, initially of ten years. Within this time the key elements of the restoration should be in place and overall institutional strengthening achieved. After ten years the Federal Government, on reviewing the status of the environmental restoration and the overall institutional capacity, may either extend the Authority's mandate for another term or redistribute the tasks to the other, strengthened, agencies
3. The Authority will work under the Federal Ministry of Environment
4. The Authority's staff will largely be seconded from relevant national and state institutions

Garri (cassava) at an Ogoniland market. It is hoped the environmental clean-up of Ogoniland will secure livelihoods

5. The Authority will have a separate budget which will accrue from the Ogoniland Environmental Restoration Fund (see next section)

6. The Authority, in addition to dealing with matters of environmental restoration, will have a full team of communication experts to ensure ongoing engagement and dialogue with the Ogoni community and continue the educational initiatives aimed at raising awareness of the issues arising from oil spills, whether they result from operational failure or illegal activities

7. The Authority will have an oversight mechanism which could be equivalent to the current Presidential Implementation Committee (PIC).

Creating an Environmental Restoration Fund for Ogoniland

A detailed costing of the various recommendations made in this report was not within the scope of the work and was therefore not attempted. However, it is clear that major investments will be needed to undertake the report's recommendations. A preliminary estimate of the initial investments needed to rehabilitate and restore the environment is presented in Table 54.

It must be noted that the estimates given above are preliminary only, and are provided so that there is sufficient funding to initiate follow-up actions. The final clean-up costs are likely to be different, indeed much higher, for the following reasons:

1. Full environmental restoration of Ogoniland will be a project which will take around 25-30 years to complete, after the ongoing pollution has been brought to an end. The current cost estimates are operational costs of the new institutions over the first five years.

2. The clean-up costs for contaminated soil, a key component of the overall costs, will depend substantially on the remediation standards set. A more stringent standard will lead to higher clean-up costs.

3. The cost of clean-up of groundwater is not included in this costing (except for Nsisioken Ogale). The clean-up objectives, standards and target will first need to be decided before a volume estimate and associated costing can be attempted.

4. No estimate is given for the clean-up of surface water. It is assumed that once the ongoing input of oil into the surface water is stopped, natural process will flush the floating oil. However, in locations where there is not enough water exchange, intervention will be needed for the clean-up.

5. The response and clean-up costs for any new spills, or newly discovered spills, simply cannot be estimated

6. Land will need to be leased to establish the Integrated Contaminated Soil Treatment Centre and mini treatment centres in situ. The cost of land acquisition is not included.

7. The report recommends a set of asset integrity actions for the oil industry, which include better securing of the facilities and proper decommissioning of abandoned facilities. These costs also are not included above.

8. A major cost item will be the restoration of mangroves and forests within the creeks around Ogoniland. The current estimates are limited to a pilot area of impacted mangroves and forests around the Bodo West oil field facilities.

The creation of an 'Environmental Restoration Fund for Ogoniland', with initial capital of USD 1 billion, is therefore recommended:

1. The Fund should be established with financial inputs from the oil industry operators with prevailing interests in Ogoniland (currently SPDC and NNPC) and the Federal Government of Nigeria as a major shareholder in both these entities

2. The Fund should be used only for activities dealing specifically with the environmental restoration of Ogoniland, including capacity building, skills transfer and conflict resolution

3. Management of the Fund should be the responsibility of the Ogoniland Environmental Restoration Authority.

Table 53. Preliminary cost estimate for the first five years of restoration

Sl #	Item	Estimated cost (USD)
1	Emergency Measures (80 % for providing alternative drinking water to communities with contaminated water supply)	63,750,000
2	Clean up of Land contamination	611,466,100
3	Clean up of Benzene and MTBE Contamination and Nsisioken Ogale	50,000,000
4	Clean up of Sediments	20,000,000
5	Restoration of Artisanal Refining Sites	99,452,700
6	Mangrove restoration and rehabilitation	25,500,000
7	Surveillance and Monitoring	21,468,000
8	Ogoniland Restoration Authority	44,000,000
9	Center for Excellence in Restoration	18,600,000
10	Alternative Employment to those in Artisanal Refining	10,000,000
	Sub total	**964,236,800**
	Thirdparty Verification and International Expert Support to implementation recommendations @ 5 %	48,211,840
	Total	**1,012,448,640**

Creating a Centre of Excellence for Environmental Restoration

The environmental restoration activities in Ogoniland will be extensive, extend over a long time period and involve thousands of the Ogoni people. However, the problems currently affecting Ogoniland are also being experienced, and on a bigger scale, throughout the Niger Delta, as well as in many other parts of the world. The experience gained from the restoration work in Ogoniland will provide an excellent basis for establishing a Centre of Excellence for Environmental Restoration in Ogoniland. Offering a range of activities and services, the Centre could:

- run training courses in environmental monitoring and restoration
- enhance the capacity and skills of the Ogoni community, with opportunities for employment
- promote learning, both in the region and more widely, including abroad
- become a model for environmental restoration, attracting visiting experts, students and visitors from overseas
- assist with business development, offering training on all aspects of setting up and running a successful company (legal, financial, technical, health and safety, etc.)
- open its enrolment to people outside Ogoniland and the wider Niger Delta (including from other countries)

Declare the intent to make the wetlands around Ogoniland a Ramsar site

The Convention on Wetlands (Ramsar, Iran, 1971) – more familiarly called the Ramsar Convention – is an intergovernmental treaty that embodies the commitments of its 160 member countries to maintain the ecological character of their Wetlands of International Importance and to plan for the 'wise' or sustainable use of all of the wetlands in their territories. Nigeria became a Contracting Party to the Convention on 2 February 2001 and it now has 11 Ramsar sites covering a total area of 1,076,728 ha.

The wetlands around Ogoniland are highly degraded and facing disintegration. However, it is still technically feasible to restore effective ecosystem functioning, although this will only be possible if a series of technical and political initiatives are undertaken. In order to demonstrate the Federal Government's resolve for effective action and its sustained interest in this issue, it may be appropriate to declare the intent to designate the wetlands around Ogoniland as a Ramsar site in due course. This would provide the Government with a roadmap for restoration and sustainable management of the wetland. This would also bring the site onto the international spotlight, which will act as a peer pressure to make the agencies focus on the task.

Mount a campaign against environmental degradation

Since oil industry infrastructure and related environmental damage are an integral part of people's day-to-day life in Ogoniland, a concerted effort needs to be made to improve the community's understanding of the health and environmental consequences of oil contamination. This should be done at three levels:

1. Mount a community-wide campaign to inform people of the environmental and health impacts arising from hydrocarbon contamination in Ogoniland
2. Include environmental and health issues associated with the oil industry in academic curricula in the Niger Delta
3. Run a specialized campaign aimed at Ogoni youth engaged in illegal bunkering and artisanal oil refining to create awareness of the disproportionate environmental impacts of their actions and the potential for severe damage to their health

7.2 Recommendations for oil industry operators

Oilfield facilities throughout Ogoniland are currently in various states of repair and it appears unlikely that any have been maintained or decommissioned to the industry's own standards. If and when a future decision on re-commissioning the oilfield is taken, the integrity of the existing infrastructure will have to be examined with the utmost attention to detail in order to avoid creating new environmental damage and health risks. Based on its review of the environmental and social sensitivities in Ogoniland, UNEP recommends that in the event that a decision be made to restart oil exploration and production activities in Ogoniland, the region be treated as a greenfield site of high environmental and social sensitivity. This would mean applying the latest technologies and environmental guidelines, including:

1. Undertaking an environmental impact assessment of oil operations in Ogoniland, to include social and health dimensions, as well as a public consultation process as is the current industry standard
2. Re-evaluate the location of the existing oil wells within the context of the latest technology for horizontal and directional drilling
3. Complete drainage and groundwater management for any new oil wells, as for example the state-of-the-art and sensitive well sites in Europe where liquid and solid wastes can also be properly contained and treated off site
4. Re-evaluate pipeline routes to minimize environmental damage. This may, for example, lead to decommissioning of the existing pipeline from Bodo West, which cuts across the mangrove swamps, and relaying it along the creek
5. Treating operations in Ogoniland, and ultimately within the Niger Delta as a whole, as an offshore operation in determining safety standards and operational footprint
6. Improved regimes for both inspections of facilities and preventive maintenance programmes
7. Enhanced facilities, using modern technologies, for faster oil spill detection, in conjunction with more locally accessible resources for faster spill response
8. Allocating a percentage of all project costs for environmental and sustainable development initiatives in Ogoniland
9. Regular public consultation and reporting on environmental and social performance of industry activities
10. Encourage new investors by creating a licensing and environmental due diligence culture

Pupils in Ebubu, Eleme LGA, planted trees with the UNEP project team to mark World Environment Day 2011. The involvement of the entire Ogoni community will be crucial to achieve sustainable environmental improvement for future generations

7.3 Recommendations for the Ogoniland community

Sustainable environmental improvement in Ogoniland can only be achieved with the involvement and cooperation of the entire Ogoni community. In this respect the following elements are of critical importance:

1. The proposals outlined in this report have the potential to bring in substantial new investment, employment opportunities and a new culture of cooperation into Ogoniland. The Ogoni community should take full advantage of the opportunities that will be created by these developments. These projects potentially offer the community an unprecedented opportunity to be at the forefront of a world-class environmental restoration project that will improve their living conditions and livelihoods and provide them with skills that can be exported nationally, regionally and internationally. This is a transformative moment and the Ogoni community should endeavour to seize it in a positive manner.

2. Presently, some community members prevent access to oil spills using protest and the threat of violence. Protracted negotiations over access with oil spill response teams means that responses to spills are delayed, often by weeks, resulting in a far greater environmental impact, the negative consequences of which are borne by the wider community.

3. The community should take a proactive and public stand against individuals or groups who engage in illegal activities such as bunkering and artisanal refining. These activities result in a huge environmental footprint, seriously impacting public health and livelihood activities, particularly fishing and agriculture.

7.4 Interim actions to move forward

In order to implement the technical and strategic recommendations in UNEP's report, it is necessary to initiate a series of practical actions, as detailed on the following pages.

Chief Gilbert Warine speaking during a Community Consultation Committee meeting at the UNEP project office, Port Harcourt. New multiple stakeholder working groups are recommended

1. **New and enhanced mandate for the Presidential Implementation Committee (PIC)**: The PIC was established with a broad mandate to oversee the implementation of the assessment project. With the successful completion of the assessment, this mandate is coming to an end. However, in order for the assessment phase to lead to clean-up and restoration of the environment in Ogoniland, it is important that continuity is maintained and a logical approach will be to give a new and enhanced mandate to the PIC. Such a mandate could include oversight of the recommended Ogoniland Environmental Restoration Authority (OERA). The membership of the PIC should be expanded to include representatives from stakeholders with an interest in the restoration project.

2. **Technical Working Groups:** The formation of various working groups will enable this report's recommendations to be initiated and actioned in parallel. Due to the scale and diverse technical nature of the follow-up actions, the working groups should comprise experts with broad-ranging skills and knowledge from the following sectors:

- Government of Nigeria (Federal Ministries and Agencies)
- Government of Rivers State (State Ministries and Agencies)
- academicians
- oil industry
- the community

The following working groups are recommended:

1. **Technical Working Group on Environmental Restoration (TWG-ER):** This working group will focus on the strategies and approaches for environmental restoration in Ogoniland, as outlined in the report. This will be the forum where prioritizing areas and sites for clean-up will be discussed and finalized. This will also be the forum to consider the appropriate technical approaches for each of the restoration actions (land, sediment, water and mangroves).

2. **Technical Working Group on Surveillance and Monitoring (TWG-SM):** The TWG-SM will focus on designing and providing guidance for surveillance and monitoring of the environmental situation in Ogoniland. This group will further discuss the surveillance and monitoring actions recommended in the report and finalize detailed plans in terms of locations, methodologies and frequency.

3. **Technical Working Group on Water Supply (TWG-WS):** This working group will focus on prioritizing the communities which need to be provided with alternative drinking water supplies and other actions needed for the community to be protected from unsafe water.

4. **Technical Working Group on Legislation and Standards (TWG-LS):** The focus of this working group will be the review of existing legislation and standards and institutional roles and responsibilities as applying to environmental contamination, monitoring and management in Nigeria. The group will discuss the required changes and make further detailed recommendations to the Government of Nigeria.

5. **Technical Working Group on Community and Communication (TWG-CC):** This group will have the important task of communicating with, and gaining the approval of, Ogoni communities regarding the contents of UNEP's report, including the key recommendations and follow-up actions.

7.5 Transition Phase

With the submission of this report, the Environmental Assessment of Ogoniland project comes to an end. If the Government of Nigeria accepts the various recommendations in this report, a new institution, the Ogoniland Environmental Restoration Authority (OERA), will be established to carry forward the work towards the clean-up and environmental restoration.

However, in the period between when the report is published and the new authority is in place, there needs to be an interim arrangement to maintain the existing positive momentum, keep the issues active and continue to move towards environmental restoration.

It is therefore proposed that a Transition Phase is initiated as a priority, which would help ensure a seamless transition from UNEP's environmental assessment to the clean-up of oil contamination. The key objectives of the Transition Phase will be:

- developing terms of reference for the technical working groups
- detailed design for, and establishment of, the OERA
- identifying members for the various technical working groups
- providing a secretariat for the working groups
- providing capacity building, such as training, to support the working groups
- identifying the preferred site for setting up the Integrated Contaminated Soil Management Centre
- gathering commercial and technical information for detailed design of the clean-up plans
- initiating the ambient environmental monitoring of various environmental sectors, and
- preparing a socio-economic study for the development of a livelihoods strategy for Ogoniland.

Appendices

Appendix 1
Acronyms and abbreviations

ASTER	Advanced Spaceborne Thermal Emission and Reflection Radiometer
ASTM	American Society for Testing and Materials (known as ASTM International)
Ba	barium
bgs	below ground surface
bpd	barrels per day
BTEX	benzene, toluene, ethylbenzene, xylenes
CDU	crude distillation unit
CL	Contaminated Land
cm	centimetre
cps	counts per second
DPR	(Nigerian) Department of Petroleum Resources
EGASPIN	Environmental Guidelines and Standards for Petroleum Industry in Nigeria
EIA	environmental impact assessment
FCCU	fluid catalytic cracking unit
g	gram
GC	gas chromatography
GC-FID	gas chromatograph-flame ionization detector
GC-MS	gas chromatograph-mass spectroscopy
GPS	Global Positioning System
ha	hectare
HDPE	high-density polyethylene
ICP-MS	inductively coupled plasma mass spectrometry
IPIECA	International Petroleum Industry Environmental Conservation Association
ICSMC	Integrated Contaminated Soil Management Centre
keV	kilo-electron volt
kg	kilogram
km	kilometre
km2	square kilometre
l	litre
LGA	local government area
LPG	liquefied petroleum gas
m	metre
m2	square metre
m3	cubic metre
mg	milligram
ml	millilitre
mm	millimetre
MOPOL	Nigerian mobile police
MOSOP	Movement for the Survival of the Ogoni People

m/s	metres per second
msl	mean sea level
MTBE	methyl tertiary butyl ether
MW	megawatt
NNPC	Nigerian National Petroleum Company
NORM	naturally occurring radioactive material
NOSDRA	National Oil Spill Detection and Response Agency
nSv/h	nanosievert per hour
OERA	Ogoniland Environmental Restoration Authority
OGFZ	oil and gas free zone
OSCP	Oil Spill Contingency Plan
PAH	polycyclic aromatic hydrocarbon
PHRC	Port Harcourt Refining Company
PIC	Presidential Implementation Committee
PM	particulate matter
ppm	parts per million
PPMC	Pipelines and Products Marketing Company
QA/QC	quality assurance/quality control
RBCA	Risk-Based Corrective Action
RBSL	risk-based screening level
RENA	remediation by enhanced natural attenuation
RMS	(SPDC) Remediation Management System
RSUST	Rivers State University of Science and Technology
SVOC	semi-volatile organic compound
SEPCiN	Shell Exploration and Production Companies in Nigeria
SPDC	Shell Petroleum Development Company (Nigeria) Ltd
TDU	thermal desorption unit
TPH	Total Petroleum Hydrocarbon
TPHCWG	Total Petroleum Hydrocarbon Criteria Working Group
TWG-CC	Technical Working Group on Community and Communication
TWG-ER	Technical Working Group on Environmental Restoration
TWG-LS	Technical Working Group on Legislation and Standards
TWG-SM	Technical Working Group on Surveillance and Monitoring
TWG-WS	Technical Working Group on Water Supply
UNDP	United Nations Development Programme
UNDSS	United Nations Department of Safety and Security
UNEP	United Nations Environment Programme
USEPA	United States Environmental Protection Agency
µm	micrometre
µS/cm	micro Siemens per cm
VDU	vacuum distillation unit
VOC	volatile organic compound
WHO	World Health Organization

Appendix 2
Glossary

Abandonment	The act of disengaging an oil well or oil facility from active operation
Absorption	The property of some liquids or solids to soak up water or other fluids
Adsorption	The property of some solids and liquids to attract a liquid or a gas to their surfaces
Aliphatic compounds	Acyclic or cyclic, non-aromatic carbon compounds (of, relating to, or designating a group of organic chemical compounds in which the carbon atoms are linked in open chains)
Aquifer	A body of rock whose fluid saturation, porosity and permeability permit production of groundwater
Aromatic hydrocarbon	A hydrocarbon characterized by general alternating double and single bonds between carbons (of, relating to, or containing one or more six-carbon rings characteristic of the benzene series and related organic groups)
Asphalt	A solid or nearly solid form of bitumen that can melt upon heating and contains impurities such as nitrogen, oxygen and sulfur. Forms naturally when the light components or volatiles of petroleum have been removed or evaporated
Associated gas	(Also termed 'formation gas') A natural gas found in association with crude oil either dissolved in the oil or as a cap of free gas above the oil
Benthic	Pertaining to the environment and conditions of organisms living at the water bottom, or benthos
Bitumen	Naturally occurring, inflammable organic matter formed from kerogen in the process of petroleum generation that is soluble in carbon bisulfide. Includes hydrocarbons such as asphalt and mineral wax. Typically solid or nearly so, brown or black, bitumen has a distinctive petroliferous odour
Blowout	An uncontrolled flow of fluids (salt water, oil, gas or a mixture of these) into the borehole, and sometimes catastrophically to the surface. Blowouts occur in all types of exploration and production operations, not just during drilling operations
Borehole	The borehole itself (also termed 'wellbore'), including the open hole or uncased portion of the well. Also refers to the inside diameter of the borehole wall, the rock face that bounds the drilled hole
Bunkering	The act or process of supplying a ship with fuel. In Ogoniland and the wider Niger Delta, also used to refer to illegal tapping into oil industry infrastructure with a view to stealing oil
Clean-up	The act of removing pollutants from a location by treating soil and groundwater contaminated with hydrocarbons

(Petroleum) Cracking
: The breaking down of high-molecular value hydrocarbons into low-molecular weight compounds. The process involves very high temperature and pressure and can involve a chemical catalyst to improve the process efficiency

Crude oil
: Unrefined petroleum or liquid petroleum

Cuttings / tailings
: Small pieces of rock that break away due to the action of the drill-bit teeth. Cuttings are screened out of the liquid mud system and are monitored for composition, size, shape, colour, texture, hydrocarbon content and other properties

Decommissioning
: The act of disengaging an oil well or oil facility from active operation but doing so in a safe and environmentally acceptable manner

(Oil) Exploration
: The initial phase in petroleum operations that includes the location of an area in which hydrocarbon accumulations may occur and the drilling of an exploration well. Appraisal, development and production phases follow successful exploration

Feedstock
: Crude oil – essentially the hundreds of different hydrocarbon molecules in crude oil which, separated in a refinery, can be used in petrochemical processes that manufacture such products as plastics, detergents, solvents, elastomers and fibres such as nylon and polyesters

Flaring
: The burning of unwanted gas through a pipe (also called a flare). Flaring is a means of disposal used when there is no way to transport the gas to market and the operator cannot use the gas for another purpose

Flow station
: Separation facilities (also called gathering centres) which separate natural gas and water from crude oil extracted from production wells

Formation water
: Water that occurs naturally within the pores of rock

Fugitive emissions
: Emissions of gases or vapours from pressurized equipment due to leaks and various other unintended or irregular releases

Groundwater
: Water held in the pores of rocks in the subsurface below the water table

Gypsum
: A highly insoluble sulphate mineral that is the first to precipitate from evaporating seawater

Hydrocarbon
: A naturally occurring organic compound comprising hydrogen and carbon. Hydrocarbons can be as simple as methane [CH4], but many are highly complex molecules and can occur as gases, liquids or solids. The molecules can have the shape of chains, branching chains, rings or other structures. Petroleum is a complex mixture of hydrocarbons. The most common hydrocarbons are natural gas, oil and coal

Light hydrocarbons
: Hydrocarbons with low molecular weight such as methane, ethane, propane and butane

Liquefied petroleum gas
: Gas mainly composed of propane and butane, which has been liquefied at low temperatures and moderate pressures. The gas is obtainable from refinery gases or after the cracking process of crude oil

Manifold	An arrangement of piping or valves designed to control, distribute and often monitor fluid flow
Mineral oil	Oil found within rock formations, specifically petroleum or crude oil
(Drilling) Muds	Fluids prepared by mixing clay and other chemicals along with water, diesel or synthetic oil for use in oil well drilling operations.
Naturally occurring radioactive materials (NORM)	Potentially hazardous materials typically found in certain types of barium or strontium scales that may be deposited in the borehole
Oil industry	Collective term covering the exploration, extraction, production, transportation and exportation of crude oil and associated refined products
Oil spill	Accidental release of crude or refined oil products into the environment
Oil well	A well drilled into oil-bearing geological formations to produce crude oil as the primary commercial product. Oil wells almost always produce some gas and frequently produce water; most eventually produce mostly gas or water
Operator	The company that serves as the overall manager and decision-maker of a drilling project. Generally, but not always, the operator will have the largest financial stake in the project
Petroleum	Generally used to refer to liquid crude oil, a complex mixture of naturally occurring hydrocarbon compounds found in rock, ranging from solid to gas
Pigging	Forcing a device called a pig through a pipeline or a flow line for the purpose of cleaning the interior walls of the pipe, separating different products or displacing fluids
Pipeline	A tube or system of tubes used for transporting crude oil and natural gas from the field or gathering system to the refinery
Produced water	Water produced along with the oil and gas which originates from water trapped in permeable sedimentary rocks within the well bore. Disposal of produced water can be problematic in environmental terms due to its highly saline nature
Receptor	Organisms (including human beings), ecosystems or water resources at risk from exposure to oil contaminants
Remote sensing	The process of measuring, observing or analysing features of the Earth from a distance – satellite photography and radar are techniques commonly used for remote sensing
Right(s) of way	Designated land around oil pipelines or oil industry installations to facilitate access to and protection of oil industry assets
Sediment	Unconsolidated grains of minerals, organic matter or pre-existing rocks, that can be transported by water, ice or wind, and deposited
Tailings	See 'Cuttings'

Total Petroleum Hydrocarbons (TPH)
The family of hydrocarbons which originate from crude oil

Valves — Apparatus designed to maintain, restrict or meter the flow of materials through pipes, hoses, tubing or entire systems by using various mechanisms such as a choke, a ball or a gate. Valves generally function by allowing flow while in their open position, and restricting flow when closed

Wellhead — The topmost point of a well and the structure built over it. Includes control equipment such as outlets, valves, blowout preventers, casing heads and tubing heads

Principal source (adapted): 'The Oilfield Glossary: Where the Oil Field Meets the Dictionary' at www.glossary.oilfield.slb.com

Appendix 3
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Appendix 4
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Rivers State University of Science and Technology
Port Harcourt, Nigeria: http://www.ust.edu.ng/

Area of collaboration

Technical collaboration in area of contaminated soil and groundwater, aquatic, vegetation and public health.

Al Control Laboratories
Chester, United Kingdom: http://www.alcontrol.com/

Area of collaboration

Analyses of all soil, sediment and water samples. Specialised analyses of crude oil samples.

Spiez Laboratory
Spiez, Switzerland: http://www.labor-spiez.ch/en/lab/index.htm

Area of collaboration

Analyses of Naturally Occurring Radioactive Materials (NORM).

Fugro Nigeria Limited
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Area of collaboration

Drilling and installation of groundwater monitoring wells.

Universal Survey Services
Port Harcourt, Nigeria: http://www.universalsurveyservices.com

Area of collaboration

Topographic survey of the groundwater monitoring wells.

ALS Scandinavia AG
Luleå, Sweden: http://www.alsglobal.se/default_eng.asp

Area of collaboration

Analyses of fish samples.

Rivers State Polytechnic
Bory, Nigeria: http://rivpoly.net/

Area of collaboration

Assistance with site access and community liaison.

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Concerns over petroleum-related contamination have been at the heart of social unrest in Ogoniland, a kingdom in Rivers State, Nigeria. Although oil industry operations were suspended in Ogoniland in 1993, widespread environmental contamination remains.

Following a request from the Government of the Federal Republic of Nigeria, UNEP conducted an independent study to determine the environmental and public health impacts of oil contamination in Ogoniland, and options for remediation. This report sets out the background and context to the present-day conditions in Ogoniland, provides a synthesis of UNEP's findings and gives a set of overarching recommendations to deal with the multi-faceted environmental challenges currently facing the Ogoni people.

The assessment covers thematic issues of contaminated land, groundwater, surface water, sediments, vegetation, air pollution, public health and institutional reform. It represents the best available understanding as to what has happened to the environment of Ogoniland – and the corresponding implications for affected populations – and provides clear operational guidelines as to how that legacy can be addressed.

UNEP wishes to acknowledge and thank the many members of the Ogoni community who contributed to this study, without whose cooperation the assessment would not have been possible.

The report and data gathered by UNEP as part of its assessment are available online at: www.unep.org/nigeria

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