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
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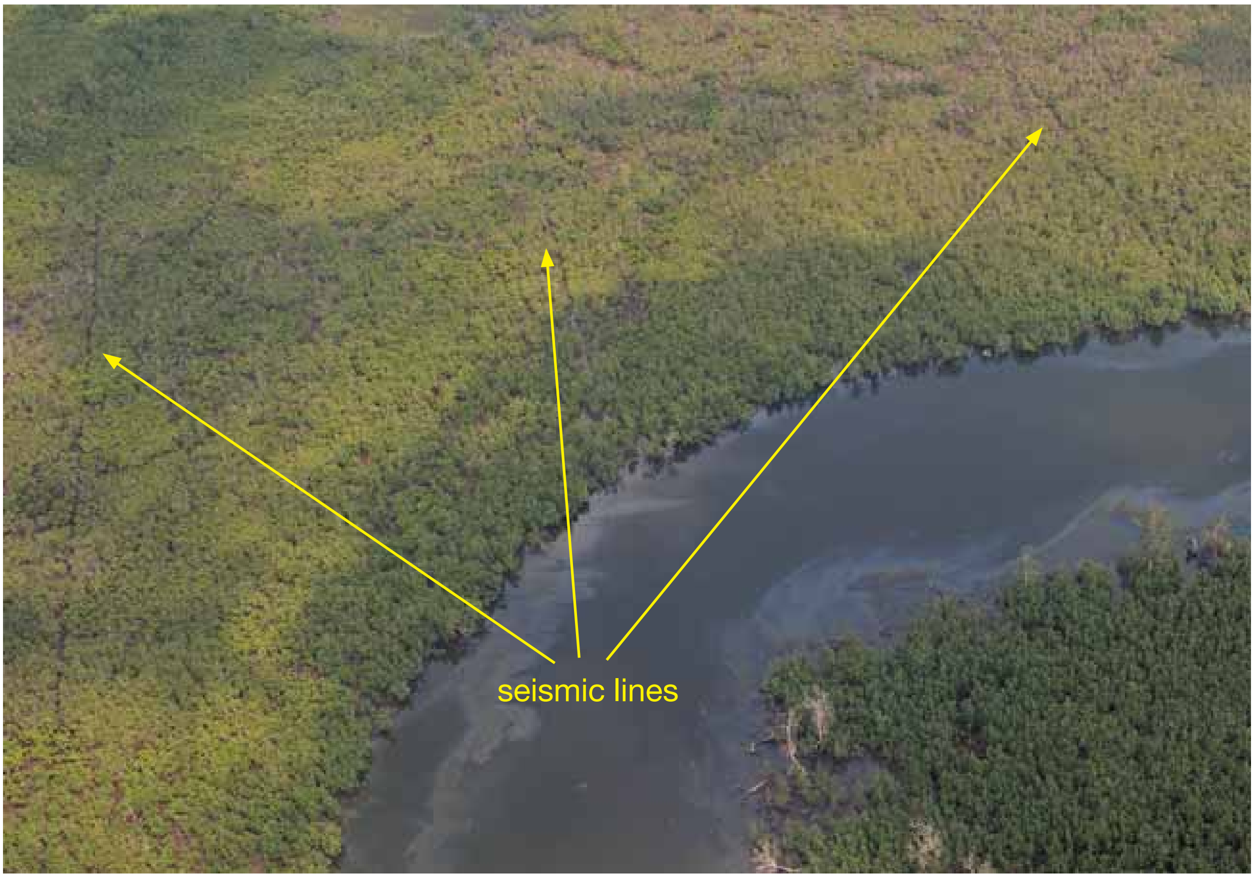
Chapter 4 dealt with site-specific land contamination issues where the focus was on soil and groundwater contamination. Sites were assessed on a case-by-case basis, where it was often possible to pinpoint the source of the contamination and identify the operator responsible for clean-up. Soil and groundwater 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.

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.

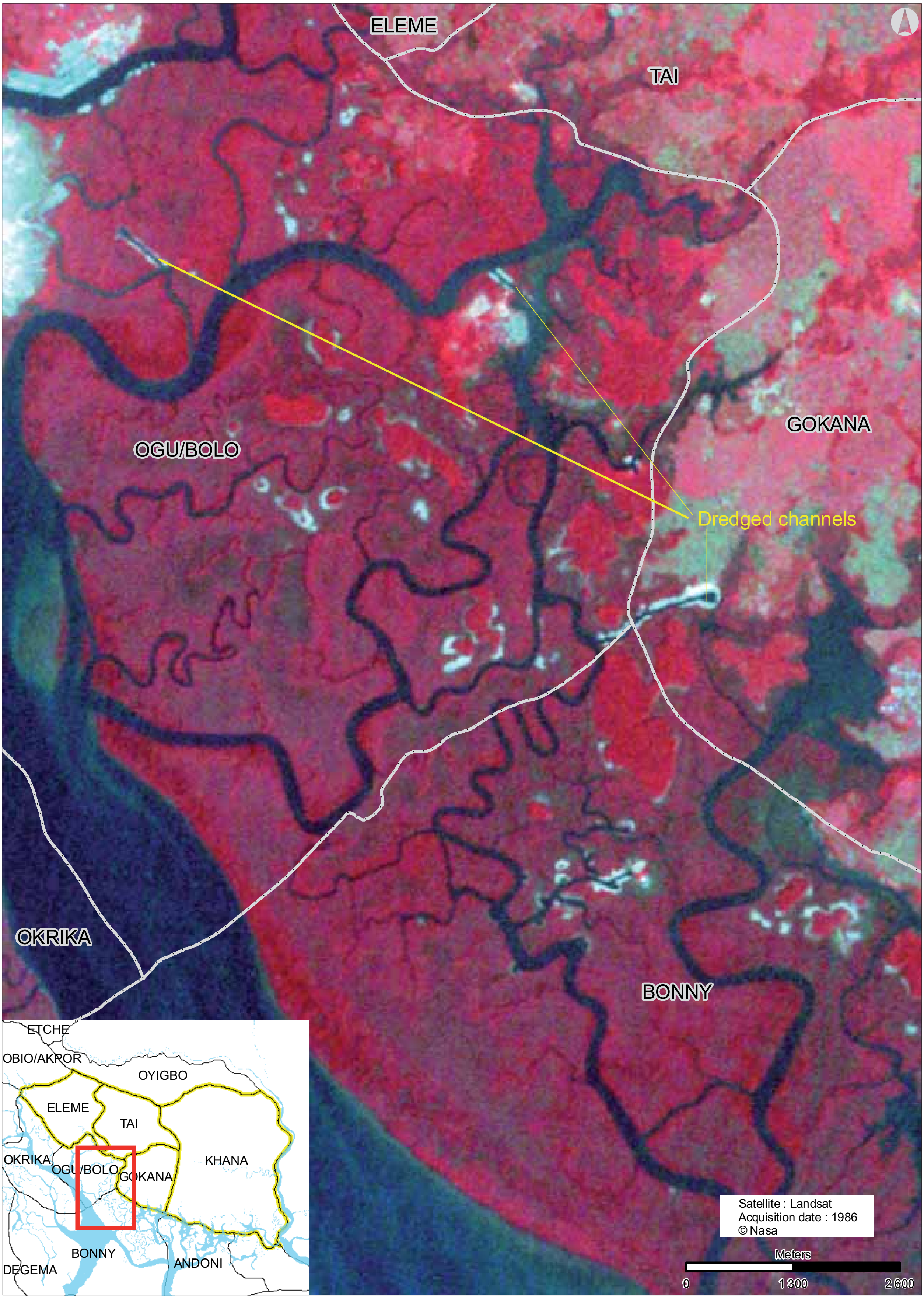
Without proper rehabilitation, former mangrove areas have been converted to bare ground which eventually may become colonized by invasive species such as nipa palm. The impacts of dredging on mangroves are far reaching because it affects almost all components of the ecosystem, including the mangrove 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

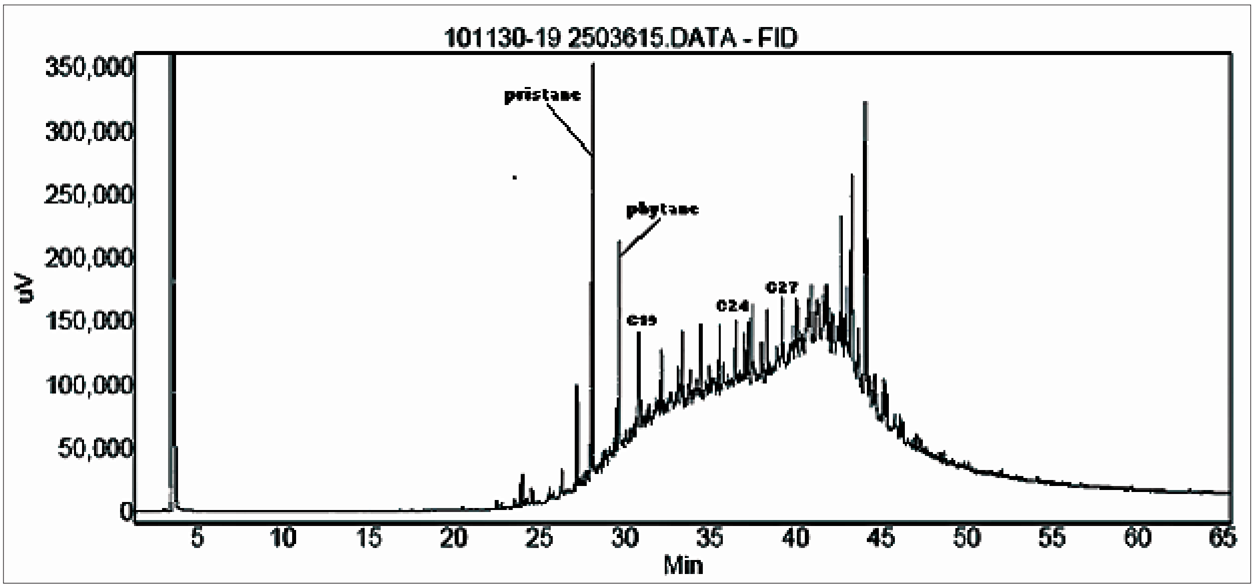
The impact of oil on mangrove vegetation in Ogoniland has been disastrous, as was evident to the UNEP team during an early reconnaissance mission along the creeks. Impacts vary from extreme stress to total destruction. In the most impacted areas, only the roots of the mangroves remains, with no stems 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

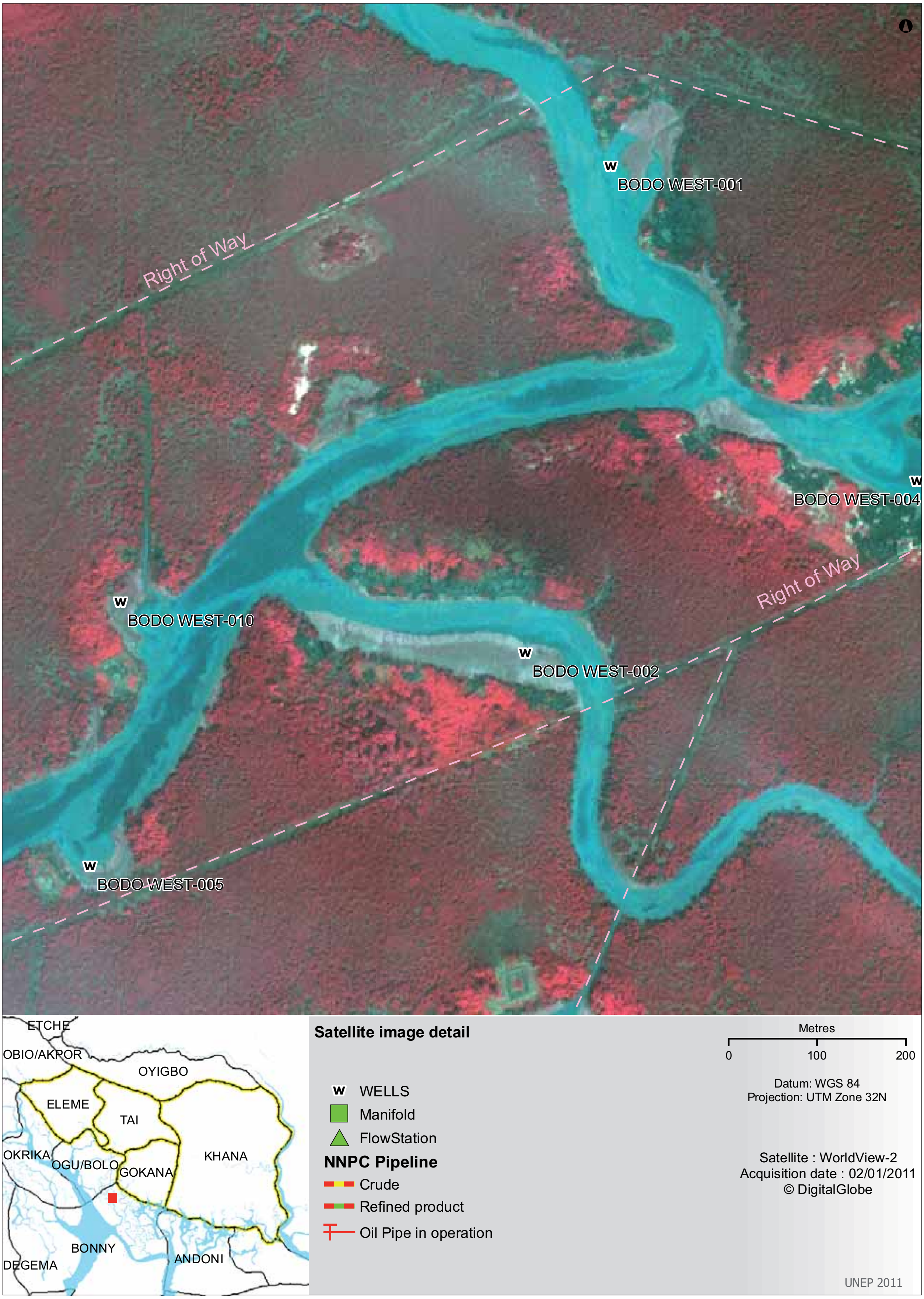
From a typical GC fingerprint of the hydrocarbon coating the mangrove roots (Figure 14), it can be seen that the hydrocarbon is highly degraded with extensive depletion of low molecular mass alkanes (saturated hydrocarbons) and dominance of pristine/phytane isoprenoids (naturally occurring organic chemicals). 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.

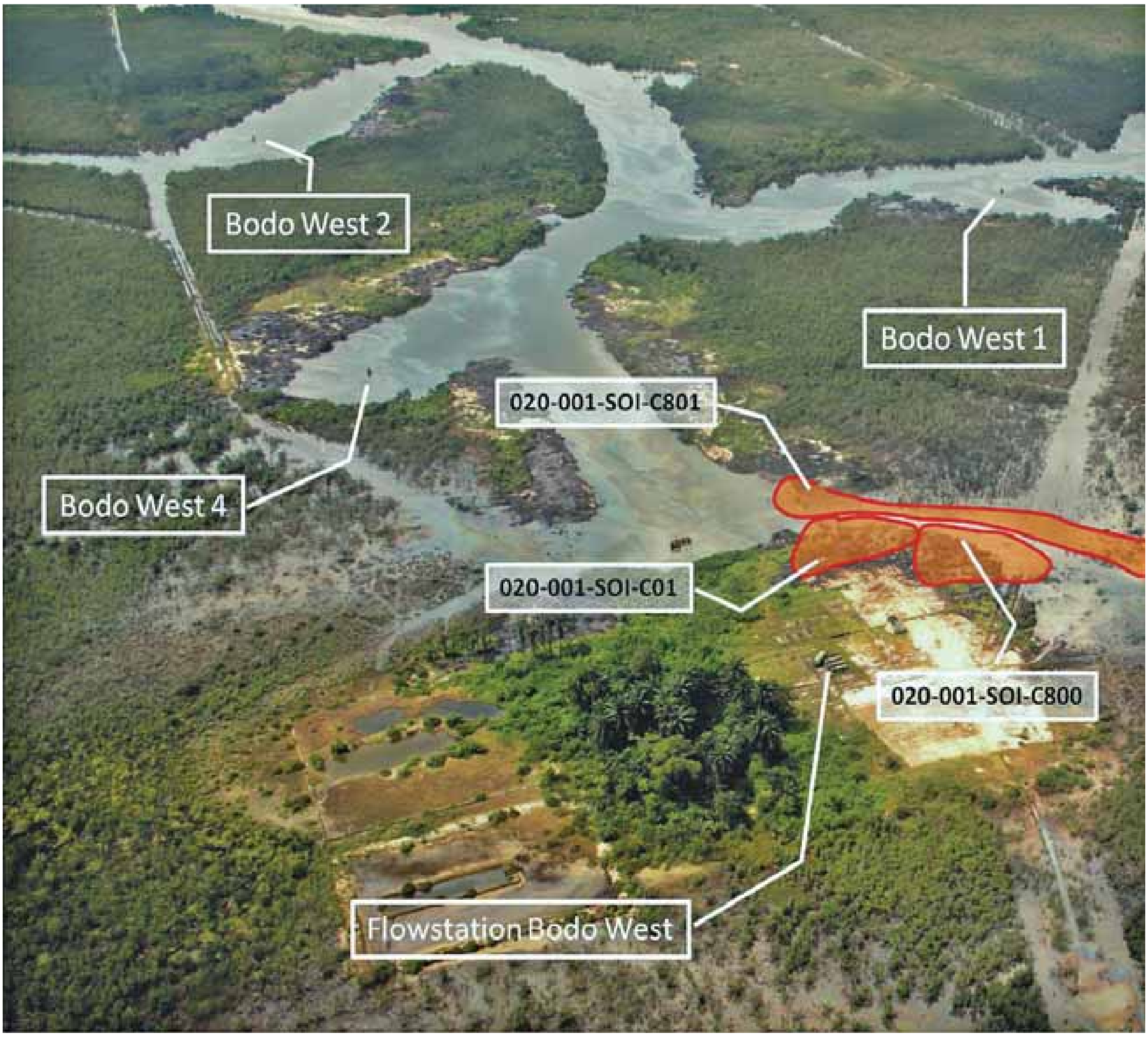
Arranging a field visit to Bodo West was logistically complex, requiring permission and support from the local police as well as the navy. The team that entered the site had to be vigilant and in constant radio contact with a support team at Bodo Jetty should additional assistance have been required.

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 (m²)	Area 2011 (m²)	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.

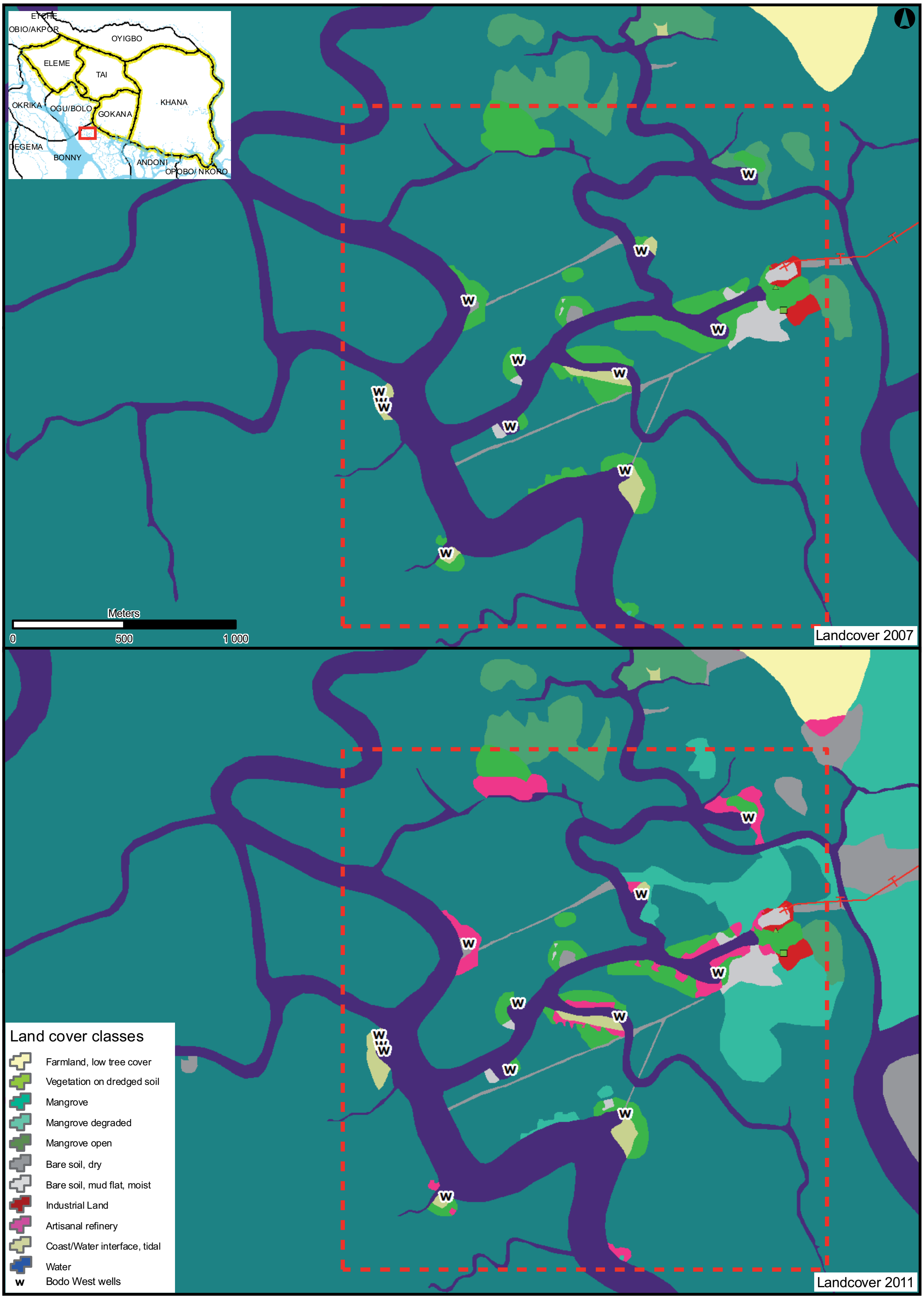
In addition, as mangroves die back and their roots decay, their binding effect is lost and sediment is exposed to erosion leading to receding shorelines [11, 50]. Other effects are changes to navigable channels and changes to the hydrology of an entire area.

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

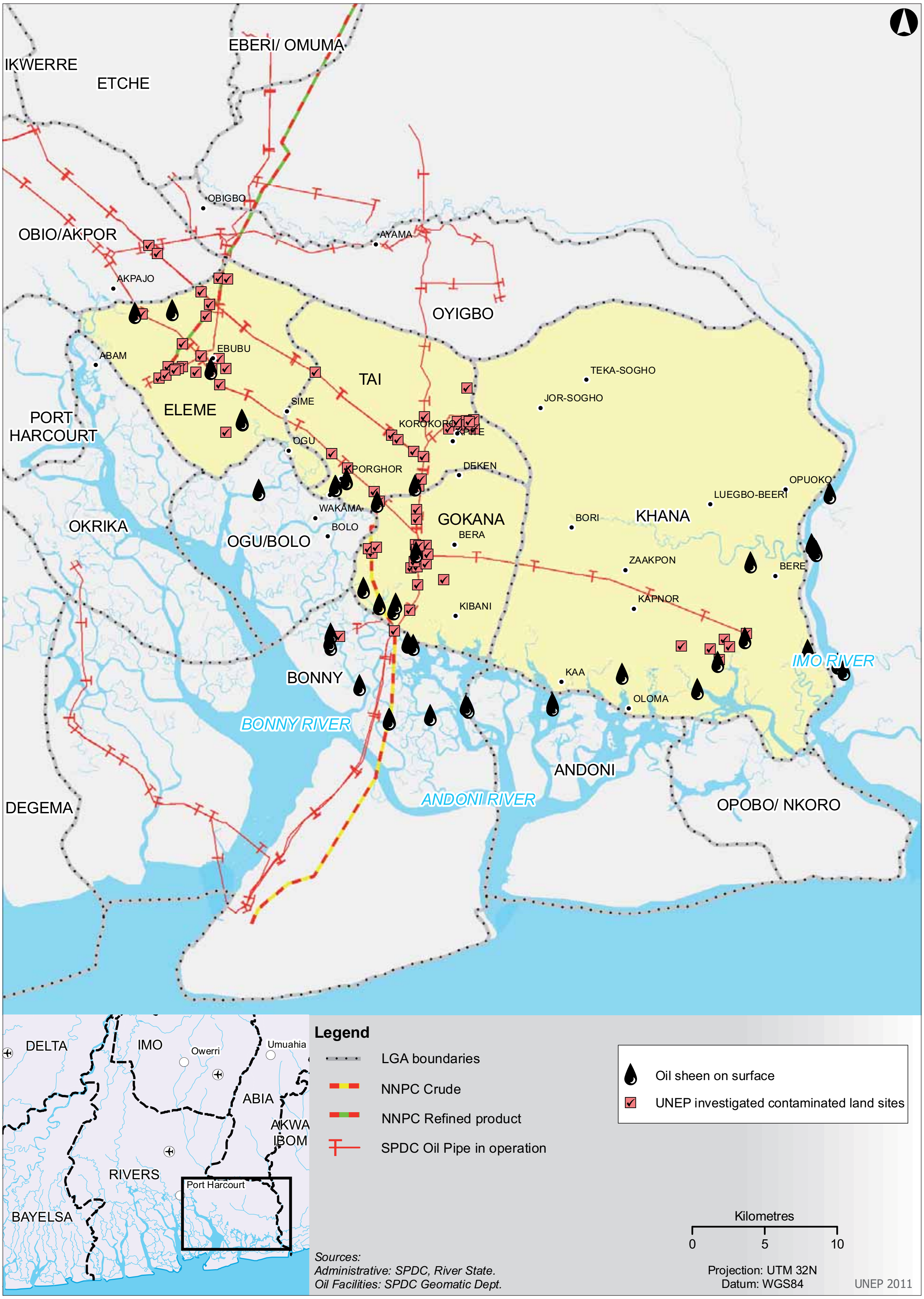
In addition to visual observations in the creeks, scientific monitoring of water, sediments and fish was also undertaken along the Imo River and the creeks in the Bodo area. The results are presented below.

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.

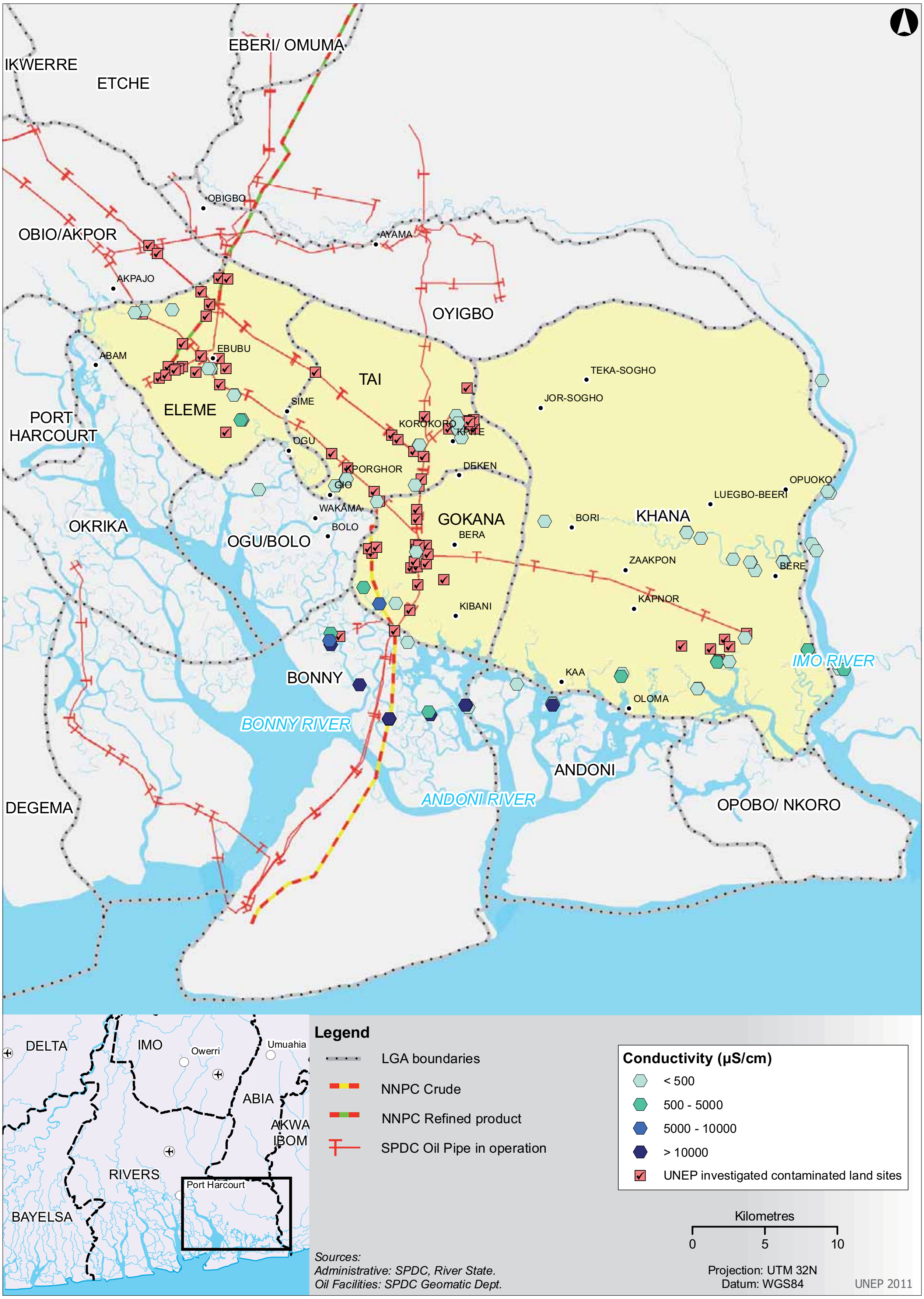
Salinity, as measured as conductivity, showed low readings as expected (Map 21), except for mangrove stations affected by the tidal flow of the Gulf of Guinea water through the Bonny and Andoni Rivers.

An aerial view of the pollution within the creeks

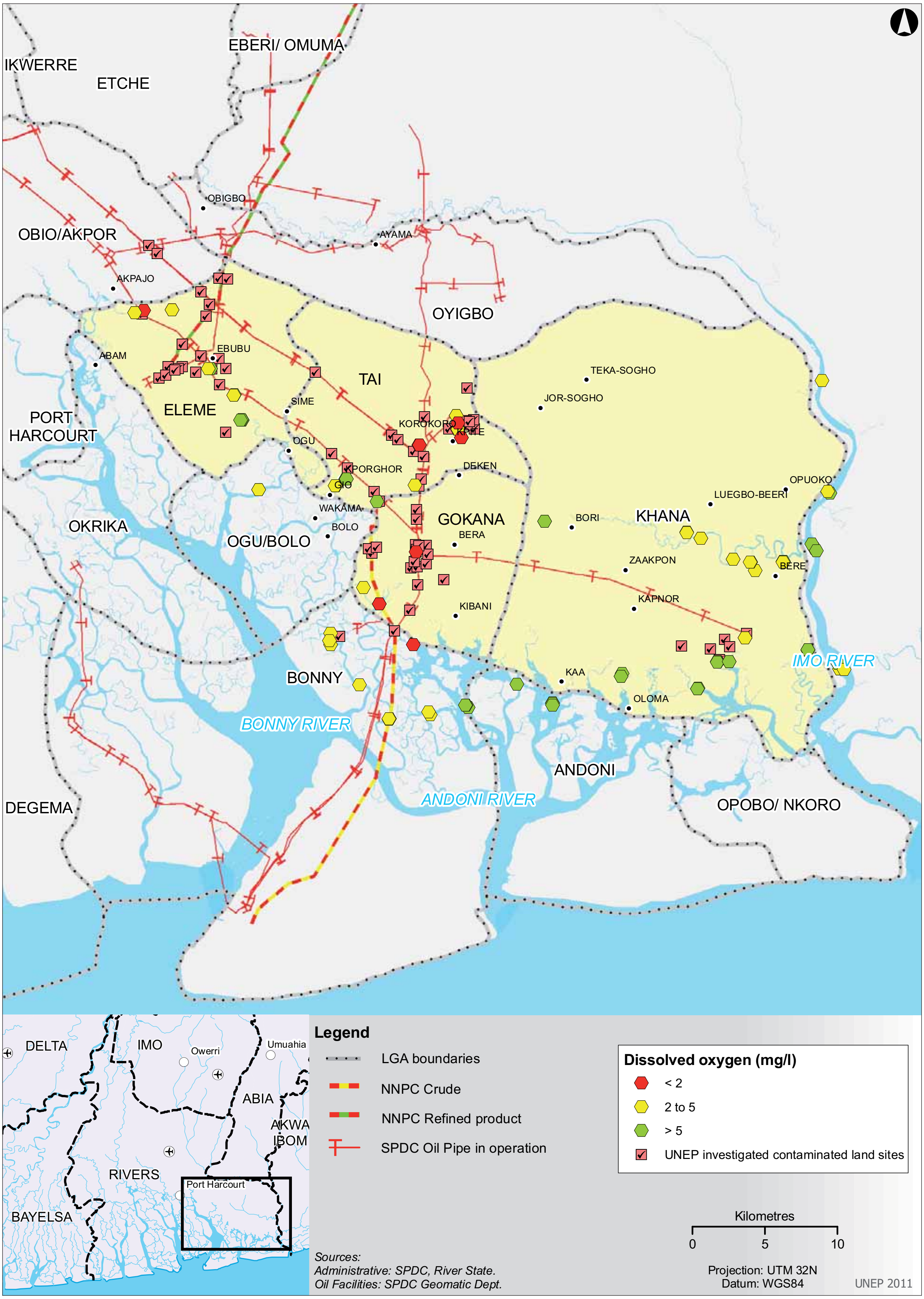
Map 20. Observed surface water sheen in surface water in and around Ogoniland



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

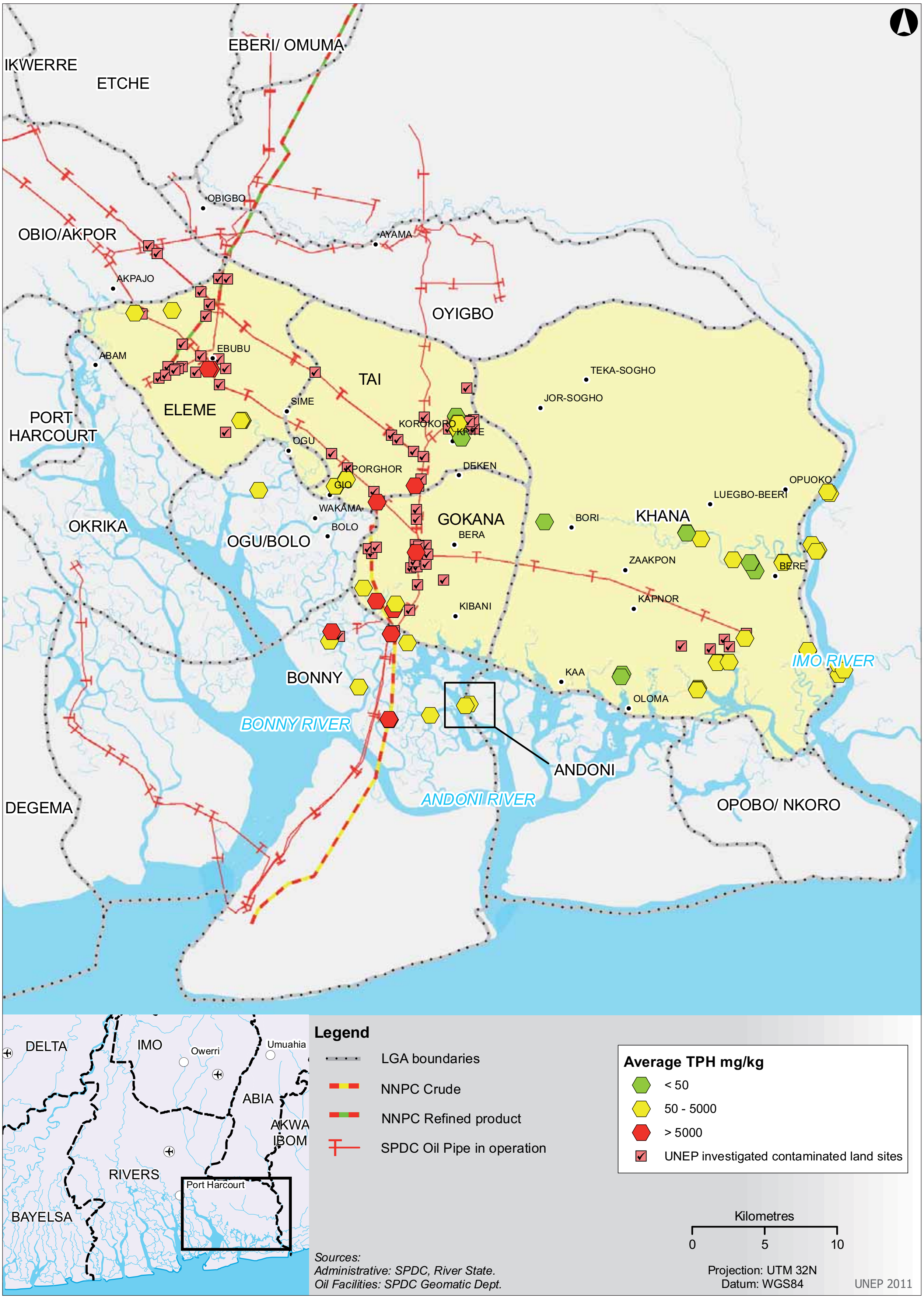


Figure 15a. Occupation of the head of household in all sampled areas of Ogoniland

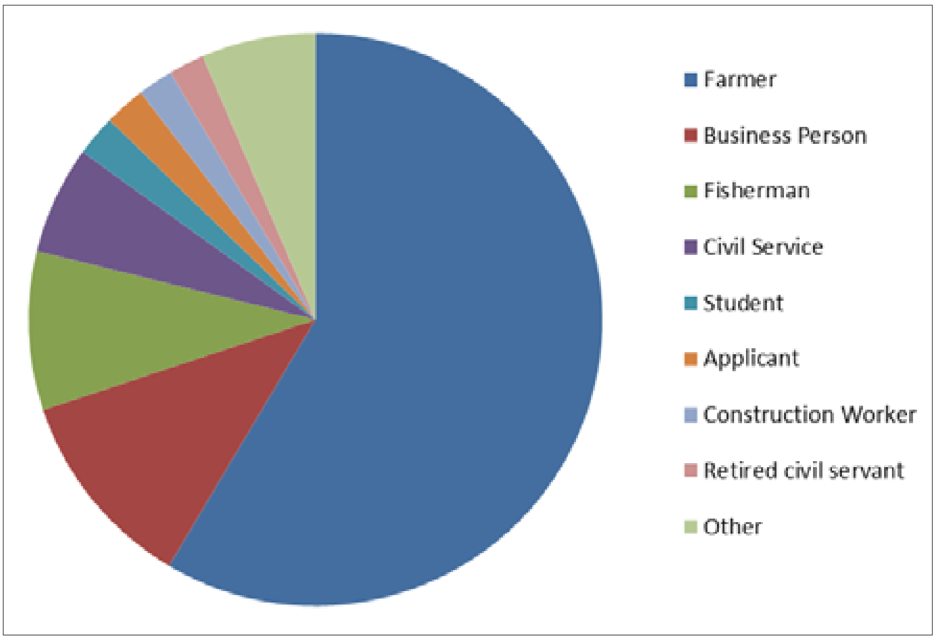
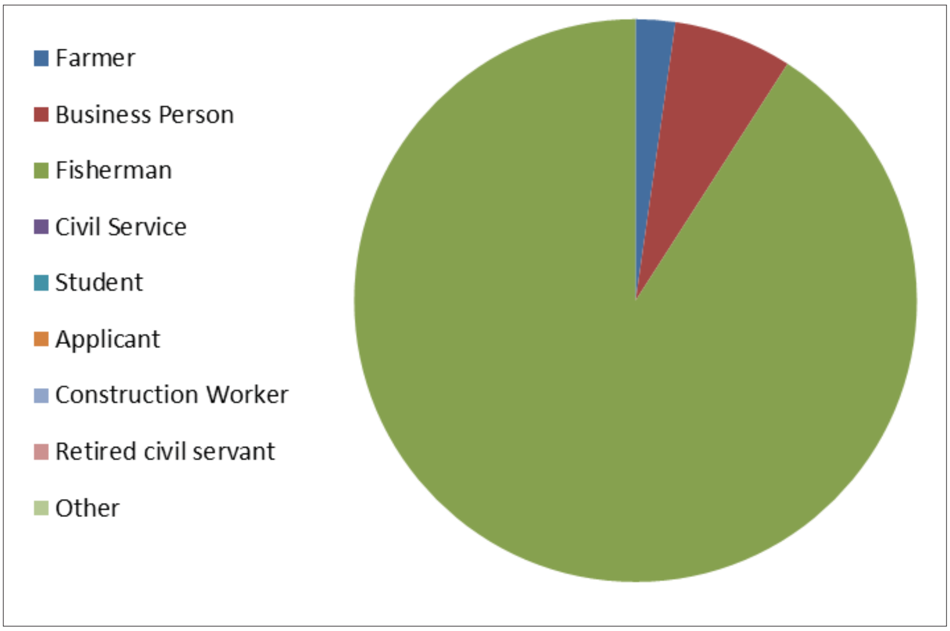


Figure 15b. Occupation of the head of household in Kaa, Khana LGA



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.

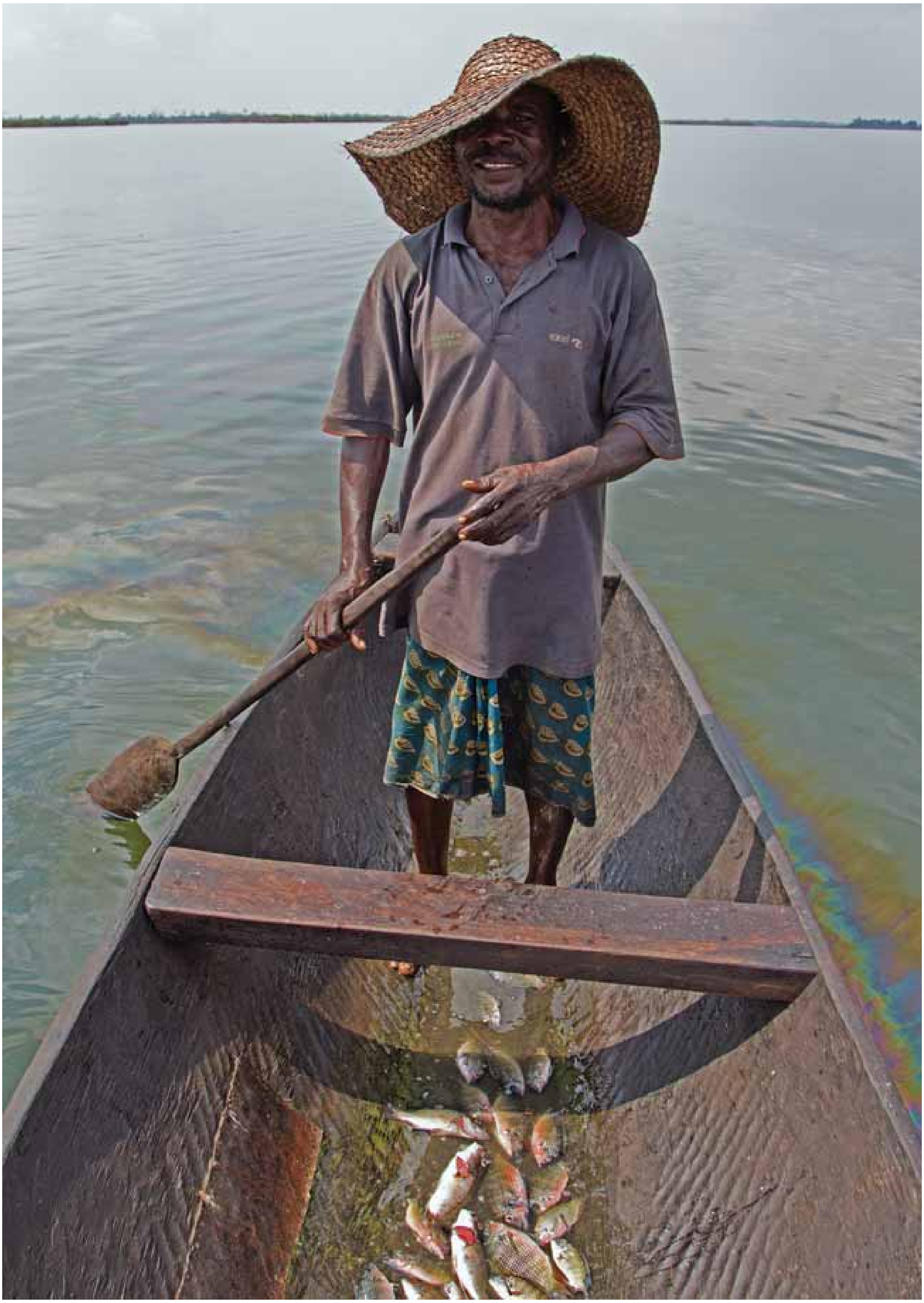
Destruction of fish habitat

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

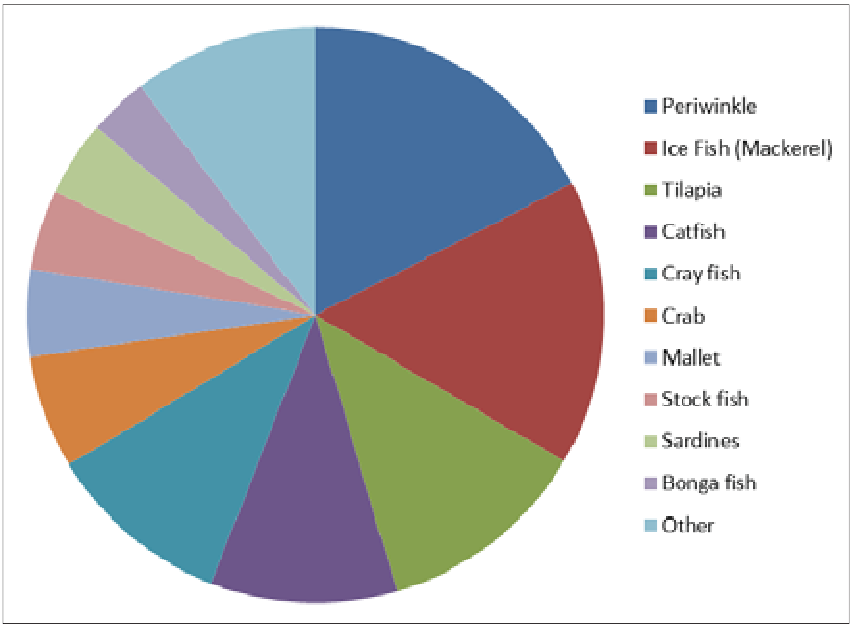
Figure 16 summarizes reported fish consumption in Ogoniland by species. Among all communities, periwinkle, ice fish, tilapia, catfish and crayfish are consumed most frequently. However, the importance of species varies considerably. In some communities, such as in the fishing village of Kaa, no one species 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

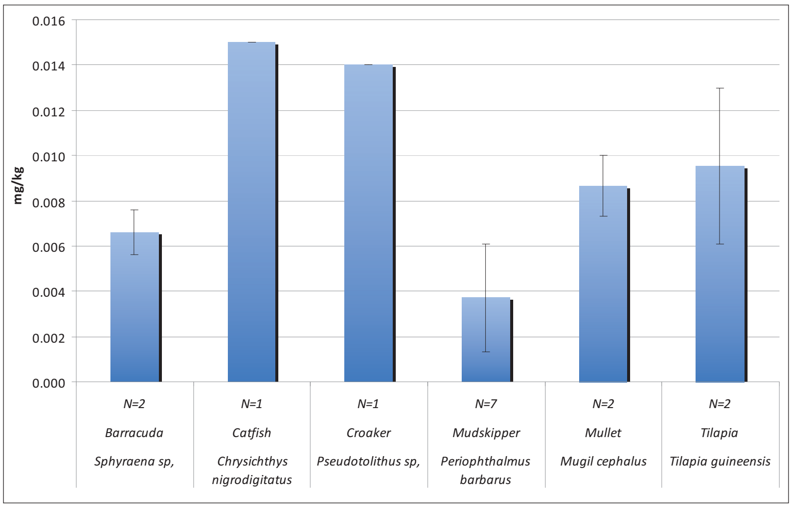


Figure 17b. Total PAHs in mollusks from fishermen

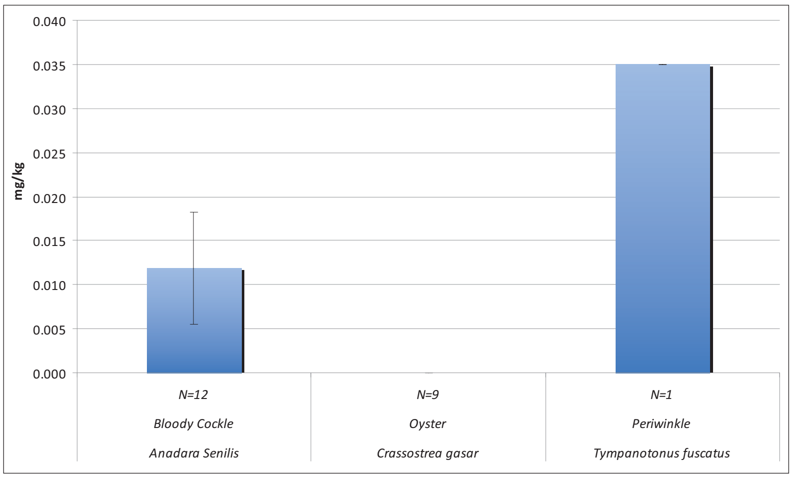
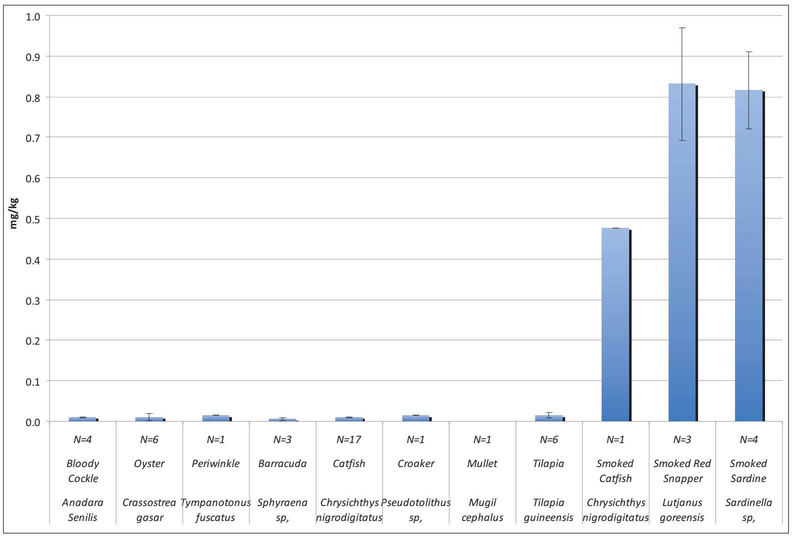


Figure 17c. Total PAHs in Fish and mollusks fought from fishermen and markets



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

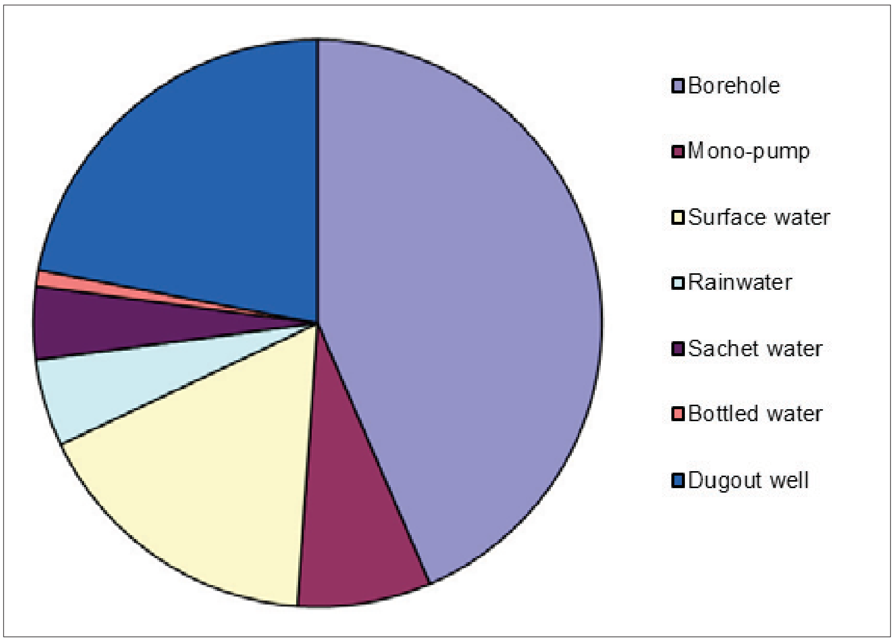


Figure 19. Sources of bathing and washing water

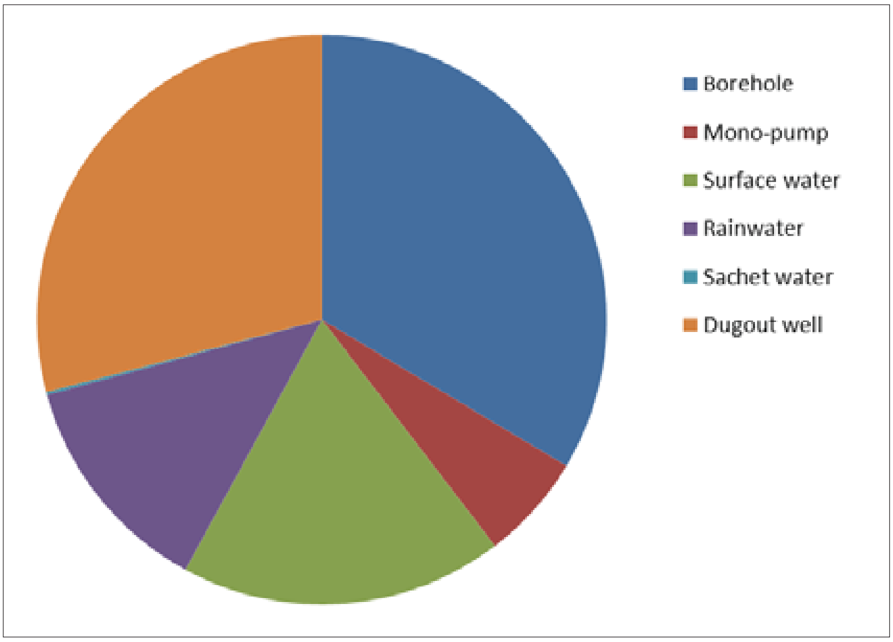


Figure 20. Primary health-care providers for the community

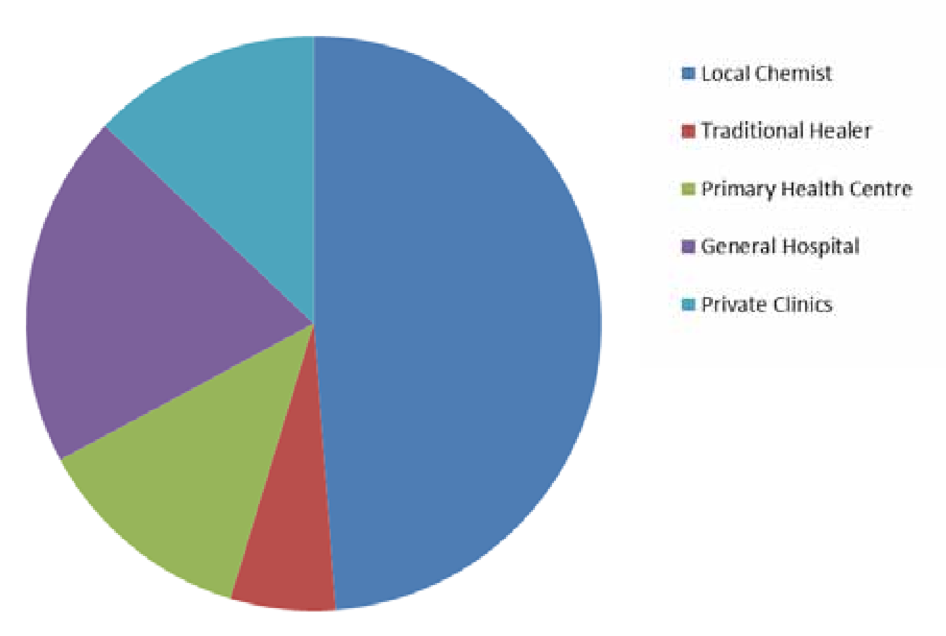


Table 42. Basic parameters and observations on rainwater samples

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.

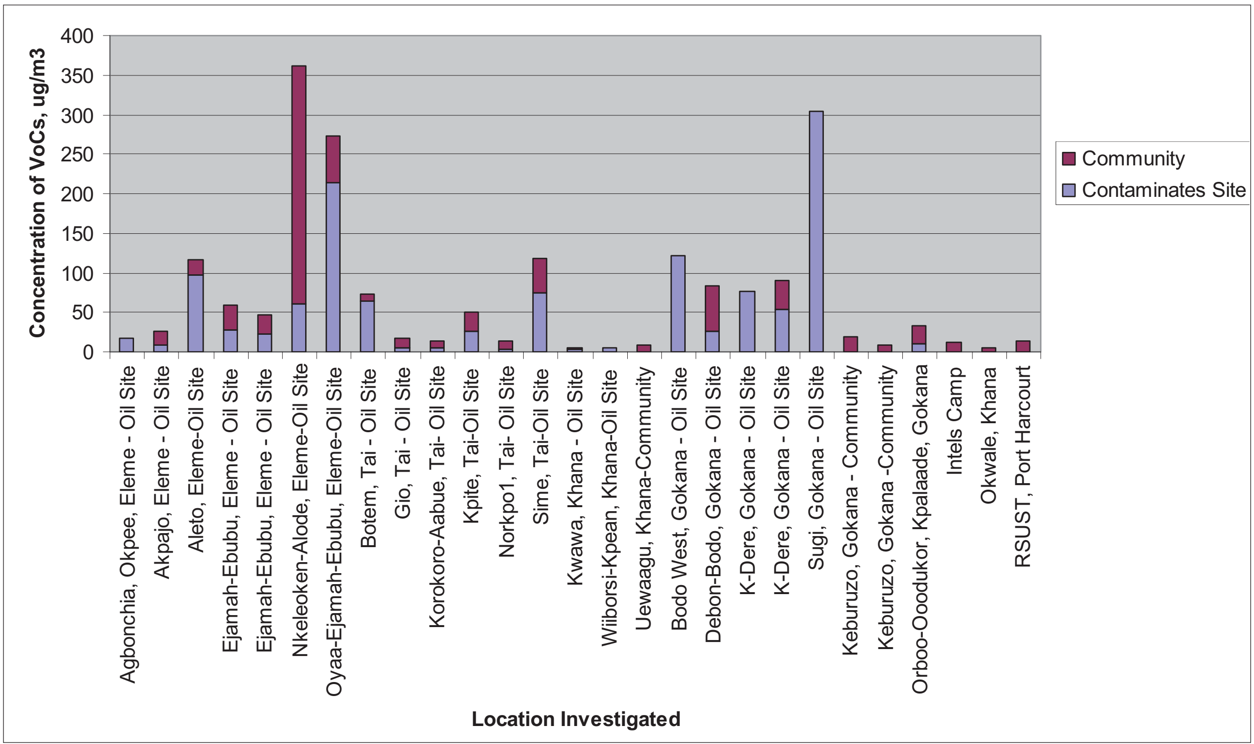
As the situation warranted immediate attention, UNEP communicated this information to the Government of Nigeria in December 2010 once laboratory results had been confirmed, along with the following recommendations:

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.

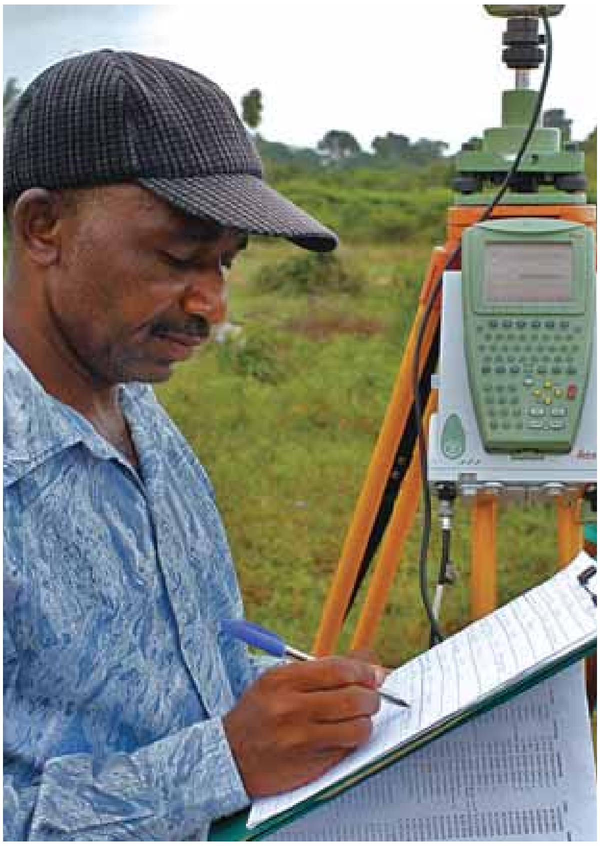
Concentrations of VOCs in air were generally higher near oil spill locations with larger quantities of relatively unweathered product on the ground than at spill locations with weathered or combusted oil. This was to be expected given that these VOCs are among the petroleum hydrocarbons that volatilize 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 µg/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

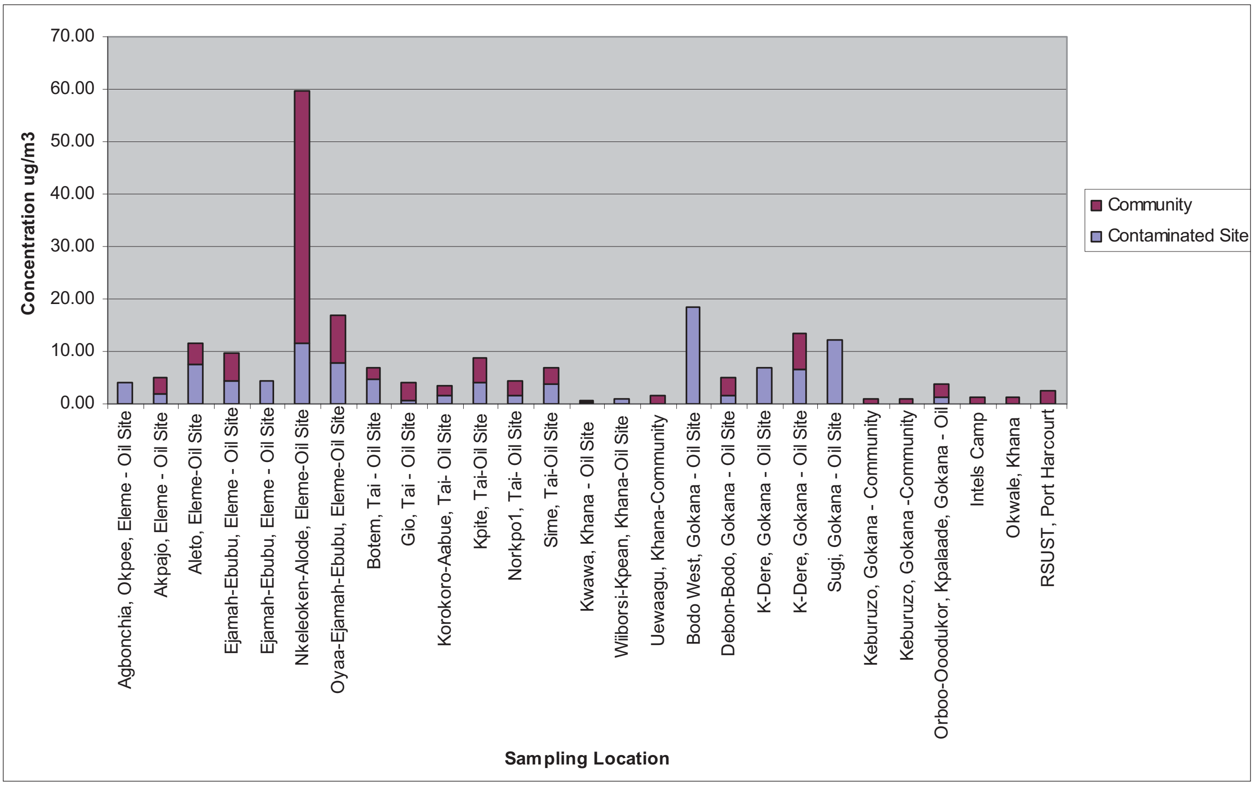


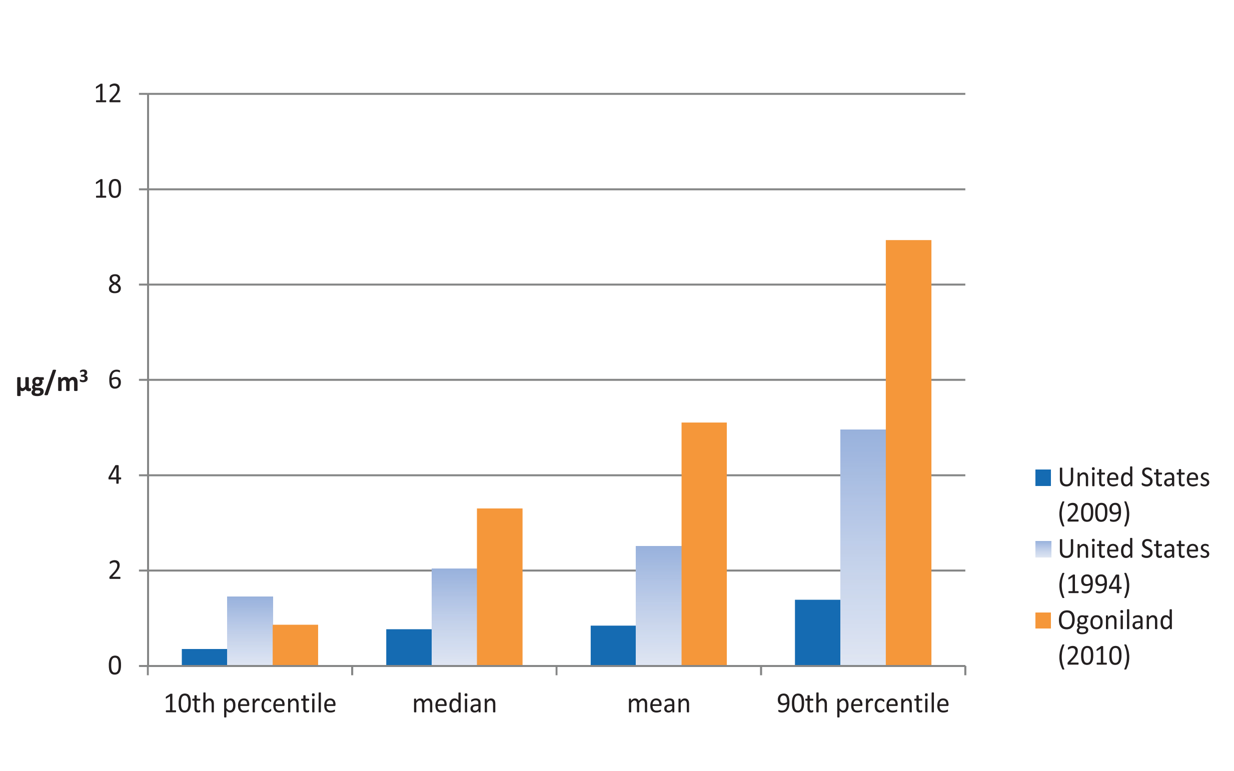
Table 46. Concentrations of benzene in air that correspond to different levels of excess lifetime cancer risk, reported by WHO and USEPA

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

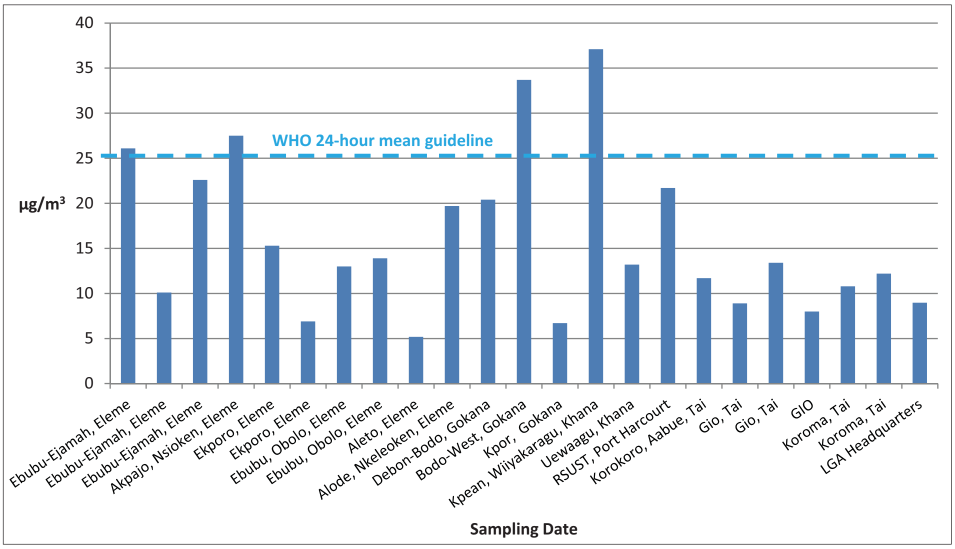
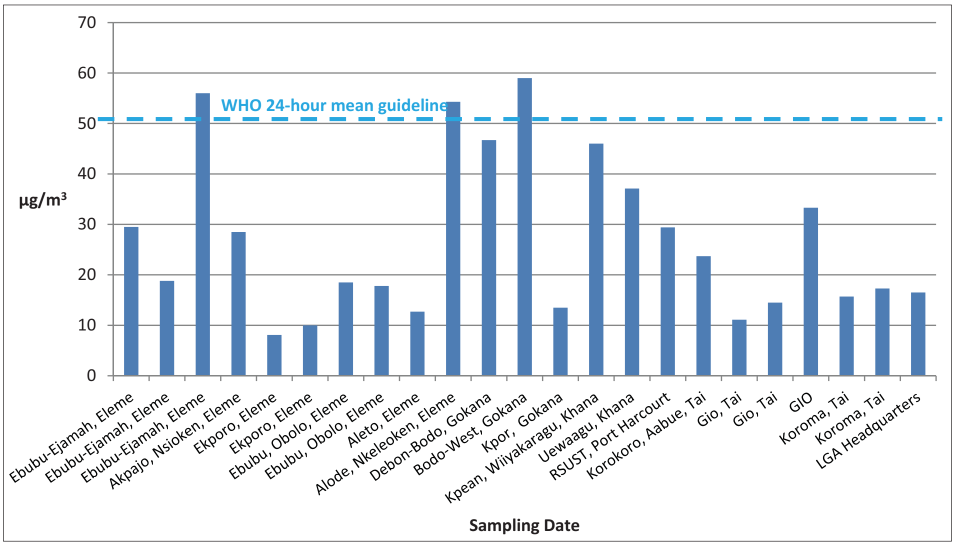


Figure 24b. One-hour concentration of particulate matter (PM10) in Ogoniland



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

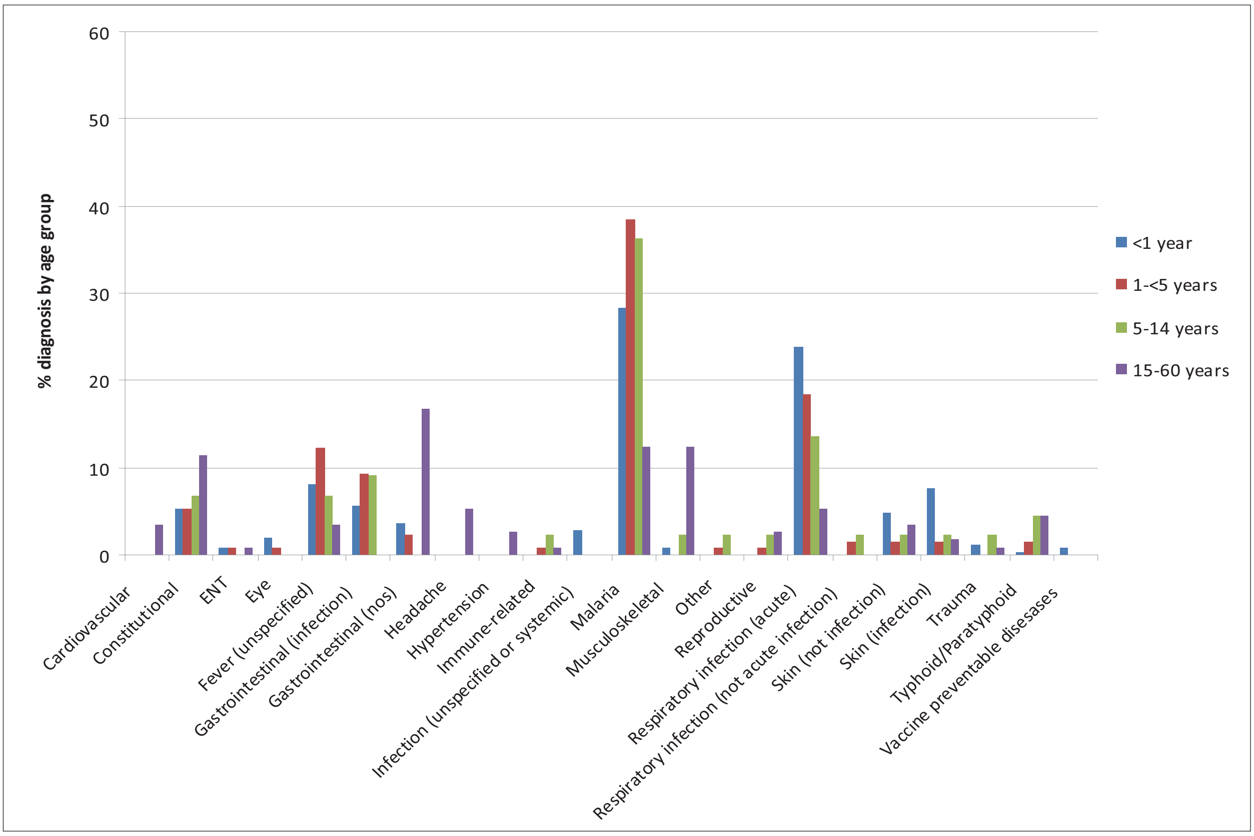


Figure 25b. Frequency of health symptoms in Ogoniland

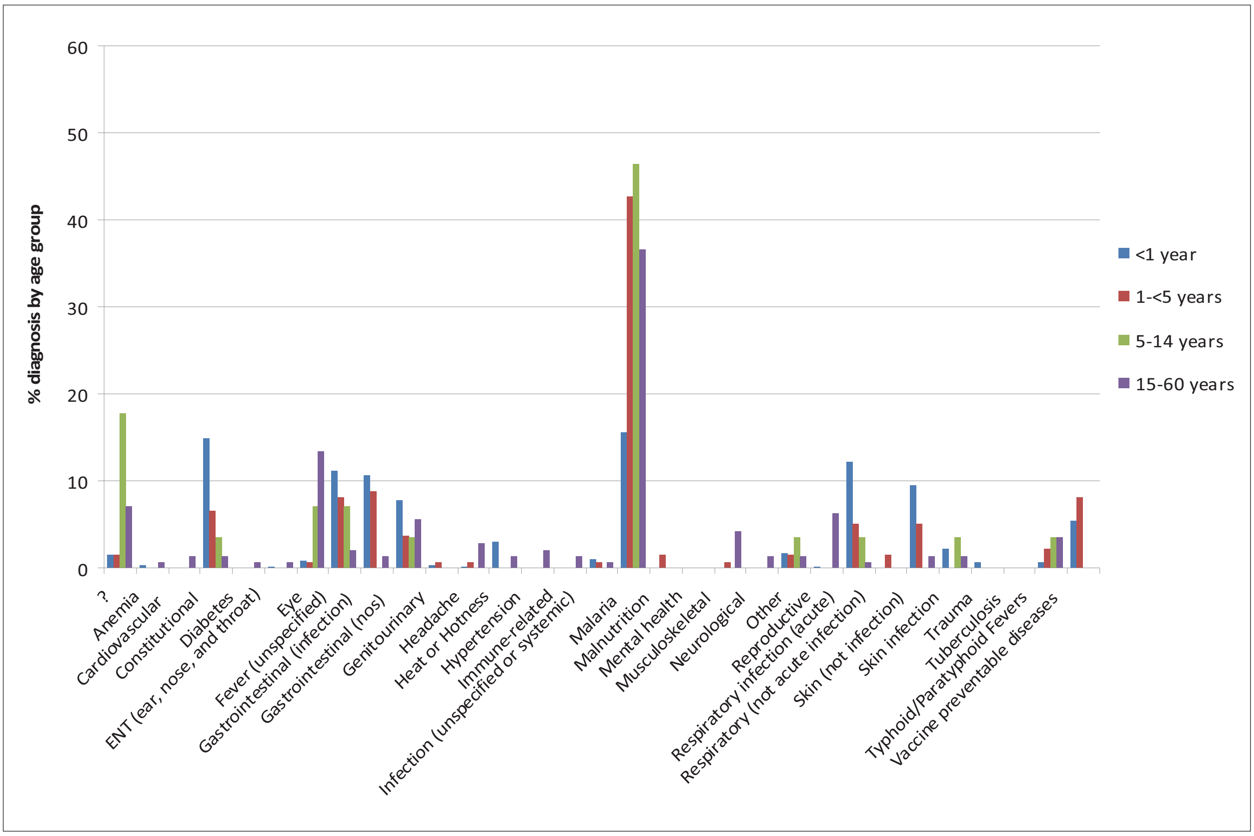


Figure 25c. Frequency of health symptoms in Ogoniland

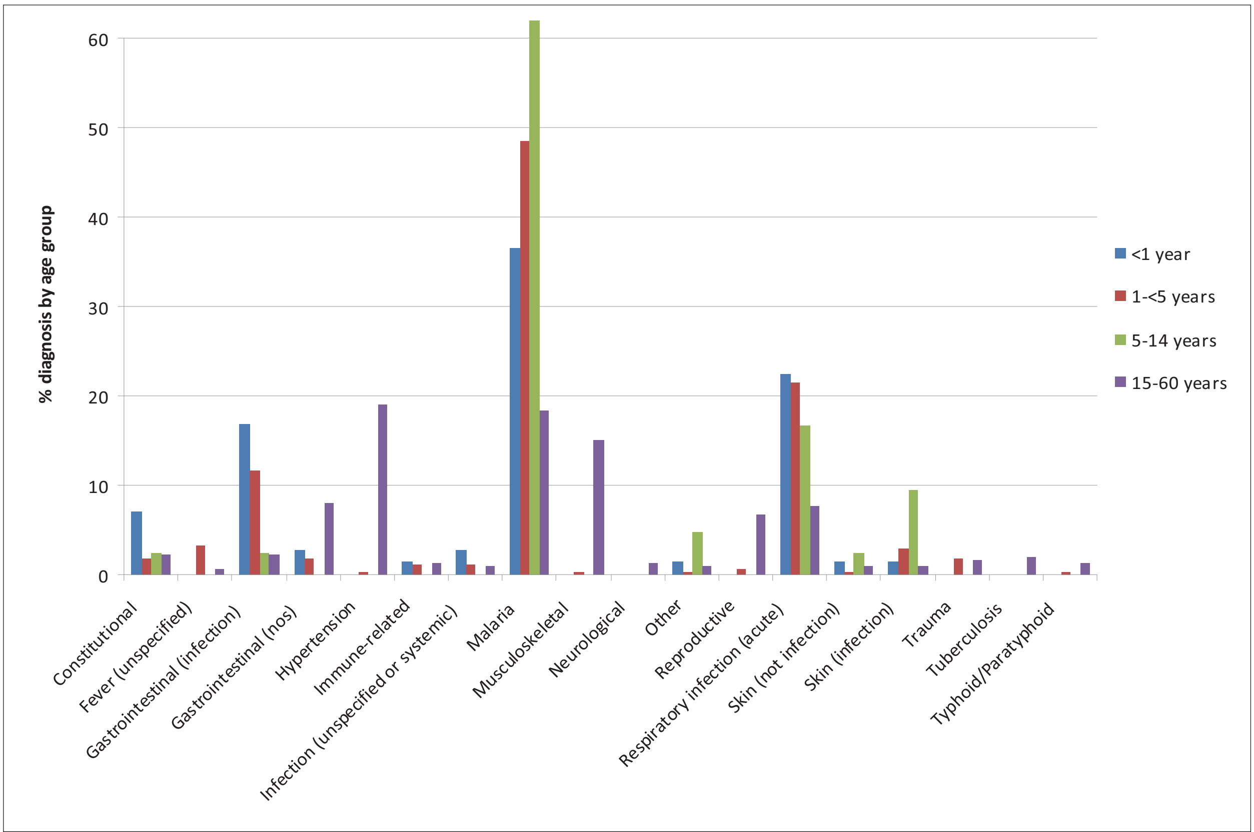


Figure 25d. Frequency of health symptoms in Ogoniland

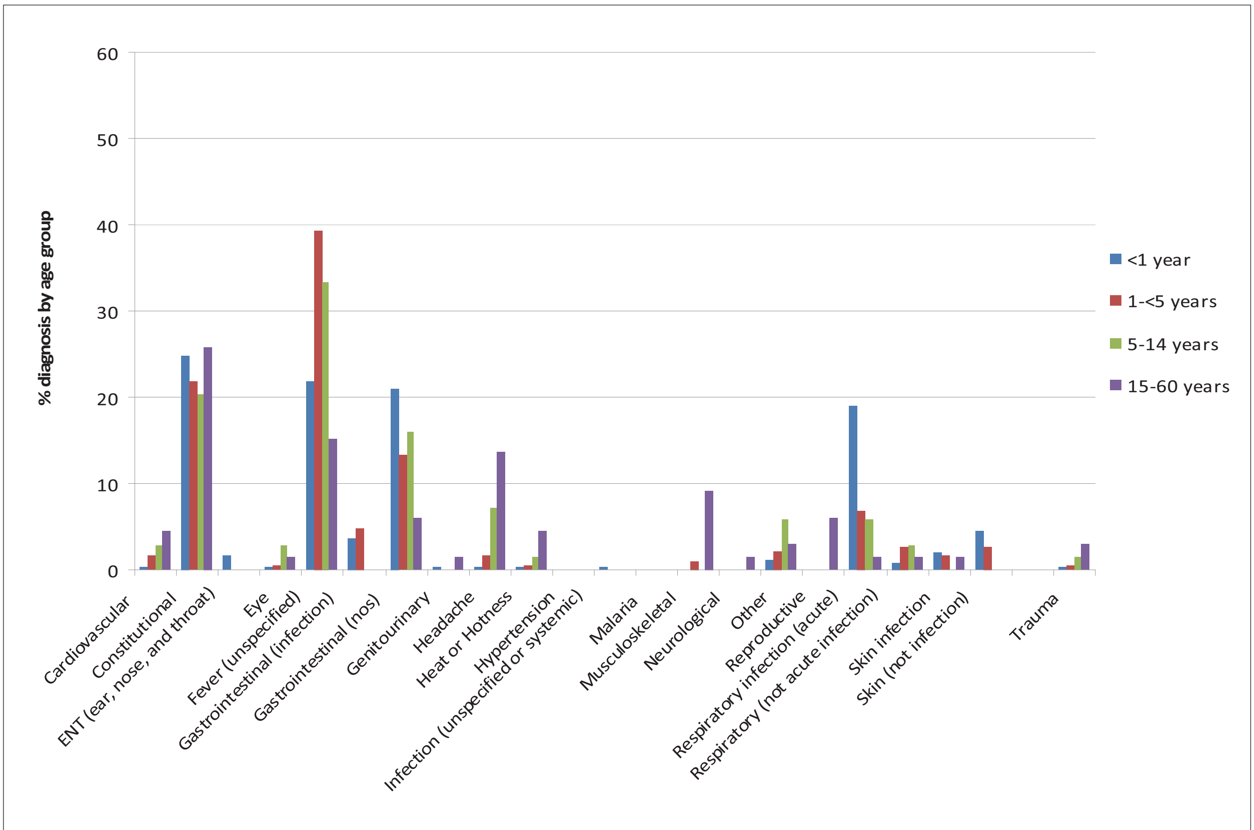
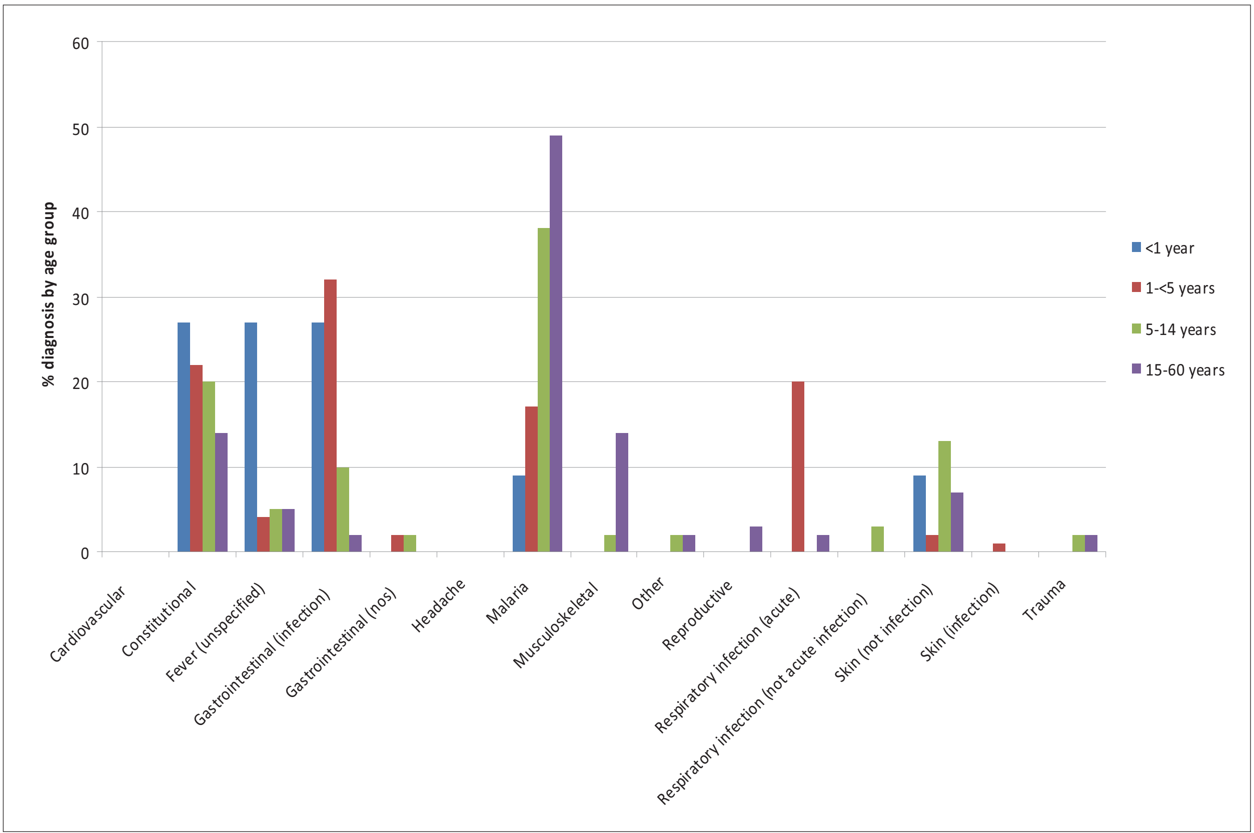


Figure 25e. Frequency of health symptoms in the reference primary health-care centre in Okwale



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.

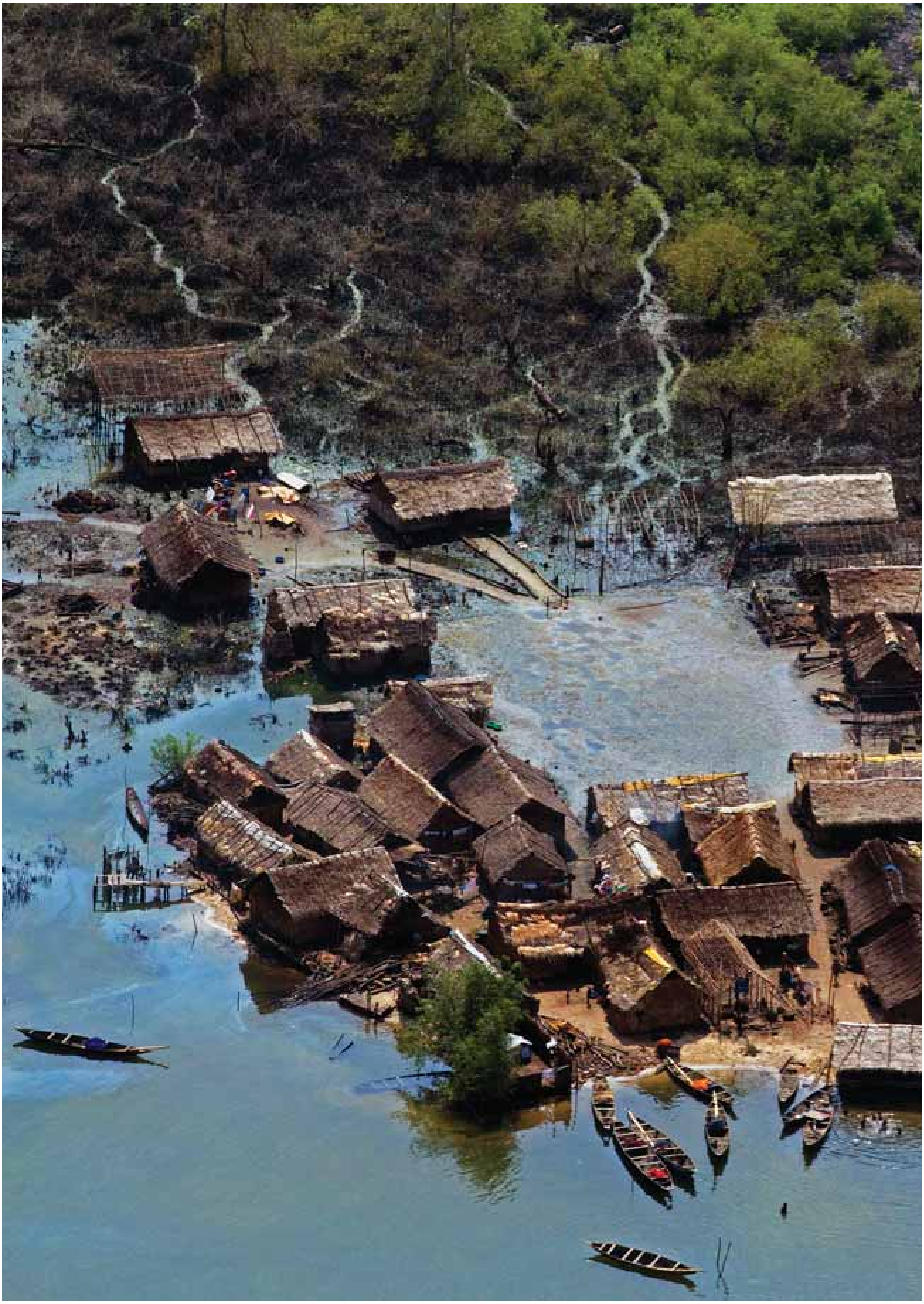
Ogoniland is not an island

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)