

CRANFIELD UNIVERSITY

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SCHOOL OF APPLIED SCIENCES
THE NIGER DELTA: ASPECTS OF HUMAN HEALTH RISK
ASSOCIATED WITH THE PETROLEUM INDUSTRY

M.Phil
Academic Year: 2010- 2014

Supervisor: DR TERRY P. BROWN
November, 2014

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ABSTRACT

The Niger Delta has been described as one of the most petroleum-polluted places in the world. The oil and gas industry located in this region is the economic mainstay of Nigeria and has contributed to key aspects of life in our modern society. However, the indigenous nationalities and residents of the Niger Delta have been exposed to appalling environmental conditions due to the operations of the upstream petroleum industry within their communities. Whereas much is known about the environmental consequences of the operations of the oil and gas industries, including the fallout of crude oil spillage incidences, comparatively, very little is known about the risks to human health due to exposures to these environmental conditions. This could be a source of fear and frustration. The knowledge about the human health repercussions of the upstream petroleum industry operations in the Niger Delta is nonexistent.

This study investigated some aspects of risk to human health in the Niger Delta due to the operations of the petroleum industry, especially carcinogenic risk. The major risk drivers were identified as benzene and the other BTEX compounds, PAHs, heavy metals, and particulates. A combination of observational studies, focus group meetings, structured self-report questionnaire administration, and cross-sectional biomonitoring assays were used as methods in the study which was carried out in Bayelsa and Rivers State. Ethnographic inquiries were undertaken to understand peculiarities and lifestyles that may underpin exposure characterisation. In the cross-sectional studies, Ogate-Elime, which has been described as the poster child of the crude oil pollution in Niger Delta was sampled. The demographics, biometrics, self-reported health effects, full blood count parameters and micronucleus count in peripheral blood lymphocytes in 258 volunteers from the community were compared with the results obtained from 111 volunteers from Rumuche, Emohua, which was analysed as the reference community.

Significantly lower counts were recorded for mean whole white blood cells ($p < 0.001$), and in the differential count, for the mixed middle cells (basophil, eosinophil and monocytes) ($p = 0.031$), lymphocytes ($p = 0.006$), while that of neutrophils approached significance ($p = 0.057$) compared with referents. Using the haematology reference range for University of Port Harcourt Teaching Hospital (UPTH) as a standard, a significantly higher proportion of respondents from the exposed community recorded

WBC counts below normal compared with respondents from the reference area ($p < 0.001$). However, the difference in the red blood cell parameters between the exposed and reference respondents was not remarkable, although the respondents sampled from the exposed community were significantly younger in age ($p < 0.001$). The cytokinesis-block micronucleus assay in peripheral blood lymphocytes showed significantly higher mean count per 1000 binucleate cells in the exposed respondents ($P < 0.001$).

A significantly higher prevalence rate of cough was self-reported among the exposed respondents. Although the prevalence of cold, catarrh and stuffy nose was only marginally higher among the exposed respondents, those that self-reported this respiratory symptom had significantly higher frequencies of it compared with those that self-reported from the reference community ($P = 0.003$). Despite the fact that the prevalence rate of wheeze was higher in the reference community, the respondents sampled from the exposed community had a much lowered age of first attack ($p = 0.002$). The prevalence of dizziness self-reported in the respondents from the exposed community compared with the reference community was also significantly higher ($p = 0.019$).

The impacts of the protracted oil spillages and environmental despoliation on the mental and psychological health of the residents and indigenous people of the Niger Delta have derived from the social, cultural and economic disruption attendant to these events, including post-traumatic stress disorders, anxiety, fear, loss of community cohesiveness, and a myriad other social effects. The consequent militarisation has resulted in frequent break-ins into oil pipelines, bunkering, artisanal refining, hostage-taking, particularly of expatriates workers, and frequent force majeure by the international oil companies.

The results of this study show that there is plausible risk to health for residents of the Niger Delta associated with exposure to the widespread environmental pollution due to the operations of the oil and gas industry in the area. The risk is especially high for those living in proximity to the facilities of the industry, and those who are involved in activities related to oil spillages and remediation. Already, increased incidences of various cancers are reported in these geographical areas. These findings should serve as a sentinel for a more structured epidemiological research, especially a long-term study into the human health effects due to environmental exposures in the Niger Delta. Public

health measures and safeguards aimed at the containment of these outcomes should be put in place in line with the precautionary principle.

Keywords: Oil spillage; Pollutants; Gas flaring; Micronucleus; Crude oil.

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LIST OF ABBREVIATIONS

API	American Petroleum Institute
ASTM	American Society for Testing and Materials
ATSDR	Agency for Toxic Substances and Disease Registry
BTEX	Benzene, Toluene, Ethylbenzene and Xylene
CDC	Centre for Disease Control and Prevention
COPD	Chronic Obstructive
CEHRD	Centre for Environment, Human Rights and Development
CWA	Clean Water Act
DNA	Deoxyribonucleic Acid
E&P	Exploration and production
EGASPIN	Environmental Guidelines and Standards for the Petroleum Industry in Nigeria
EIA	United States Energy Information Agency
EIA	Environmental Impact Assessment
FAO	Food and Agricultural Organisation
FEPA	Federal Environmental Protection Agency
FOE	Friends of the Earth
FMENV	Federal Ministry of Environment of Nigeria
GGFR	Global Gas Flaring Reduction
GHG	Green House Gases
GuLF Study	Gulf Long-term Follow-up Study
HPA	Health Protection Agency
HRH	His Royal Highness
IARC	International Agency for Research on cancer
IDEM	Indiana State Department of Environmental Management
IPCS	International Programme on Chemical Safety
MADEP	Massachusetts Department of Environmental Protection
NAFDAC	National Agency for Food and Drug Administration and Control

NIEHS	National Institute of Environmental Health Sciences
NIS	Nigerian Industrial Standard
NNPC	Nigerian National Petroleum Company
NOSDRA	National Oil Spill Detection and Response Agency
NPC	National Population Commission of Nigeria
NRC	National Research Council
NTP	National Toxicology Program
O&G	Oil and Gas
OECD	Organisation for Economic Cooperation and Development
OGAP	Oil and Gas Accountability Project
OGP	International association of Oil and Gas producers
OML	Oil Mining Licence
PAHs	Polycyclic Aromatic Hydrocarbons
SDWA	Safe Drinking Water Act
SON	Standards Organisation of Nigeria
SPDC	Shell Petroleum Development Company
TDS	Total Dissolved Solids
TPHCWG	Total Petroleum Hydrocarbon Criteria Working Group
UNDP	United Nations Development Programme
UNEP	United Nations Environment Programme
UNIPORT	University of Port Harcourt
UPTH	University of Port Harcourt Teaching Hospital
USDOE	United States Department of Energy
US EPA	United States Environment Protection Agency
WHO	World Health Organisation

1 Introduction

The Niger Delta region of Nigeria has been described as "the global capital of oil pollution" (BBC News, 15 June 2010 11:33). Nigeria is ranked the tenth largest crude oil producer in the world (EIA, 2013), but it seems to be ahead of the pack in crude oil spillage and environmental despoliation. The Niger Delta region is the centre of crude oil production in Nigeria. The total production output from the region averages about 2.5 million barrels a day of sweet crude oil. Petroleum exploration and production has been going on in the region for about 60 years and in this period, it has gone from sedate and pristine, mangrove- and rain-forest covered communities and habitats with one of the greatest biodiversity in Africa, through various states of restiveness and intra- and inter-community conflict over quests for resource control, to headline-grabbing militancy, hostage-taking and piracy. The shock waves of these activities affect international oil prices, stock markets and hedge funds globally. Although stealth, the risks to the health of the residents and indigenous population could be as seismic. The Niger Delta makes a good, but mostly unsavoury, topic as far as the international energy politics goes. Different organizations and popular media take interest in the volatility and the unrest that occurs quite sporadically in the region. Unfortunately, the attendant human health issues are muted.

The agitation for environmental justice and international best practices in the operations of the petroleum industry in the Niger Delta has generated an awareness about the severity of oil pollution that has been happening in the region for a very long time. This agitation took to a global stage in November 1995 with the execution by the military government in Nigeria of Ken Saro-Wiwa, a playwright, and eight other environmental activists from Ogoniland (one of the many ethnic nationalities in the Niger Delta). This brought the issues around environmental pollution and human right violation in the Niger Delta to international attention and gave it prominence. The execution led to cessation of the operations of Royal Dutch Shell in Ogoniland, and the expulsion of Nigeria from the Commonwealth. Today, Shell is still not operating in Ogoniland, although Nigeria has since resumed its membership of the Commonwealth. However, the Niger Delta is still scarred by poverty, violence and pollution, all centred around the

petroleum industry and its operations in the region. Environmental assessments have been carried out in pockets of the Niger Delta, but not in any coordinated manner. The overarching question of the impacts on health of the residents of the communities that call the Niger Delta home, those whose lives are delicately intertwined with the environment and its ecosystem functions remains unanswered. Ogoniland is only a small area in Rivers State, Nigeria, with less than 15% of the total population of that state. The operations of the oil and gas industry is carried out in all the other areas of the state, and the consequences have been the same, or worse. There are nine states in the Niger Delta that are classified as oil-producing, with several ethnic nationalities. None of these states and ethnic nationalities is free from the serious pollution issues due to the operations of the oil and gas industry that Ogoniland typifies. In every part of the Niger Delta where there has been environmental impacts due to the operations of the oil and gas industries, especially in the areas where the residents have been exposed to pollutants in the environment, questions are asked, and anxiety and fear persist. Unfortunately, there has been no answers provided in majority of the cases, and sadly, none may come for a while. The government remains far away at the centre, while the issues and challenges remain on the environment locally, where the people reside with the potential for health consequences. A generation in the Niger Delta has gone through this, and the next may have to, unless answers are provided.

1.1 Crude oil.

Crude oil, also known as petroleum, is the unrefined, naturally occurring flammable liquid derived from decaying plants and animals. It is a fossil fuel, composed of a complex combination of aliphatic, alicyclic and aromatic hydrocarbons, and may contain varying amounts of nitrogen, oxygen and sulphur compounds. Trace amounts of metals such as chromium, nickel and vanadium are also found in crude oil. The chemical composition of crude oil varies widely from region to region, and also intra-regionally, irrespective of the geological source of the crude oil (NRC., 2003).

Structurally, petroleum is described by the nature of the constituents which include saturated hydrocarbons, olefins, aromatics and polar compounds. The carbon number range of the hydrocarbon constituents spans from C1 to greater than C60, which also play important roles in the toxicology of petroleum. Saturated hydrocarbons or saturates

are a group of alkane compounds (C_2H_{2n+2}), and are composed of carbon and hydrogen, with the maximum number of hydrogen atoms attached to each carbon atom in the chain; the chain is thus said to be saturated with hydrogen. In alicyclic alkanes or cycloalkanes, the carbon atoms are bonded to each other to form a ring. The small saturates, with less than 18 carbon atoms in the chain, are very dispersible in water, whereas the large saturates tend to occur as waxes (NRC., 2003; Speight, 1991).

The unsaturated compounds in petroleum, known as olefins, are those compounds that have at least one carbon to carbon double bond in their structure. They are deficient in hydrogen atoms compared with the saturates. The olefins are found in significant quantities in refined petroleum products (NRC., 2003).

The aromatics in crude oil have at least one benzene ring as part of their chemical structure. The benzene ring in aromatic hydrocarbons confers stability to these chemicals and renders them refractory to environmental degradation, which leads to this group of compounds persisting in the environment. Benzene, toluene, ethylbenzene and xylene (BTEX), and the substituted benzenes are the most common aromatic compounds in petroleum, and could make up to 20% of the total hydrocarbon in petroleum (NRC., 2003; Speight, 1991; Speight, 1991). They are the most soluble and dispersible components of petroleum, and frequently, in oil spill incidences, seep into the soil, sediments and aquifers, resulting in contamination. The BTEX compounds are classified as priority pollutants due to their carcinogenic properties and neurotoxic effects (ATSDR, 1999).

The polycyclic aromatic hydrocarbons (PAHs), or polynuclear aromatic hydrocarbons, are hydrocarbons compounds containing more than one ring in their chemical structure due to the fusion of two or more benzene rings. They are constituents of crude oil, and could be present in a concentration of about 0.2% to more than 7% (NRC., 2003). The combustion of fossil fuels like coal and petroleum products, including other pyrolytic processes are major sources of PAHs in the environment. PAHs are some of the most toxic of the petroleum hydrocarbons, and are of great health and environment concern due to the association of some these compounds with carcinogenesis and other diseases (Werres and Johnson, 2008). The two ring aromatic compounds (PAHs) found in crude oil include naphthalene, phenanthrene and dibenzothiophene. The PAHs with a three-ring

structure include fluorene, anthracene, and acenaphthalene, as examples. Other PAHs with 4-ring or greater are also present in crude oil, and include pyrene, benzo(b)fluoranthene, and benzo(a)pyrene, for instance. However, the concentration of individual aromatic hydrocarbon in crude oil decreases with increasing number of rings in the chemical structure, so that almost 90% of the total aromatics in crude oil is made of the single ring (e.g. benzene) through to the 3-ring aromatic hydrocarbons (e.g. phenanthrene) and related compounds. The 4-ring and higher molecular weight aromatic compounds are usually present in much smaller concentrations in crude oil (NRC., 2003).

Resins and asphaltenes are the major polar compounds present in crude oil. They are characterised by the presence of elements such as oxygen, nitrogen, and sulphur in their chemical structure. Asphaltenes are seen more as very large resins, and make up the greatest percentage of hydrocarbon content of asphalt, which is used in road construction. Resins and asphaltenes do not evaporate to any appreciable extent, neither do they disperse nor degrade reasonably. Metals such as nickel, vanadium, and iron are often associated with asphaltenes (NRC., 2003).

1.2 The petroleum industry

There are various sectors in the petroleum industry. Broadly, they are divided into the upstream and downstream sectors, which are linked by a loosely defined midstream sector, comprising the refineries and transportation. However, common preferences tilt towards the dichotomous upstream and downstream categorisation. The downstream oil and gas industry is broad and very permissive. It could range from refineries and the other operations that bring their products to the end users, and would include petrol stations and road tankers that supply them, tank farms that store refined products, to plastic and petrochemical industries, fertilizer and fine chemical industries, pharmaceutical industries, and pesticide manufacturing (Gary and Handwerk, 1984). The human health and environmental issues related to the downstream oil and gas industry have a global reach, although they could be disproportionately localised depending on where these industries are sited and how they operate, including the regulations governing the operations. However, it is outside the remit of the present study to discuss this further.

The upstream sector in the oil and gas industry consists of the exploration and production (E & P) processes, which are also known as the drilling and extractive sectors. It includes such operations required in the search for potential underground and underwater oil and gas fields and reserves, the drilling of exploratory wells, and the subsequent operation of such wells to exploit the recoverable oil and gas and bring that to storage and/or transport facility. These operations are classified into the following subsets

- Exploration
- Drilling
- Well completion
- Field production including pipeline operations, offshore transportation, tanker loading and other ancillary and support operations

It also involves activities required to decommission the well at the end of its life and restore the site to other uses (API, 2001; Alemagi, 2007; World Bank Group, 2007). The upstream operational activities can be carried out offshore and onshore.

The petroleum industry affects every aspect of modern society, from the energy it supplies to the fine chemicals and pharmaceuticals that are derived from it. The ubiquity and utility of petroleum products translates into high volume output of crude oil, the source material. The world production of crude oil is of the order of 3 billion tonnes per year, with an average daily consumption of more than 85 million barrels (~7barrels =1 metric tonne) (API, 2003), which justifies the listing of petroleum as a high production volume chemical. As a consequence, pollution by petroleum is a common phenomenon that could arise either accidentally or operationally from the life cycle of the crude oil. All areas in the loop, including production, transportation, storage, refining, or use of petroleum, either at sea or on land could be subject to a breach and spillage. It is a subject of so many reviews and position papers from sources that range from academics, industrialists, consultants, to regulatory authorities, and many others. The literature on the health and environmental effects of crude oil have derived from sources bordering on contaminated land remediation and landfill sites, oil spillages onshore and

offshore, occupational and industrial exposures to petroleum by products, oil in the sea and other aquatic bodies, underground storage tanks, air quality management issues, ground level ozone and smog, and so many other areas, reflecting the multi-faceted nature of the involvement of our modern society with crude oil.

The upstream operation in the oil and gas industry is associated with hazards, some of which are acute and others chronic. Some of the hazards derive from the component chemicals of the crude oil and gas, while others relate to the technology and equipment required for these operations and the chemicals utilised, including the type of wastes generated in these usually massive and risky ventures. Cases of fires and blowouts, as evidenced by the BP Deepwater Horizon incidence in the Gulf of Mexico in April, 2010, and the Piper Alpha disaster in the North Sea, near Aberdeen, Scotland, in July 1988, with the resultant environment and health consequences are examples

1.2.1 Exploration

These are the operations involved in the search for oil and gas deposits in geological formations. It entails the performance of seismic surveys using airplanes and satellite imaging to gain high quality knowledge about rock formations that could be potential drilling site. It uses a combination of photography, radar, infrared imagery, microwave frequency receivers, and other technologies to provide a basis for exploration drilling. Sequel to the analysis of seismic survey data, exploration drilling is undertaken to verify and quantify the amount and extent of oil and gas reserve. This may lead to the drilling of further exploratory wells, and subsequently, to development drilling if the quantity of crude oil and gas reserve is judged to be of commercial quantity. When an exploration well is drilled, there is potential to penetrate into an oil and gas reservoir under pressure, which may lead to uncontrolled flow of large amounts of oil to the surface, which is known as a blowout. This is a common cause of operational oil spillage (World Bank Group, 2007; Epstein and Selber, 2002; Norwegian Petroleum Directorate, 2011).

1.2.2 Field development.

When exploration leads to the discovery of commercial quantities of oil and/or gas reserve, more wells are drilled and tested in the field development stage, leading to the completion of producer wells. Field development may require that there is a platform

that is sufficiently serviced for drilling and other operations. The production platform may also serve as a facility for the separation of formation liquid into oil, gas, and formation water, including any solids trapped in the formation liquid (World Bank Group, 2007). The platform for field development may also serve as storage for the crude produced, until it is either loaded on a vessel or sent through pipelines to a flow station or another facility for further processing. It may also require the development of improved access to the facilities, if the well development is onshore. Other facilities that may be required in field development include well heads, flow lines, separation and treatment equipments, flare stacks, gas production plants, accomodation, and transport facilities. There are several environmental and health issues attendant to field development in the upstream oil and gas industry, including gas flaring and venting of associated gas, incidences of equipment failure leading to oil spillages, fugitive emissions from crude oil storage and transportation facilities, fire outbreaks, and more.

1.2.3 Decommissioning, site abandonment and rehabilitation.

These are the actions taken to plug wells, demolish and remove installations and restore the site after the exploitation of the oil and gas reserves, or when the drilling operations fail to return economically viable quantities of petroleum for field development. The goal in decommissioning is to restore the site to as near its pre-drilling state as is possible. It is an integral part of the overall management plan in the exploration and production of crude oil, and is one of the legal requirements in the application for any licence for an acreage -which is the limited area over which an operator is licensed to search for and exploit oil and gas (E&P Forum/UNEP, 1997). Sometimes the ideal target in decommissioning which is to leave the land, air and water in the pre-drilling state, and which involves the capping or plugging of wells, and reclamation of land, is not attained. One of the consequences of unplugged wells is that formation water continues to migrate, and could contaminate aquifers and surface water, and pose a risk to environment and its ecosystem functions, including human health.

1.3 Sources of health issues in the petroleum industry

The upstream petroleum industry conducts its operations on a global scale and in every habitat. They can be found operating everywhere from frozen parts of Alaska to the arid deserts of Australia; from tropical rainforests to the woodlands of the temperate regions, and from the mangroves swamps to deep sea offshore (E&P Forum/UNEP, 1997). In every segment of the exploration and production of crude oil, waste streams are generated, starting from seismic drilling, field development, production and well abandonment (Bashat, 2003). With a global output of over 80 million barrels of crude oil per day, and the associated waste stream in orders of magnitude higher, there are potentials for environmental and human health impacts (EIA, 2013; Webster, 2012). The severity of the impact could vary from place to place, depending on the nature of the waste and the sensitivity of the environment. The issues that could affect the environment and human health with the exploration and production of oil and gas could be classified broadly into

- Air emissions
- Wastewater discharges
- Solid and liquid waste management
- Noise generation.

1.3.1 Air emissions

Different types air pollutants are generated in the course of oil and gas exploration and production. The major sources of the release of these air contaminants include condensates, which are semi-liquid hydrocarbons produced alongside gas, that are liquefied during the process of production. Condensates are rich in aromatic hydrocarbons such as benzene, toluene, ethylbenzene and xylene (BTEX) compounds, and may release these, especially in low-lying areas (Earthworks., 2012).

Venting and flaring of associated gas, which is the gas brought to the surface with crude oil, is widely recognised as a waste of very valuable resource, and a significant contributor to greenhouse gas (GHG) emission. Flaring is the controlled burning of associated gas, whereas venting is the controlled release of the same into the atmosphere without burning (OGP, 2000). In the oil and gas industry, gas flaring could be an important safety measure in emergencies and shutdown situations, especially if the flare

is located at a safe distance from dwelling places of the workforce and the local community (World Bank Group, 2007).

The combustion of unprocessed associated gas leads to the emission of oxides of nitrogen (NO_x), carbon dioxide, and carbon monoxide, hydrogen sulphide, sulphur dioxide, carbon disulphide, volatile organic compounds (VOCs), polycyclic aromatic compounds (PAHs), particulate matter and other human and environmental toxicants. Oxides of nitrogen, such as nitric oxide and nitrogen dioxide contribute to ground-level ozone (a component of smog) and acid deposition. Ground level ozone has been implicated in various respiratory ailments, including exacerbation of asthma attacks and chronic obstructive pulmonary disease. According to the Canadian Centre for Energy Information, some of the operations required for removing water from natural gas which requires the use of glycol dehydrators, are the largest industrial source of benzene emission in the upstream oil and gas industry in Canada (Bott, 2007) .

Many of the substances released into the atmosphere by venting and flaring of associated gas in the upstream petroleum industry affect humans, livestock and the environment. The effects are predicated on the magnitude, duration, frequency, the content of the emission, and the susceptibility of the exposed. In humans and animals, petroleum-related emissions have been implicated in respiratory, ocular, and dermal ill health (Bott, 2007). Exposure to VOCs and PAH substances have been associated with increased incidences of cancers. Emission of sulphur dioxide and oxides of nitrogen cause acidification of soils and lakes with implications for agriculture, forestry and aquaculture (Derome and Lukina, 2011). Acid deposition downwind of emission stack has been implicated in the corrosion of architectural and civil structures (Epstein and Selber, 2002; Bott, 2007). The acidification of soil may trigger the leaching of lead, copper, and aluminium into drinking water sources and aquifers, and contribute to eutrophication with the consequent algal blooms. This has implications for quality of seafood and the productivity of water bodies (Epstein and Selber, 2002).

Other sources of air pollution associated with exploration and production in the oil and gas industry include construction activity that accompany every phase of development in the petroleum industry, and which may lead to disturbances of the soil and the generation of particulates and dust; and the emission from diesel engines that power

much of the plants and machineries, including vehicles. Another is fugitive emissions, which occur due to breaks or minor cracks in seals, valves, pipelines, or release from caps and lids that are not secured properly. Although fugitive emissions are unintended release, the public health consequences can be far reaching because they can go unnoticed over a long period since they are generally not visible to the naked eye, and may require regular monitoring and surveillance with specialised equipments to be identified as present (Earthworks., 2012; OGAP, 2005).

1.3.2 Wastewaters

Produced water, which is the formation water that is brought to the surface with the crude oil when extracted, is the largest waste product by volume in the oil and gas industry in both onshore and offshore installations. The ratio of produced water to oil is about 10 barrels of produced water to one barrel of oil. It is estimated that about 20 billion barrels of produced water is generated in the USA in a year (Kharaka and Dorsey, 2005). The ratio of produced water to oil tends to increase with the life of the well, sometimes reaching up to 98% of the materials brought to the surface (Veil et al., 2004.). Produced waters are high in saline content, more saline than seawater (3000 to 350000mg/L total dissolved solids). It may be enriched with organic and inorganic components for example radium 226/228 and other naturally occurring radioactive materials (NORM), metals such as zinc, lead, manganese, iron and barium; sometimes, their concentration may be higher than ambient seawater concentration (Veil et al., 2004.). It may also contain residual chemical additives such as scale and corrosion inhibitors, coagulants, flocculants, and solvents that are added into the crude oil production process (World Bank Group, 2007; Kharaka and Dorsey, 2005; US EPA, 2011). In onshore and offshore operations, oil and grease are the constituents of produced water of concern, while the salt content is of primary concern in onshore operations. Measurements of total dissolved solids (TDS) in the range of 6,000 to 100,000mg/l of produced water, or higher have been made (Hayes and Arthur, 2004).

The management of produced water in oil and gas production is so important that high water producing wells are sometimes shut in because they will be uneconomic to run (World Bank Group, 2007). Feasible methods for the management of produced waters include reinjection into the reservoir to enhance recovery of oil, or by injection into a

dedicated disposal well that was drilled specifically for this purpose taking cognisance of required environmental best practices, which includes ensuring that it does not get into drinking water sources. There have been reports of contamination of potable water sources and aquifers from underground injection of produced water and other exploration and production wastes (Mall et al., 2007). Unfortunately, subsurface geology is not an exact science, and could be quite unpredictable, which means that the best of efforts would not guarantee success in managing produced water.

The other ways that produced waters have been managed include use in irrigation, use for dust control, discharge to surface water bodies, such as ephemeral streams and to land (Veil et al., 2004.; Clarke and Veil, 2009).

From the outline of the many chemical constituents of produced water, it can be deduced that these chemicals either singly or in concert, when discharged in large quantities would pose risk to human health, to aquatic and terrestrial environments. For example, discharges to small streams would have a far higher impact than similar discharges to large water bodies due the dilution that would take place in the larger water body. It has been demonstrated that produced water can contaminate sediments and affect benthic organisms when discharged in coastal and nearshore environments (Rabalais et al., 1992). In recognition of the potential shallow water impacts of produced water, the US EPA banned its discharges into coastal waters (Veil et al., 2004.). Produced water discharges into streams and shallow waters may affect native riparian and wetland plants, especially when the dissolved constituents of the produced water are greater than that of the receiving stream. The method of dumping produced water and other wastes into open air pits to allow the evaporation of volatile compounds is common. In addition to the resultant contamination of the ambient air shed, the method may still leave some hazardous waste behind that may need further treatment. The discharge of produced water into surface ponds for evaporation or irrigation can cause the infiltration of contaminants into drinking water supplies. There are reports of breaches in the lining of pits leading to seepage of toxicants into underground water sources (Veil et al., 2004.).

The other wastewaters include hydrostatic testing waters which are used to check for leakage in equipments and pipelines. The effluent from hydrostatic testing may contain

chemical additives such as corrosion inhibitors, oxygen scavengers, and dyes. The others are water used for heating and cooling systems, which may contain chemical additives and biocides; tank bottom waters, which may be rich in toxicants derived from the sludge in the tank; wash waters from the cleaning of equipments, and other oily waters from drip trays and liquid slugs from process equipments and pipelines (World Bank Group, 2007).

Some of the recorded effects attributable to the constituents of produced water include endocrine disruption, reproductive deficit, loss of membrane integrity, DNA adducts, cytotoxicity, changes in hepatic lipid composition, among others (Bakke et al., 2013). Among the constituents of produced water, alkylphenols have especially been fingered for their endocrine disrupting properties in certain species of fish (Arukwe et al., 2000; Arukwe et al., 2001).

1.3.3 Drilling wastes

In offshore and onshore operations, once exploration surveys suggest the potential for commercially recoverable hydrocarbon deposit, drilling of boreholes is the step that follows. During drilling, drilling fluids/muds are used for cooling and lubricating the drilling bits; they also serve to control the formation pressure and to remove the drill cuttings to the surface. Their other uses include the sealing of permeable formations, maintaining the stability of the drill hole, and the transmission of hydraulic pressure to the drill bits. Operationally, the drilling fluid/mud is pumped down under high pressure into drill string from the surface, and exit through the nozzles in the drill bit, and return to the surface through the annular space between the string and the walls of the well, carrying the entrained drill cuttings in the flow back to the surface (World Bank Group, 2007; Veil et al., 2004.). Drill cuttings, which are the rock particles ground up by the drill bit, and the drilling fluid/mud are the largest waste stream from the drilling operations, and are the second largest wastes associated with the upstream petroleum sector. The disposal of drilling muds could constitute a major operational and environmental issue in both onshore and offshore oil and gas industry (Rojas-Avelizupa et al., 2007). In 1995, it was estimated that 150 million barrels of drilling waste were generated from onshore operations in the USA alone, with produced water being the highest exploration and production waste in the oil and gas industry (Haut et al., 2007).

Drilling muds are usually a mixture of clay, a weighting material, which is often barite, and a continuous phase and suspending medium. Numerous drilling fluid/mud systems are available, and include water-based drilling mud, oil-based drilling mud, synthetic-based drilling mud and diesel-based drilling mud, depending on the nature of the suspending medium. The drilling mud may contain various additives, including alkalinity or pH control agents, biocides, defoamers, emulsifiers, flocculants, filtrate reducers, foaming agents, shale control agents, thinners, surfactants, etc (World Bank Group, 2007; Hyne, 2001). According to the US EPA (2000), since the 1990s, there have been a trend to develop and rely more on the synthetic-based oleaginous drilling muds due to health, safety and environmental issues, especially issues related to PAHs and other VOCs, which are associated with the disposal of diesel-based drilling muds, although diesel-based drilling muds offer excellent drilling performance. Diesel-based drilling muds were very commonly used in 1970s and 1980s due to the economic benefit and high drilling performance derived from them, but toxicological considerations lead to the ban of their disposal in marine environments in 1991, and effective from year 2000, their use in offshore exploration was banned in some countries, including the United Kingdom (Strachan, 2010).

The discharged drill cuttings will typically contain a residual amount of drilling fluid and some formation oil, and, in combination with the spent drilling mud, make the drilling waste stream. As a component of the drilling fluid, barite, which is composed primarily of barium sulphate, is discharged as a contaminant of the drill cutting. Barite may also contain trace amounts of heavy metals such as mercury, cadmium, arsenic, chromium, copper, lead, nickel, and zinc (US EPA, 2000). There are reports of toxic effects of drilling muds and the additives to amphipods (crustaceans), and other marine organisms. The effects range to mechanical smothering of benthic organisms when large volumes are discharged offshore to significantly higher concentration of toxic heavy metals in red crabs (US EPA, 2000; Rose, 2009). There are also reports of toxic effects due to drilling muds on plants attributable to the hydrocarbon and, metals and salts in the waste fluids when discharged onshore in disposal practices such as land farming, landfills and waste pits. Total hydrocarbon concentrations of 1% or greater in soil is considered the limit level for toxic effects to plants, and the threshold for contamination. It is also considered that at this level of hydrocarbon concentration, soil oxygen balance

is affected, with a tendency to create anaerobic conditions that are unfavourable to plant growth. Plants could also bioaccumulate the heavy metals and other toxins in drilling muds disposed onshore and create a pollutant linkage to animals and humans who consume such plants (McFarland et al., 2009). The high salt content in waste drilling muds could be a primary contributor to poor soil quality and subsequent denudation when such wastes are disposed onshore in waste pits and land farming.

The potential for human health impact may derive from the consumption of seafood tainted with contaminants as a result of improper disposal of drilling wastes, especially recreationally-caught finfish and commercially caught shrimps. In occupational exposures, especially with workers involved in handling of drilling muds in operational settings, such as workers in shale shaker room, the reported health effects have ranged from skin irritations and dermatitis, which have been attributed to petroleum hydrocarbon contents of drilling muds, to carcinogenic effects due to PAHs and heavy metal exposure (OGP/IPIECA, 2009). Other reported health effects include headache, nausea, eye irritation, cough, fatigue, neuritis, narcosis, and increased incidences of pulmonary fibrosis (OGP/IPIECA, 2009; Skyberg et al., 1986).

The methods employed in the disposal of drilling fluids include land farming, dewatering and onsite burial, underground injection, incinerating and other thermal treatment, bioremediation and composting, including vermiculture, reuse and recycling. The method employed by an operator will depend on the environmental regulatory laws applicable to the operational areas and how costly these options are for the well in question (Haut et al., 2007). Some of the onshore disposal methods could potentially lead to surface and underground water contamination with the toxicants present in the drilling fluids. This could have effects on human and animal health especially where these water bodies are sources of untreated drinking or recreational water. In the past, land farming and land spreading have been extensively practised in the management of oil-based muds and other exploratory wastes, including the water-based muds. Impacts on the soil and water resources have been recorded (Haut et al., 2007; Rose, 2009).

Produced sand, which is the sand originating from the reservoir that is separated from the formation fluids during hydrocarbon processing, is often treated in the manner as

drilling muds. Produced sand can be contaminated with crude oil, subject to the source (World Bank Group, 2007).

Naturally occurring radioactive materials (NORM), which refers to the radionuclide which occur naturally in the environment, may precipitate as scales or sludge in process piping and vessels for production. When NORM accumulates as a result technological activity, such as the processes involved in crude oil exploration and production, it is referred as technologically enhanced NORM (TENORM). The NORM that is present in subsurface formations could be concentrated in certain oil and gas waste streams such as produced water, sludge, tank bottom, scale deposits, oil-contaminated soils or at the places where wastes are disposed, with the possibility of low grade exposure to human beings. There have been reports of low-level exposure to radium through leakage via waterborne pathways to human beings living and working in NORM contaminated areas (Epstein and Selber, 2002).

1.3.4 Noise

The explosions, seismic survey, including the noise from aircrafts employed in geological mapping, dredging, drilling, vehicular movement, trucks applying their brakes and all manner of transport-related noise, crackling sound from flare stacks, and industrial activities such as the operation of pumps and generators, all contribute to anthropogenic noise associated with the activities of the oil and gas industries. Noise has impacts not only on marine and terrestrial life, but also on human health. The effect on wildlife may vary from subtle behavioural changes, avoidance reaction, hearing loss, injury, and in extreme cases, fatalities (OSPAR., 2009). The effects on humans include annoyance, loss of sleep, sleep disturbances, anger, stress, and a feeling of loss of control of one's environment. There are empirical evidences that have linked environmental noise to acute myocardial infarction and hypertension in humans (HPA., 2010b; HPA., 2010a). Noise has increasingly been associated with detrimental effects on cognitive development and hearing impairment in children. It also has impacts on amenity in hedonistic evaluation of quality of life. There are people whose choice it is to live in rural areas due to the tranquillity and peace it affords. For these people, noise from oil and gas installations located in proximity to their dwelling place can become a major annoyance (OGAP, 2005).

1.4 Human health effects of petroleum spillages

Crude oil is classified in Group 3 of the International Agency for Research on Cancer (IARC) monographs, suggesting that there is inadequate evidence for its carcinogenicity in humans. It also means there is limited evidence for the carcinogenicity of crude oil in experimental animals. However, a variety of hydrocarbons that are naturally present in crude oil, such as volatile organic compounds, including benzene, and some polycyclic aromatic hydrocarbons (PAHs), are known human carcinogens, having been linked with causing a range of haematopoietic malignancies (Savitz and Andrew, 1997; Hayes et al., 2001; Glass et al., 2003; Wickliffe et al.; 2014). Naphthalene, a polycyclic aromatic hydrocarbon present in crude oil, has been associated with olfactory neuroblastomas and lung cancers in rodents (ATSDR, 1995). Other chemicals of potential concern speciated in crude oil include heavy metals, hydrogen sulphide, oxides of nitrogen, and an array of other chemicals, and additives used in the extraction of crude oil. Although data are limited, several human epidemiological studies have consistently shown there are association between exposures to petroleum hydrocarbons with the risk of adverse health outcomes, including effects based on studies in workers involved in clean-up of spilled crude oil, toxicological effects on community members and residents, mental health consequences of economic and social disruptions, and effects on the ecosystem that could affect human health (Aguilera et al., 2010; Goldstein, 2011). Among the adverse human health outcomes associated with petroleum hydrocarbons, carcinogenesis remains one of the most important and most studied.

1.4.1 . Environmental exposures

Most of the information about the human health effects of crude oil have come from studies of tanker accidents that resulted in spillages, most of which have happened since 1960 (Aguilera et al., 2010). Majority of these studies were cross-sectional, and investigated the short term effects on the health of the population associated with exposure to spilled crude oil. Generally, standardized questionnaires were used to measure acute symptoms and general health of the exposed population, and the outcome was compared to a referent population. However, few of the studies have investigated into the effects realised in vitro, mainly on human cell lines, while others were carried

to investigate human health effects due to transference of toxic constituents of crude through the food chain.

1.4.1.1 In vitro studies

All the studies reviewed were from investigation into the impacts of heavy fuel oil spilled in the aftermath of the Erika tanker accident off the coast of Brittany, France. The table-1 below shows a summary of the studies reviewed.

Amat-Bronnert et al. (2007), studied the effects of the Erika oil extract on two cell lines, the human epithelial bronchial cells and human hepatoma cells. Their study was aimed at understanding the mechanism by which the Erika oil caused genotoxic effects in previous in vivo studies (Amat et al., 2004; 2005). Their study was performed by 32P-post labelling, and DNA adducts were detected only in hepatoma cell, which was interpreted as indicative of biotransformation via the cytochrome P450 (CYP)1A2 and 1B1. The expression of a wide range of metabolic enzymes by the hepatoma cells was given as the reason for the result, since the bronchial do not express these enzymes. Again, in western blot and densitometry analysis and quantification, the Erika fuel extract induced some metabolizing enzymes such as CYP 1A2, cyclooxygenase 2 (COX2), and 5-lipoxygenase (5-LOX), and it is remarkable that the later two are involved in carcinogenesis. In epithelial bronchial cells, the induction of leucotriene B4, a mediator of inflammatory processes was recorded. This has significance in human health and disease prevention since inhalation is one the primary exposure routes to crude oil and its congeners.

In a study by Lemiere et al. (2005) aimed at assessing the potential genotoxic risk to consumers of seafood due to exposure to PAHs through seafood contaminated as a result of the Erika tanker shipwreck, contaminated mussels (*Mytilus* sp) from the affected area were fed to rats daily for a period of 2weeks and 4 weeks. DNA damage were assessed in the blood, bone ,marrow and liver of the fed animals using the single cell gel electrophoresis (Comet) assay. It was found that a dose-effect-time relationship existed between the level of DNA damage and PAH contamination, but only in the liver and bone marrow, while no damage was recorded in the blood at $p < 0.001$. It was concluded that seafood contaminated by crude oil in spillages could be portals of

exposure to genotoxic risk for humans, and the risk could be higher for coastal dwellers whose diet contain a higher proportion seafood.

In a similar work to that Lemiere et al.(2005), Chaty et al. (2008) studied the possibility of transfer of PAHs from mussels contaminated with crude oil from the Erika tanker wreck to rats that are fed with the mussels for 2 days. Subsequently, CYP 1A1 mRNA expression and ethoxyresorufin-O-deethylase (EROD) catalytic activity was measured by RT-PCR flourimetry respectively. The results showed the consumption of contaminated led to the transient induction of CYP 1A1 mRNA and EROD activity, with peak value after 12 hours, which returned to normal levels within 36 hours.

Table 1-1 In vitro studies and studies on effects caused by transference to the food chain

Accident reference	Study characteristics	Methods	Results
<i>Erika – Amat-Bronnert et al. (2007)</i>	<i>In vitro</i> genotoxicity of an <i>Erika</i> fuel extract in human epithelial bronchial cells and human hepatoma cells	DNA adducts. CYP 1A1, 1A2, 1B1, 2C9, COX1, COX2 and 5-LOX protein expression. LT B4 and PG E2 detection	Adducts formation and induction of CYP 1A2, COX2 and 5-LOX in hepatoma cells. Formation of LT B4 in bronchial cells
<i>Erika – Lemiere et al. (2005)</i>	Genotoxicity associated with <i>Erika</i> oil-contaminated mussels consumption in rats fed daily for 2 and 4 weeks	Comet assay in hepatic cells, bone marrow and blood cells	Dose–effect–time relationship in hepatic and bone marrow cells. No effect in blood cells
<i>Erika – Chaty et al. (2008)</i>	CYP 1A1 induction associated with <i>Erika</i> oil-contaminated mussels consumption in rats fed for 2 days	CYP 1A1 mRNA expression and EROD catalytic activity in liver	CYP 1A1 mRNA and EROD activity transient induction
COX, cyclooxygenase; CYP, cytochrome P450; EROD, ethoxyresorufin-O-de-ethylase; LOX, lipooxygenase; LT, leucotriene; PG, prostaglandine. Source: (Aguilera et al., 2010)			

1.4.1.2 Epidemiological studies

MV Braer (United Kingdom, 1993). Campbell and others (1993) carried out cross-sectional epidemiological study on community residents following the grounding of the marine tanker, MV Braer in Shetland, United Kingdom and the discharge of almost 85,000 tonnes of crude oil, to identify major acute toxicity effects reported by the cohorts in the first 2 days of exposure following the oil spill. Among the subjects sampled (420 exposed, and 98 controls), the researchers found evidence of neurological,

ocular, and respiratory deficits in the exposed, but there were no significant differences between the exposed and the referent population in lung, liver, or renal function. Six months follow up studies on the same population (344 exposed and 77 controls) by Campbell et al. (1994) found that the general questionnaire symptom score of the exposed cohorts was significantly higher than the control, although there was still no evidence of adverse outcomes in the lung, liver, and renal function. In a separate investigation into the lung function in children exposed to the Shetland oil spill, Crum (1993) found no deterioration in the expiratory flow between the exposed and the referents, in a study within the first 2 weeks of the spillage. In another study by Cole and others (1997), blood samples of the cohorts were examined for evidence of DNA-adducts, and for mutations in hprt locus of T lymphocytes, to determine potential genotoxic effects that may be associated with their exposure. No evidence of genotoxic effects was found. The MV Braer was carrying the Gulfaks crude, a light and easily biodegradable crude, and the impact of the spill was hugely abated by gale-force wind that was prevalent at the time the vehicle ran aground.

Sea Empress (United Kingdom, 1996). The Sea Empress was grounded at Milford Haven, Pembrokeshire, South Wales. It discharged about 73,000 tonnes of its 130,000 tonnes crude oil cargo on the first day it grounded, resulting in catastrophic damage to wide expanse of the coastline. Following the Sea Empress oil spill in Pembrokeshire, South Wales, Lyons and colleagues (1999) undertook a retrospective cohort study in the area to investigate the self-reported physical and psychological health symptoms among the resident in the communities impacted by the oil spill. A cohort of 539 and 550 referents were sampled. The finding from this study was that the exposed residents had significantly higher symptoms of acute toxicity, including neurological, ocular, and respiratory symptoms compared with the referent population. Further investigation on the psychological health effects of the Sea Empress oil spillage found a heightened perception of risk among the exposed compared with the referents (Gallacher et al., 2007).

Nakhodka (Japan, 1997). In a study by Morita et al. (1999), a surveillance of 282 people involved in the clean-up of the Nakhodka oil spillage in Japan was carried out. Alongside the self-reported health symptoms among the cohorts, urine samples were analysed to check for hydrocarbon metabolites. The principal symptoms reported by the

exposed included lower back pain, pains in the extremities, headache, and forms of eye and throat irritation. There were some findings of hippuric acid in the urine of some respondents, a marker of exposure to solvents like toluene and other benzene-like aromatic compounds, which returned to normal with cessation of exposure (Pero, 2010). It was concluded that exposure to crude oil and the efforts that went into clean up of oil spills inflicted acute health problems on local residents.

Erika (France, 1999). In a cross-sectional human health risk assessment carried out by Schvoerer et al. (2000), an exposed population of 3669 was interviewed for physical health symptoms related to participation in the clean up exercise sequel to the oil spillage. Symptoms like dermatitis, migraine, ocular and respiratory irritations, lumbar pain and nausea were reported by the exposed cohort. The length of time spent by the exposed in the clean up exercise was a significant risk factor for these health outcomes.

In another study on the Erika oil spill, the health risk for the cohorts involved cleaning up the spilled oil was studied with emphasis on the associated cancer risk (Baars, 2002). In this study, the risk to the exposed population was found to be low, except those who had not used personal protection equipment, and as result had bare-handed contact with the spilled oil. The results showed an increased risk for developing temporary dermatitis and skin irritations, and a potential, but limited risk of developing skin tumours.

Prestige (Spain, 2002). The Prestige tanker oil spill off a densely populated coastal region of Galicia, in northwest Spain attracted a lot research into the human health risks associated with oil spill. A cohort of about 400 from each affected region was evaluated for acute health effect (Suarez et al., 2005; Carrasco et al., 2006). In these studies, the effect of duration of exposure and the use of personal protection equipment were taken into consideration in the analysis. It was found that working for more than 20 hours in highly polluted areas was associated with the increased risk of injuries, and toxic health reactions. There was a greater toxic manifestation in the exposed population who had not used personal protection equipment, and as a result had contact skin contact with oil on neck/head or the extremities, including those who ate while performing tasks or who spent time in areas where they could perceive nauseous smell from the spill. There was a significant excess risk of itchy eyes, dizziness, nausea and vomiting, throat and

respiratory irritation in the exposed volunteers associated with being uninformed about the use of personal protection equipment, and general health protection matters.

In a study by Zock et al (2007) in the aftermath of the Prestige oil spill in Spain, the prevalence of respiratory symptoms in local fishermen who had participated in the cleanup the spilled oil was evaluated more than a year after. Participation in cleanup exercise was positively correlated to higher prevalence rate of lower respiratory tract symptoms among the fishermen; the risk was higher the longer the length of time (days) spent in the cleanup activities, even after more than a year of involvement in the exercise.

In studies that focused on genotoxic effects of the Prestige oil spill, Laffon and others (2006) evaluated the potential genotoxic damage associated with the handling of oil-contaminated birds at autopsies and cleanup exercise in 34 exposed volunteers, compared with 35 referents. Genotoxicity was evaluated using the single cell gel electrophoresis test (comet assay) and the micronucleus (MN) test in peripheral blood samples. The result of this study showed significantly higher DNA damage ($p < 0.01$) as measured by the comet assay, but no cytogenetic damage as measured by the micronucleus test in the exposed compared to the control. The extent of DNA damage was related to the duration of exposure. Other studies by Perez-Cadahia et al (2007; 2008; 2008) evaluated possible genotoxic damage in various volunteers involved in the Prestige oil spill cleanup exercise, but who used either high pressure washers or were involved in manual cleaning either for a fee or as volunteer. Sister chromatid exchange, micronucleus test and comet assay tests were carried out to determine genotoxic damage in peripheral blood. The results obtained from their studies showed that genotoxic damage due exposure to oil was present, with the highest incidence in the volunteers and the group paid to clean manually, with the lowest damage in the group using high pressure washers. There was evidence of cytogenetic damage in exposed individuals, which varied with age, sex, use of protective devices, genetic polymorphism in metabolising enzymes and repair proteins and the consumption of tobacco. The comet assay was the most sensitive detector of genotoxic effects in the studies by these authors. Perez-Cadahia and colleagues (2008) also investigated the relationship between blood levels of heavy metals and genotoxic and endocrine parameters in individuals

exposed to the Prestige oil spill. Blood concentrations of nickel and aluminium were found to be inversely related to the cortisol levels in blood, while that of cadmium was positively related to it. The authors highlighted the relevance of plasma cortisol level as potential biomarker of exposure to certain types of heavy metals in man. In a cohort study by Rodriguez-Trigo and others (2010), there was evidence of increased risk of structural chromosomal alteration in circulating lymphocytes among the exposed 2 years after the spill. In studies conducted as follow-up seven years after Prestige oil spill, 54 residents of Galician village of Spain, where there had been heavy impact of the oil spill, were sampled for genotoxic effects. The objective of the follow-up studies was to determine if the initial observed genotoxic damages in those who participated in the clean-up persisted. There was no significant genotoxic in the exposed cohorts compared with the referents seven years post-incidence for all the measured parameters, including primary DNA damage, which was measured by the comet assay, micronucleus frequency in peripheral blood lymphocytes, evaluated by cytokinesis-block micronucleus assay and flow cytometry (Laffon et al., 2014). Nevertheless, some endocrine and immunological changes, especially cortisol levels, kynurenine, and some other markers in peripheral lymphocytes were significantly different between the exposed and the referent populations sampled, suggesting a need to monitor the exposed cohorts for adverse health outcomes (Laffon et al., 2013).

Tasman Spirit (Pakistan, 2003). In a cross-sectional study by Junjua et al (2006), exposed residents to the oil were evaluated for acute toxic health symptoms related to eye, respiratory tract, nervous system, smoking, allergies, and perception of risks to health due to oil exposure. From their finding, there was a moderate to strong association between proximity to the spill site and toxic acute symptoms like respiratory, skin and eye irritations, and some nervous system deficits. They had used 2km and 20km to represent exposed and control populations. In a short term study by Khursid et al (2008) communities and workers around the spill site were found to have elevated haematological and biochemical parameters investigated, including liver and renal tests metrics compared with referents far from the exposure areas. In a number of studies by Meo and others (2008; 2009a; 2009b) in the aftermath of the Tasman Spirit oil spill, lung function and other health complaints among subjects exposed to air pollution as a result of their participation in cleanup operations, were compared with

data from referents, including the effect of duration of exposure to the severity of these outcomes. Their investigations showed that there was a higher prevalence of respiratory and general health complaints in the exposed population compared to the control, and that subjects exposed for longer than 15 days to the polluted air around the spill through cleanup tasks had more severe health outcomes, including significant reduction in forced vital capacity, forced expiratory volume, and maximum voluntary ventilation.

The Deepwater Horizon drilling rig exploded on April 20, 2010, killing eleven platform worker and injuring 17 others. In what has been described as the largest oil spill recorded, about 5million barrels of crude oil was spilled into the Gulf of Mexico before the well was capped on July 15, 2010. The Gulf of Mexico oil spill required about 55,000 workers, out of more than 100,000 who were trained, for the clean-up, and countless numbers of residents and community members were affected. The GuLF Study, or The Gulf Long-Term Follow-Up Study, was sponsored by the National Institute of Environmental Health Sciences (NIEHS) in 2011 to investigate the health effects associated with the clean-up activities. It is a prospective cohort study aimed at assessing a wide range of health outcomes, and to create a resource base for collaborative research. It has as its primary objective the investigation into the potential short- and long-term human health outcomes associated with the clean-up and exposure to crude oil spilled from the Macondo well. It also aims at investigating into biomarkers of potential adverse human health outcomes in relation to these exposures, and to create a resource to better understand the short-and long -term human health outcomes. The endpoints targeted in the Gulf study include respiratory, genotoxic neurological, and mental health outcomes, with cancer, reproductive, cardiovascular, hepatic and renal deficits targeted.

The study design of the Gulf study involves the recruitment of 55,000 exposed through telephone enrolment. The telephone enrolment questionnaire would seek to establish the health, lifestyle, usual occupation, socioeconomic status, and demographic details about the cohort. It would also ask questions on spill-related health effects, such as rashes, respiratory problems and neurological symptoms, including stress, depression, anxiety and perceived risk issues. From the 55,000 potential recruits, 27,000 would be marked as approached for a home visit, and inclusion in the active follow-up cohort, and long-

term clinical study. These would be recruited from all clean-up job categories, and be classified and sampled on the basis on the degree of recreated exposure. The potential for exposure would be based on work history. The remaining 28,000 would be the passive follow-up cohort that would be tracked through record linkage. The control cohort would be drawn those that completed training but who did not work, those adjudged eligible for work but were not deployed, or other community members.

Table 1-2 Epidemiological studies on acute toxic and psychological effects, and studies on potential toxicological risk assessment (ordered by the chronology of the spills)

Accident-reference	Study characteristics	Methods	Results
<i>Exxon Valdez – Palinkas et al. (1992)</i>	Cross-sectional. Ethnic differences in stress, coping, and depressive symptoms in indigenous people (N = 188) and Euro-Americans (N = 371)	CES-D scale	Level of exposure significantly associated with CES-D scores in both groups. Indigenous people had significantly higher mean depressive symptom score. In Euro-Americans perceived family support was a moderator of effects of exposure on depressive symptoms
<i>Exxon Valdez – Palinkas et al. (1993)</i>	Cross-sectional, 1 year after the spill. Community patterns of psychiatric-disorders in exposed (N = 437) and controls (N = 162)	CES-D scale. Questions from the National Institute of Mental Health Diagnostic Interview Schedule	The exposed group showed higher prevalence of generalized anxiety disorder and CES-D scores _ 16 and 18. Women exposed were particularly vulnerable
<i>Exxon Valdez – Gill and Picou (1998)</i>	Longitudinal (4 years). Chronic community stress and social effects in residents: 1989 (N = 118) 1991 (N = 228) 1992 (N = 152) and controls: 1989 (N = 73) 1991 (N = 102) 1992 (N = 41)	Questionnaires of out-migration desires, expectations and social disruption. Psychological stress by Events Scale	High levels of social disruption were associated with PTSD in both ethnic groups. Low family support, participation in cleanup activities, and a decline in subsistence activities were significantly associated with PTSD only in indigenous people
<i>Exxon Valdez – Palinkas et al. (2004)</i>	Cross-sectional, 1 year after the spill. Ethnic differences in symptoms of PTSD in indigenous people (N = 188) and Euro-Americans (N = 371)	Modified form of Version III of the DIS	High levels of social disruption were associated with PTSD in both ethnic groups. Low family support, participation in cleanup activities, and a decline in subsistence activities were significantly associated with PTSD only in indigenous people
<i>MV Braer – Campbell et al. (1993)</i>	Cross-sectional. Initial acute effects in residents (N = 420) and controls (N = 92)	Questionnaires of acute symptoms, peak expiratory flow, hematology, liver and renal function tests, blood and urine toxicology	Principal health effects arose on days 1 and 2 (headaches, itchy eyes, and throat irritation). No significant differences between exposed and controls were found for any of the biological markers. Toxicological studies did not show any exposure that are known to affect human health

Accident-reference	Study characteristics	Methods	Results
<i>MV Braer – Campbell et al. (1994)</i>	Cross-sectional. Follow up after 6 months of acute effects in residents (<i>N</i> = 344) and controls (<i>N</i> = 77)	General health questionnaire. Peak expiratory flow, urine analysis, hematology, and liver and renal function tests	The mean general health questionnaire score of exposed was significantly greater than that of controls. Exposed had greater overall scores for somatic symptoms, anxiety and insomnia, but not for personal dysfunction and severe depression
<i>MV Braer – Crum (1993)</i>	Cross-sectional. Effect on respiratory tract in children living close to <i>Braer</i> shipwreck (<i>N</i> = 44 at 3 days and 56 at 9–12 days after oil spill)	Peak expiratory flow rate	Peak expiratory flow rates were within the normal range in both parts of the study, and no deterioration was seen over the study period
<i>Sea Empress – Lyons et al. (1999)</i>	Cross-sectional. Acute health and psychological effects in exposed (<i>N</i> = 539) and controls (<i>N</i> = 550)	Questionnaires of acute symptoms. HAD and SF-36 scores	Exposed showed significantly higher anxiety and depression scores, worse mental health and self-reported headache and sore eyes and throat
<i>Sea Empress – Gallacher et al. (2007)</i>	Cross-sectional. Acute symptomatology attributable to psychological exposure in exposed (<i>N</i> = 794) and controls (<i>N</i> = 791)	Questionnaires of acute toxic and non-toxic symptoms and Hospital Anxiety and Depression Scale	Perceived risk was associated with raised anxiety and non-toxicologically related symptom reporting. Toxic symptom reporting was associated with oil exposure and with raised perceived risk
<i>Nakhodka – Morita et al. (1999)</i>	Cross-sectional. Acute health problems in exposed (<i>N</i> = 282)	Questionnaires of acute and toxic symptoms. Personal air samplers to assess carcinogenic benzene, toluene and xylene.	Levels of hydrocarbons in air were far below the occupational acceptable limit. The principal complaints of symptoms were low back pain, headache and symptoms of eyes and throat
<i>Erika – Schvoerer et al. (2000)</i>	Cross-sectional. Acute health effects in exposed (<i>N</i> = 3,669)	Questionnaires and telephone interviews on acute symptoms	The main described acute symptoms were lumbar pain, migraine, dermatitis, ocular irritation, respiratory problems and nausea. Duration of the cleaning work was identified as risk factor
<i>Erika – Baars (2002)</i>	Potential toxicological risk assessment for people involved in cleaning activities and for tourists	Risk characterizations on the basis of suppositions of the potential exposure during cleaning and tourist activities	The risk for the general people was limited. Increased risk for developing skin irritation and dermatitis, and very limited risk for developing skin tumors, were described for people who had been in bare-handed contact with the oil
<i>Erika – Dor et al. (2003)</i>	Potential toxicological risk assessment after decontamination of 36 beaches polluted by the <i>Erika</i> oil spill and seven control beaches	Determination of the 16 PAH selected by the US EPA in sand, water and surface of rocks. Seven scenarios of exposure for people using the beaches were contemplated, and the most conservative available toxicological values were selected for computing risks	The sand and water were slightly polluted, with values similar to those found in the control beaches. The rocky areas were still highly polluted. No lethal risk was found for a young child who had accidentally ingested a small ball of fuel. The life-long excess risks for skin cancer and for all other cancers were about 10-5 in scenarios including contact with the polluted rocks. The hazard quotient for teratogenic effects was very small, except in scenarios where pregnant women would walk among rocks containing high pollution levels

Accident-reference	Study characteristics	Methods	Results
<i>Prestige – Suarez et al.</i> (2005)	Cross-sectional. Acute health problems among subjects involved in the cleanup operation after the spill (<i>N</i> = 800)	Questionnaire on exposure conditions, acute health problems, and use of protective material	Bird cleaners accounted for the highest prevalence of injuries. Working more than 20 days in highly polluted areas was associated with increased risk of injury in all workers.
<i>Prestige – Carrasco et al.</i> (2006)	Cross-sectional. Association between health information, use of protective devices and occurrence of acute health problems in exposed (<i>N</i> = 799)	Questionnaire on exposure conditions, acute health problems, use of protective material and health-protection information received	Health-protection briefing was associated with use of protective devices and clothing. Uninformed subjects registered a significant excess risk of itchy eyes, nausea/vomiting/dizziness, headaches and throat and respiratory problems. Seamen, the most exposed group, were the worst informed and registered the highest frequency of toxicological problems
<i>Prestige – Zock et al.</i> (2007)	Longitudinal 12-24 months after the spill. Association between participation in cleanup work and respiratory symptoms in exposed (<i>N</i> = 6780)	Questionnaires with qualitative and quantitative information on cleanup activities and respiratory symptoms	The risk of LRTS increased with the number of exposed days, exposed hours per day, and number of activities. The excess risk of LRTS decreased when more time had elapsed since last exposure
<i>Prestige – Sabucedo et al.</i> (2009)	Cross-sectional. Psychological impact in subjects from 23 coastal locations from three zones according to their proximity to the location of the spill (<i>N</i> = 938)	Questionnaires on perceived involvement and social support, satisfaction with the financial aid received and social relationships. Modified version of the CRI-ADULT. Simplified version of the SCL-36	Affected subjects received a good deal of social support and were satisfied with the economic aid received. Those affected with high support and satisfaction scores were in a better situation than those with low scores, and even better than those not affected
<i>Tasman Spirit – Janjua et al.</i> (2006)	Cross-sectional. Acute health effects in exposed residents (<i>N</i> = 216) and controls living 2 km (<i>N</i> = 83) and 20 km (<i>N</i> = 101) far from the coastline	Questionnaires on acute health symptoms and on perception about the role of oil spill in producing ill health, and anxiousness about the effect of oil spill on health	Data showed moderate-to-strong associations between the exposed group and the symptoms. There was a trend of decreasing symptom-specific prevalence odds ratios with increase in distance from the spill site
<i>Tasman Spirit – Khurshid et al.</i> (2008)	Health parameters of people working/living in the vicinity of an oil-polluted beach (<i>N</i> = 100)	Hydrocarbon/organic content in seawater and sand samples. Hematological and biochemical parameters. Liver and renal function tests	Seawater had no traces of hydrocarbon content. Lymphocyte and eosinophil levels were slightly increased. About 11 people had raised SGPT, but this was not significant
<i>Tasman Spirit – Meo et al.</i> (2008)	Cross sectional. Lung function in exposed (<i>N</i> = 20) and controls (<i>N</i> = 31)	. Spirometry	Significant reduction in FVC, FEV1, FEF25–75% and MVV in exposed. Lung function parameters were improved when the subjects were withdrawn from polluted air environment
CES-D, Center for Epidemiologic Studies – Depression; CRI-ADULT, coping response inventory; DIS, diagnostic interview schedule; FEF25–75%, forced expiratory flow; FEV1, forced expiratory volume in first second; FVC, forced vital capacity; GADS, Goldberg anxiety and depression scale; GHQ, general health questionnaire; HADS, hospital anxiety depression scale; LRTS, low respiratory tract symptomatology; MVV, maximum voluntary ventilation, PAH; polycyclic aromatic hydrocarbons, PTSD, post-traumatic stress disorder, SGPT, serum glutamic pyruvic transaminase.			

1.4.2 Occupational exposures and other studies.

Occupational cancer research remains a critically important area of study and source of knowledge and understanding for most cancer types. The study of exposures in the occupational environment has been very rewarding, especially in cancer epidemiology research (Siemiatycki, 1995). A lot of insight about the plausible human health effects of exposure to petroleum has been gained from studies on the impacts of the individual constituents of crude oil in industrial settings. Some of these studies include those conducted on volatile organic compounds found in crude oil, like benzene, and the other BTEX compounds, PAHs, heavy metals, hydrogen sulphide, among others. Most of these were retrospective epidemiological studies on cohorts of former workers whose job description was consistent with exposure to petroleum-derived chemicals in occupational and/or urban settings; or those who had worked in upstream petroleum sector, and were involved in operations that could leave them exposed to these petrogenic chemicals, albeit for a more determinate period than would be obtained in a spill incidence. In some of these studies, for example in Norway and Australia (Schnatter et al., 1992; Kirkeleit et al., 2008) excess of leukaemia, multiple myeloma, and oesophageal carcinoma have been reported in the exposed in comparison with the referent population. For example, the study by Kirkeleit and others (2008) was to investigate whether 27,919 workers registered from 1981 to 2003 as employed in Norway's upstream petroleum industry had increased risk of developing various subtypes of haematological neoplasm based on linkage to the country's cancer registry. These results are consistent with other studies showing that the low level exposure to benzene in certain occupations is associated with increased DNA damage in peripheral blood cells of the exposed (Maffei et al., 2005; Chen et al., 2008; Fracasso et al., 2010). Similar results have been obtained for exposure to PAHs, another natural component of crude oil (Novotna et al., 2007; Gamboa et al., 2008; Bagryantseva et al., 2010). In a related community based study of the upstream petroleum industry in Ecuador, Hurtig and San Sebastian (2002) observed an excess of cancers among residents related to the proximity of their residence to oil fields, and a suggestion of attribution to

environmental pollution by toxic contaminants from those fields was made. The strength of the evidence and the power of the study have drawn criticisms (Siemiatycki, 2002)

It has been suggested that while rare outcomes like acute myeloid leukaemia, multiple myeloma, and melanoma due to exposure to crude oil or to products derived it may take years to develop, intermediate biomarkers that indicate toxic effects and potential for future risks may exhibit lasting changes, and serve as sentinels of the potential for developing future diseases (NIEHS, 2010). The immune and circulatory systems have been flagged as sensitive and accessible for determining physiological effects of oil spill exposure on human health. Benzene, an immunotoxic and haematotoxic agent has been shown to cause a reduction in lymphocyte, neutrophil, and platelet counts in peripheral blood, even at relatively low levels of exposure, with reduced haemoglobin concentration among occupational cohorts with higher benzene exposure (Kirkeleit et al., 2008; Lan et al., 2005). Some of the researchers could not determine if these abnormalities in the haematopoietic system represent initial events leading up to neoplasia, or a reflection of some form of damage to the bone marrow (Kirkeleit et al., 2008). Other workers have suggested some mechanisms to account for benzene-induced haematotoxicity (Lan et al., 2005), including

- Direct toxic effect on haematopoietic progenitor cells by benzene metabolites with genotoxic and cytotoxic capabilities
- Poisoning of the microenvironment around the bone marrow stromal cells, which could result in a shift the ratio of regulatory molecules produced by the bone marrow, which would in turn lead to a disruption of normal haematopoiesis.

There are several postulates about the metabolic and cellular mechanism involved in the leukaemogenic and haematotoxic effects of benzene. Phase 1 and 2 biotransformation reactions in the liver, mediated by CYP2E1 and other hepatic enzymes, oxidises benzene to benzene oxide which is rearranged to phenol, or undergoes further transformation to mercapturic acid derivative of phenol, both of which are excreted in urine (Fracasso et al., 2010). The phenol could also act as an intermediate in other metabolic process leading to the production of quinones, and other compounds in the

bone marrow, and eventually to production of reactive oxygen species (ROS) if not detoxified (Ross, 2000). The ROS could cause damages to vital macromolecular targets, including proteins, lipids and DNA. They could also form covalent bonds with these macromolecules, and consequently induce DNA strand breaks, chromosomal aberrations, micronuclei and sister chromatid exchange (Fracasso et al., 2010). Another mechanism suggested for the genotoxic effects of benzene involves an indirect oxidative DNA damage through the formation of hydrogen peroxide which eventually leads to the production of hydroxyl radicals (Andreolli et al., 1997). No clear evidence suggests a threshold or limit value below which benzene is not haematotoxic in man, and new findings show that at levels previously considered without adverse human health effects, increased risk of malignancies of the blood and damage to blood forming cells are realised, with evidence of toxic effects at <1ppm (Kirkeleit et al., 2008). Although the mechanism of benzene toxicity is unclear, it is clear that metabolism is required, and through some studies on the dose-specific metabolism of benzene via the inhalational route that there is greater metabolism at < 1ppm. These results suggest that there are public health implications due to benzene exposures at air concentrations below 1ppm. The risks to these low benzene air concentrations could be greater than has been expected from investigations of heavily exposed workers (Rapaport et al., 2013). Further support is lent to this finding by the report of increased risks of lymphohaematopoietic cancers at average benzene exposures below 1ppm by Schnatter and others (2012). The toxic effects of benzene to the haematopoietic system, including the effects on progenitor cells may also cause chronic effects on the immune system resulting in premature immunosenescence, as evidenced by the research report of Hoxha and colleagues (Hoxha et al., 2009). In their study on traffic policemen who were occupationally exposed to high levels of benzene, there was an association between these exposures with significantly shorter leukocyte DNA telomere length compared to referent office workers in a cross-sectional study. Leukocyte DNA telomere length is a marker of immune aging, and is associated with the risk of various chronic diseases outcomes and mortality (Zhang et al., 2013).

Some of the studies on the human health effects of crude oil, and of products derived from it, have focused on the impacts due to PAHs, especially with reference to the chronic health impacts of exposures, or those due to exposures to weathered petroleum

spills. The acute health effects that are attributable to PAHs exposure include headaches, nausea, respiratory and dermal irritations, depending on the routes of acute exposure; these symptoms are not pathognomonic, as they could be attributable to other types of chemical exposures. The consensus is that PAHs tend to have low acute toxic effects in humans (ATSDR., 2009) In occupational health, the effects due to acute exposure to PAHs may be non-contributory to human health risk assessment.

The most significant human health endpoint in exposure to PAHs is cancer, especially exposures in occupational settings. Several epidemiological studies have shown increased incidences of cancers, and subsequent mortalities, for employees in industries where exposure to mixed PAHs is established (Lloyd, 1971; Redmond et al., 1976; Hammond et al., 1976). Some of the industries or trades include asphalting, coal gasification, carbon black workers, chimney sweeps, creosote workers, printers, automobile mechanics, and tyre and rubber manufacturing. In most of these studies, it was not possible to ascribe the observed adverse health outcome to any specific PAH due to exposure to a mixture of these compounds. The major organ systems with sequelae associated with PAHs exposure- related outcomes in epidemiological studies are the lung, skin and bladder. Some of the reported symptoms of chronic exposures include decrease in lung function, chest pain, respiratory irritation, cough, dermatitis and depressed immune system. However, animal studies show that certain PAHs can affect the haematopoietic and immune systems, and also lead to reproductive, neurological and developmental deficits (Dasgupta and Lahiri, 1992; Szczeklik et al., 1994). Following ingestion, myelotoxicity was observed in poor affinity Ah-receptor mice, but not in high affinity mice. There were reports of hepatotoxicity (HPA, 2014).

Exposure to PAHs occur through the air, water, soil and food sources, via inhalation, dermal, and oral routes in both occupational and non-occupational exposures. In non-occupational settings, food and dietary sources could account for up to 70% PAH exposure (Skupinska et al., 2004). It has been reported that PAHs may cross the placenta in animal experiments; as a result, unborn foetuses may be at risk, especially in mothers who smoke. Dietary intake during gestation caused reduced fertility and foetal abnormalities. It is also reported that PAHs are excreted in milk, as a result nursing infants of exposed mothers could be secondarily exposed (ATSDR, 1995). Certain food

preparation methods, such as barbecuing, roasting and smoking of meat and fish, could be major sources of PAH speciation in food. Certain food crops, such as wheat, rye and lentils also absorb or synthesize PAHs from the environment (Menzie et al., 1992). PAHs tend to accumulate in benthic dwellers, and some of the PAHs that are refractory to bioremediation may also bioaccumulate in the sediments and biomagnify through trophic levels in the food chain. Anthropogenic sources of PAHs have implicated elevated soil levels, with airborne fallouts as major cause of diffuse soil pollution. High level of PAHs have also been found in soil and sediments around petroleum installations, including refineries and petroleum exploration and production facilities, and various oil spill sites (Puder and Veil, 2006; Anyakora and Coker, 2006). The sources of PAHs in marshy and littoral sediments, especially in the areas hosting the upstream petroleum installations, include the rapid transfer of land-based pollutants into aquatic environments. This can be enhanced by heavy rainfall and flooding. It has been reported as inappropriate to have onsite disposal of petroleum wastes, or even land application of these wastes, a common practice in the upstream petroleum industry, at locations with high seasonal water tables due to the risk that this could lead high levels of pollutants (Puder and Veil, 2006). It also follows that these waste disposal practices could lead to water contamination and are potential sources of PAHs in water, including the pollution of aquifers and other sources of potable water (Skupinska et al., 2004). It has also been reported that air borne exposure to PAH mixtures could occur in communities and residents downwind from plants that emit them and flaring and venting of oil and gas associated gas (ATSDR., 2009). Historically, in areas where large amounts of PAHs existed and have remained unremediated, soil and sediments tend to still be enriched with them, although the lighter fraction PAHs (Less than 4-rings) may evaporate (Skupinska et al., 2004)

Most PAHs exhibit low toxic effects on exposure, limited to slight irritant properties on dermal contact, except for high dose exposures. In vitro, many PAHs exhibit mild to no mutagenic effects. However, when metabolised, the intermediates formed are highly reactive. The metabolism of PAHs occurs mainly through the CYP enzymes, also known as the P-450 mixed function oxidase system, of the liver (Monteith et al., 1987; Kiefer et al., 1988). The metabolism of PAHs also occurs in other areas of the body including the kidneys, adrenal glands, testes, gonads, thyroid, lungs, skin, sebaceous

glands, and the intestines (ATSDR, 1995; Ma and Lu, 2007). The biotransformation of PAHs leads initially to the formation of epoxides, which are then converted to dihydrodiol derivatives and phenol. These metabolites are conjugated via glucuronide and sulphate, and then excreted in bile and urine. In the kidney, the glutathione conjugates are metabolised further to mercapturic acid (CDC., 2005). 1-hydroxypyrene is a commonly measured urinary metabolite of PAHs.

A key factor in the toxicity of PAHs is the role played by the cytochrome P-450 mixed function oxidase enzyme system in their activation to electrophilic reactive intermediates, which eventually mediate the toxicity and even carcinogenic effects (Ma and Lu, 2007; Kemea et al., 1988)). It is believed that the covalent bonding of the PAH intermediate metabolites, mainly diol epoxides with DNA, leading to the formation of DNA adducts, particularly at a site critical to the regulation of cell differentiation and growth is the mechanism of PAH-induced carcinogenesis (ATSDR., 2009; Ma and Lu, 2007). The formation of PAH-DNA adducts leads to mutation during cell replication, unless the aberrant DNA is repaired. Exposure to PAHs tends to affect the cells that undergo rapid replicative turnover to a greater extent, such as those of the bone marrow, skin, and the lungs (Denissenko, 1996). DNA-adducts, which serves as markers of PAH exposure, especially in research, can be measured in so many biological media .Experimental studies have demonstrated that the diol-epoxide metabolite of benzo(a)pyrene preferentially form guanine nucleotides within p53 codon, a mutation that serves as trigger for further DNA damage (Brittebo, 2006) The CYP1A1, the primary isoenzyme that is responsible for the biotransformation of PAHs exhibits genetic polymorphism, and therefore confers a variation on the susceptibility of individuals to the adverse effects of PAHs. CYP1A1 inducible persons might be at greater risk for the effects of PAHs It is also inducible by other compounds, which could modify the degree of toxicity to PAH exposure, including carcinogenic effects (Ma and Lu, 2007; Hecht et al., 1994).Some of the findings in patients with chronic exposures to PAHs, especially occupational cohorts, have included weight loss, exertional dyspnoea, weakness in the extremities, chronic intermittent cough, multiple dry, scaly, hyper pigmented macules in the sun-exposed areas, hyperkeratotic papillomata in the face and neck, wheezing, and decreased immune function. However, no causal relationship was established between PAH exposure and these signs and

symptoms due to multiple chemical exposures (ATSDR., 2009; South Australia Health, 2009). There are also some laboratory findings associated with chronic exposures to PAHs that may also be contributory in risk assessment and remarkable in clinical evaluation. Some of these findings include decreased haemoglobin values, decreased haematocrit, decreased leukocyte count, elevated serum calcium, and elevated alkaline phosphatase; elevated aspartate transaminase (AST), also known as serum glutamic oxaloacetic transaminase (SGOT), and elevated serum glutamic pyruvic transaminase (SGPT)(ATSDR., 2009).

1.4.3 Biological sampling

The sampling of biological specimen, particularly blood sampling, is assuming prominence as a method of assessing the potential human health effects. Monitoring for markers that may be clinically relevant in the continuum between exposure and disease manifestation, or biomonitoring has become an important aspect of epidemiological studies, public health and health protection, as it can provide valuable perspective in the evaluation exposure to chemicals (Arnold et al., 2013). The overarching goal of environmental health studies is the correlation of exposure dose and adverse health outcomes. However, with certain exposures, there is a lag between the exposure event and the manifestation of health effects. In such cases, it may be difficult to establish a precise exposure scenario, including the full extent of the affected population using traditional epidemiological methods (Ehrenberg, 1993; Sexton et al., 2004; Knudsen and Hansen, 2007). Complicating this, in the instance of this study, is the heterogeneity in the composition of crude oil, including its environmental fate and behaviour in spill situations, with the result that exposure dynamics would vary from one event to the other.

Human biomonitoring, as opposed to ambient monitoring, provides an integrated measure of exposure from all environmental sources of pollutants and all routes of exposure to them (HPA, 2011). Ambient monitoring measures chemical substances in environmental matrices like air, water, soil, food, etc. Human biomonitoring on the other hand, relies on analytical measurement of the hazardous chemical or its metabolite in a body matrix, quantification of reaction product of the chemical substance with

biological molecules such as DNA and protein adducts or early biological effects caused by chemical substances, for example chromosomal aberrations, increased sister chromatid exchange rates, micronuclei, and enzyme activities (Ehrenberg, 1993; Angerer et al., 2007). The internal dosimeter used in biomonitoring is the biomarker, and according to IARC (1997), “a biomarker is any substance, structure or process that can be measured in the body or its product and may influence or predict the incidence or outcome of disease”. Biomarkers are differentiated according to a basic scheme determined on where they located on the exposure-disease continuum into biomarkers of exposure and biomarkers of biological effect

Biomarkers of exposure provide a direct measure of body burden of the chemical substance, and include the parent chemical or its metabolites, or the presence of specific DNA and/or protein adduct. Biomarkers of exposure are not necessarily predictive of adverse health effects on their own (HPA, 2011; Au, 2007). This reflects the internal dose, the biologically effective dose or target dose as measured in a body compartment. Some authors would classify DNA and protein adducts as biomarkers of biochemical effect. The age, sex, lifestyle, including smoking and alcohol consumption, etc could act as modifiers of the internal dosimetry of biomarkers (Angerer et al., 2007).

Biomarkers of biological effect could be measurable changes on a cellular level, such as alterations in metabolic enzyme expression, but could also include markers of early pathological changes in diseases with complex aetiology such as mutations and pre-neoplastic lesions in carcinogenesis, or even small reversible changes from normal values in packed cell volume. Among the biomarkers of early biological effects of exposure to environmental chemicals, aneuploidy, chromosomal aberrations and micronuclei have been adjudged as the most relevant as they may indicate an early stage in progression to a disease. Biomarkers of effects tend to be more unspecific for the toxicants in the exposure event. There is however an overlap in the classification of these biomarkers with some that serve as exposure biomarkers, like DNA adducts, serving also as markers of biological effect (Au, 2007; Silins and Hogberg, 2011). Biomarkers of susceptibility are innate or acquired indicators of an individual's ability to respond to exposure to specific xenobiotic substances. (Knudsen and Hansen, 2007; Angerer et al., 2007; Silins and Hogberg, 2011) Polymorphism of specific genes

associated with the metabolism of toxins, either at an individual or population level, that may modulate their response to an assault by the toxin, such as glucose-6-phosphate dehydrogenase deficiency, induced fast metabolic state in the p450-enzyme system, and other single nucleotide polymorphism (SNP) are examples of biomarkers of susceptibility. (Au, 2007; Silins and Hogberg, 2011) These biomarkers provide an indication of the level resistance or otherwise to an exposure, and may be sentinel of progression to adverse health outcome. The figure below illustrates the potential usage of biomarkers in the continuum from exposure to prognosis of diseases

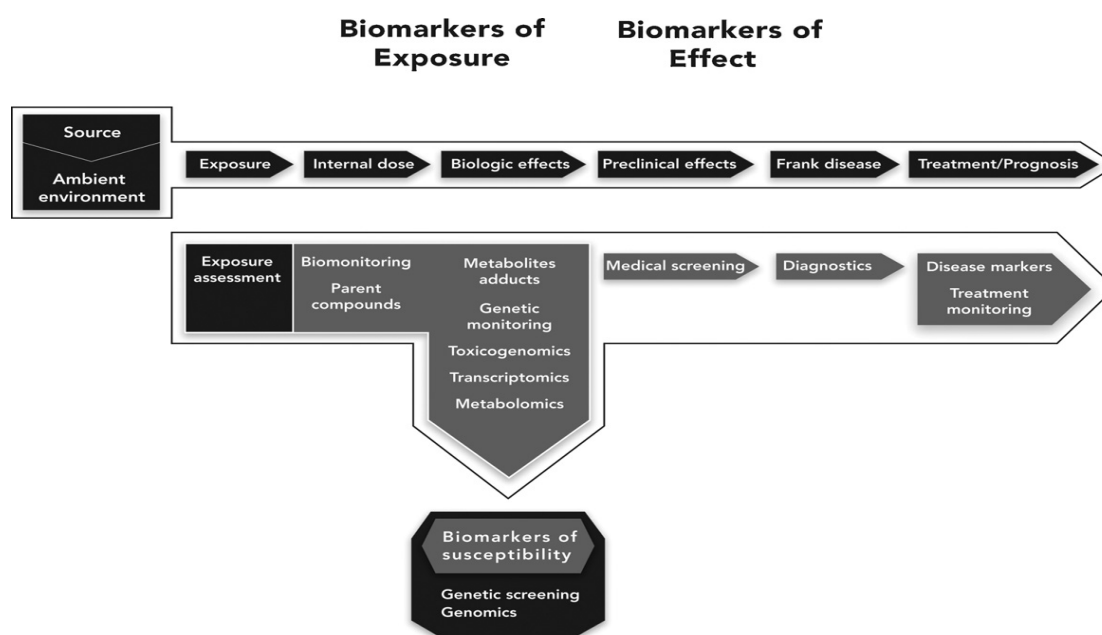


Fig. 2.4. Continuum of biomarkers from exposure to disease prognosis. Adapted from (Schulte and Hauser, 2011)(Schulte and Hauser, 2011)(Schulte and Hauser, 2011)

Although no specific biomarkers relating to exposure to crude oil was found in the literature, there are established biomarkers for the constituents of crude oil, especially benzene. For example, it has been found that blood and urine levels of benzene and toluene are significantly correlated to their levels in air, and the unmetabolised urine and blood levels of these compound could serve as surrogates of inhalational exposure (Hopf et al., 2012)

1.5 The petroleum industry in Nigeria

The petroleum industry in Nigeria has a history of about 60 years, with the first commercially viable discovery of crude oil in Oloibiri, in today's Bayelsa State, in 1956. It is also the mainstay of the Nigerian economy, accounting for 96% of the export earnings in 2012 and about 65% of the national budget (US EIA, 2013). The primary location of the oil and gas industry in Nigeria is the Niger Delta region. The exploration and production of crude oil operates predominantly onshore and coastal offshore in the region. From inception until early 1993, virtually all upstream activities in the oil and gas sector in Nigeria were restricted to land and swamps. There was hardly any activity in areas greater than 200 meters deep offshore. Recently, a deliberate policy to diversify the location of oil fields and boost production have led to the development of more deepwater acreage. The first deepwater production started in 2003, and increasingly, more and more such fields have come on stream, with an output of about 800,000 barrels a day (bbl/d) of the current total production of about 2.2M bbl/day (EIA, 2013). According to a report by the Nigeria National Petroleum Company (NNPC), there are about 606 producing oil fields in the Niger Delta, with majority of them (60%) located onshore (NNPC, 2010).

1.5.1 Properties of the Niger Delta crude oil

In line with international methods of classifying or naming crude oil types based on geographical sources of the crude oil, and in turn, using those names to define the grade and pricing of the crude oil, several grades of crude oil are produced from the Niger Delta of Nigeria. This is due to the variability in physical and chemical properties of the oil in the Niger Delta, as elsewhere. The crude oil produced in the Niger Delta has a gravity range of 16-50°API, with the lighter oils having a greenish-brown colour. About 65% of Niger Delta oils have an API gravity of 30°-40°. Crude oils with less than 25° API make up only about 15% of the Niger Delta reserve. Broadly, there are two main groups of crude oil produced in the Niger Delta. The first group of crude oil, produced from deeper reservoirs, are paraffin-based, and waxy. The second group are produced from shallow reservoirs, have lower API gravity, and are naphthenic and non-waxy crude oils (Tuttle et al., 1999).

The concentration of sulphur is low in most crude oil produced in the Niger Delta, making them of the light sweet crude grades that are sought after internationally due to the low corrosive properties. According to US Department of Energy (US DOE), Nigeria's export blends are light, sweet crude oil with API gravity range of 29°-47°, that are low in sulphur contents, with a range of sulphur concentration of 0.05%-0.3%, making the Nigerian blend comparable to the Brent Light, the North Sea benchmark crude oil. Concentrations of nickel and vanadium are less than 100 parts per million (ppm), and the gas associated with oil production in the Niger Delta is low in hydrogen sulphide; however, relatively high concentration of mercury has been reported (Tuttle et al., 1999; US DOE, 2010). A recent report by Ajayi and others (2009) show that concentration of arsenic, cadmium, nickel, cobalt, manganese, vanadium, and NORM in crude oil sampled from six different producing wells in the Niger Delta is low. They report however, there was a potential for human health risk due to heavy metal exposure through cumulative impact.

1.5.2 Regulatory framework.

In Nigeria, all mining and minerals issues, including all activities in the oil and gas sector fall within the regulatory competence of the federal government. This is without prejudice to where the minerals or mining activities are carried out, including geological surveys, as this falls within the exclusive legislative list of the Constitution of Nigeria (Ofuani, 2011). And while the federal government is vested with absolute right of ownership and control of all crude oil in Nigeria, the Land Use Act, which was promulgated as a decree by the military government in 1978 vests all the land comprised in any state of the federating units of Nigeria in the governor of the state in 'trust' for all Nigerians. As is the case with so many other crude oil producing countries, there are laws and statutes governing the oil industry in Nigeria. The most important laws, guidelines, and standards that regulate the oil and gas industries in Nigeria include

- The Petroleum Act (1969). By this act, the Federal Government of Nigeria is vested with exclusive right and control over all petroleum resources found within Nigerian territorial boundaries, and can farm out oil mining rights to oil companies, from whom it collects rents and royalties.
- The Oil Pipelines Ordinances, 1956; the Oil Pipelines Act, 1965

- Federal Environmental Protection Agency Act, 1988
- Statutory Instrument 15. National Environmental Protection Management of Solid and Hazardous Waste Regulations (1992).
- National Policy on the Environment (1999).
- Environmental Impact Assessment Act (1992).
- The Land Use Decree, 1978

There are still a host of other laws and regulations, including some international laws and conventions such the Convention on Migratory Species of Wild Animals (Bonn Convention), the Convention on Biological Diversity, among others to which Nigeria is a signatory, and have domiciled into law. For example, there is the International Convention for the Prevention of Pollution of the Sea by Oil of 1954, which was amended in 1962, which has been enacted into law as the Oil in Navigable Waters Act of 1968 (Okenabirhie, 2010); the International Convention on Oil Pollution Preparedness, Response and Cooperation, which requires to a contingency oil spill response plan, and has led to the setting up in Nigeria of the National Oil Spill Detection and Response Agency (NOSDRA) in 2006. There are also some state guidelines on the environment, that regulate the operations in various aspects of the oil and gas industry in Nigeria (NNPC, 2010; SPDC, 2006b; SPDC, 2006a). The Federal Ministry of Environment (FMENV), which was created in 1999, has most of the oversight functions of all environmental matters in Nigeria, although some functions that had existed under the Ministry of Petroleum Resources which predates the FMENV are retained under that ministry still, especially those that concern operations in the oil and gas industry. However, the rest of the oversight and operational functions in the oil and gas industry are under the petroleum ministry, which works through its agencies and departments to regulate and supervise the activities in the industry. The operations are carried out under licences and leases, which covers all activities in the upstream and downstream sectors of the petroleum industry. The Nigerian National Petroleum Corporation (NNPC) is the national oil company. It falls under the supervision of the petroleum ministry. NNPC is vested with the exclusive responsibility for upstream and

downstream developments in the petroleum industry in Nigeria, and grants the concession for oil and gas exploration and production in Nigeria (NNPC, 2010; SPDC, 2006b; SPDC, 2006a).

There are several laws and regulations targeted at waste management and pollution abatement in Nigeria, but the scope of their applicability is limited as far the oil and gas industry and its operations are concerned. The oil and gas industry, and the waste they generate, are under a different dispensation managed by under the Ministry of Petroleum Resources. The principal environmental legislation, the National Environmental Standards and Regulations Enforcement Agency (NESREA) Act, 2007, seeks to control the handling and disposal of hazardous wastes, and control environmental pollution in Nigeria, but the oil and gas industry is excluded from the enforcement of the provisions of this Act. The principal institutional framework and legislation related to environmental management in the oil and gas industry is the Environmental Guidelines and Standards for the Petroleum Industry in Nigeria (EGASPIN) Act, 1991, as amended in 2002. This legislation was made pursuant to the Petroleum Act, 1969, and aims to guard against the degradation of the environment in the course of the operations in oil and gas industry. The Department of Petroleum Resources, which is under the Federal Ministry of Petroleum Resources, is responsible for ensuring compliance with the applicable laws and regulations that are contained in the EGASPIN Act. The objectives of the Act include: (1) Establishing guidelines and standards for environmental quality and control in the oil and gas industry with regards to local conditions. (2) To provide in a concise format, an integrated, user friendly document for guidelines on pollution abatement technology and standards for oil and gas exploration and production. (3) And to standardize the environmental pollution abatement and monitoring procedures, including the methods for analysing various parameters in the upstream petroleum industry (NAPIMS, 2010). The EGASPIN is reviewed every 5 years to bring the provisions up to speed with technological advancements in the sector.

The operations in the upstream petroleum industry in Nigeria are carried predominantly by multinational oil companies in partnership with the NNPC in either a joint operating agreement or production sharing contract. The multinational oil companies are the operators of the joint venture in all phases of the concession, from the granting of oil

prospecting licences (OPL) to the issuance of oil mining leases (OML), and further to the lifting of oil for export, including the provision of loading facilities and pipelines. The national oil company, NNPC, holds about 55% to 60% equity in most upstream petroleum ventures, while the rest of the equity is held by one operator or a consortium of operators. Lately, some indigenous operators working in partnership with international companies have come into the upstream sector, and are operating as independents, although their participation have been limited to the marginal oil fields. However, in deepwater acreages, production sharing contracts (PSCs), mainly with international oil companies, is the more attractive management arrangement for exploration and development, as the more liberal terms tend to act as enhanced incentive for investment and development in these cost-intensive fields (EIA, 2013).

The major joint venture multinational oil companies operating in Nigeria are Shell Petroleum Development Company (SPDC) of Nigeria, which is the oldest and largest operator in Nigeria, and according to 1997 figures, accounts for more than 40% of Nigeria's oil production, in partnership with Elf and Agip. Shell has been operating in Nigeria since 1936, and it is estimated that their production capacity could be about 1.3 million barrels per day (NNPC, 2010; US DOE, 2010). Most of the oil fields operated by SPDC are located onshore on dry land or in the mangrove swamp. The other international oil companies include Chevron Nigeria Limited, Mobil Producing Nigeria Unlimited, Nigerian Agip Oil Company Limited, Elf Petroleum Nigeria Limited, and Texaco Overseas Petroleum of Nigeria Unlimited, ConocoPhillips, Petrobras, StatoilHYdro, and new entrants from China, and so many others (NNPC, 2010; US DOE, 2010).

The upstream petroleum sector oil and gas sector has a long history of association with adverse environmental impacts globally, ranging from impacts on climate change to impacts on biodiversity, including the effects of incessant oil spillages, some of which have been of catastrophic proportions. The exploration and production of crude oil is inherently risky whether it takes place in the arctic or in the tropics. The strategic nature of crude oil and other fossil fuel to the economic and development needs of nations has meant that more and more of this non-renewable resource is required, and the provision is sometimes at great cost to the source communities. The environmental issues in the upstream petroleum industry in Nigeria are myriad and multifaceted, deriving partly

from the geopolitical and socio-cultural structure of Nigeria, to practices that appear to be specific to the oil and gas industry.

The oil and gas industry has always had strong lobbies and influence government policy and laws globally. Operation in the upstream petroleum sector is costly and capital intensive, and most of the companies involved have deep enough pockets to influence policies, laws and regulations through powerful lobbyist in the countries where they operate. Regularly, the oil and gas industries have been reported to fund political campaigns and bankroll politicians. It is instructive that in the United States of America, most wastes derived from the upstream oil and gas industry are exempt from USEPA regulation for hazardous wastes (U.S. EPA., 2002). In 1980, the US Congress gave a conditional exemption for exploratory and production wastes from the oil and gas industry from hazardous management under the Resource Control and Conservation Act (RCRA), The Clean Water Act (CWA), and the Safe Drinking Water Act (SDWA). The wastes exempted include produced water, produced sand, drilling fluids and muds, tank bottoms, among several others (Puder and Veil, 2006). Nigeria was without any formal dedicated environmental regulations before 1988, when in a knee-jerk reflex to a toxic waste dump in some parts of the Niger Delta, the Federal Environmental Protection Agency (FEPA) was created by the erstwhile military administration in the country, to enforce the Harmful and Toxic Waste Decree of the same year (Echefu and Akpofure, 2002). Prior to the formation of FEPA, the principal regulatory tool in the petroleum industry in Nigeria was the Petroleum Act of 1969, whose enforcement fell under the Department of Petroleum Resources of the Ministry of Petroleum Resources. Apparently, the major environmental policy thrust of the Petroleum Act 1969 was pollution abatement (Orubu et al., 2004).

The oil and gas industry in Nigeria operated for a long time without any stringent environmental or planning framework or legislation. For an even longer period, the country was under various military dictatorships, and expectantly, had priorities besides the protection of the environment. This led to frequent changes in government policies and programmes, inadequate enforcement of laws, standards and regulations. Even when the laws were enacted subsequently, there was a lack of capacity for their enforcement. Nigeria had turned into a mono-economic nation. Corruption was rife,

sometimes involving, or encouraged by the multinational oil companies, a case in point being the conviction of Halliburton, a major multinational company in the oil and gas industry, of corruption in an oil and gas contract with Nigeria (Wagner and Armstrong, 2010). The oil and gas industry also became the major economic base of the Nigerian economy, and there was a huge drive to aggressively pursue exploration and production of petroleum, with little attention paid to the environmental and social impacts associated with the activities. Crude oil went from providing about 30% of the total budgetary allowance of Nigerian government in 1970 to 84% in 1985 (Wagner and Armstrong, 2010; Graf, 1988). As a consequence, the main thrust of Nigeria's policy in the petroleum industry was to increase the crude oil reserve through vigorous exploration. Environmental issues were accorded very little prominence in policy design (Echefu and Akpofure, 2002; UNEP, 2011).

Nigeria's oil and gas industry has been subject to environmental issues common to all developing economies, especially the third world countries. Petroleum exploration and production are very high risk and capital intensive ventures. The technological expertise required is seldom within the reach of these developing nations. This leaves these countries with little option than a dependence on the "big" players, the so called "seven sisters" of the oil and gas industry, Exxon, Shell, BP, Chevron, Mobil, Texaco and Standard Oil. These multinational oil companies are profit driven business concerns, and are not motivated by any form of sentiments or altruism, but by their own financial balance sheets, the satisfaction of their shareholders, and continued growth, as defined by the principles of capitalism (Alegimenlen, 1991; Iyalomhe, 1998). As a result, the multinational oil companies seek ways to avoid doing anything that would work against the furtherance of their set commercial purpose including environmental best practices since some of these practices increase cost of production and affect their profit (Epstein and Selber, 2002). Bringing it home, the multinational oil companies operating in Nigeria, including the big seven, had little regulatory control, and for the better part of their operations to date, operated in very corrupt and contaminating milieu. For instance, though there are land use and planning laws in Nigeria, the interpretation and application of the laws are disparate and uncoordinated, depending on where you live in the country, due to the stubs and outcroppings of pre-legislative practices getting in the way of current legal practices. Whereas the Land Use Decree of 1978 formally vested

all land in the state, the expropriation of the land has never been accepted by the individuals, families and the communities that had customary claims to the land. This has resulted in developments and settlements around oil and gas installations, in ways that were unforeseen and clearly inimical to human health and the environment, but the government and the oil companies are resigned to (Higgins, 2009; SPDC, 2010.). Some of the standards in international environmental best practices that guide the operations of the multinational oil companies are not meant for residential settings. This is important in oil spill remediation, since the risk-based screening levels used in determining intervention in spillages are based on non-residential land use conditions (API, 2001). So, any form of remediation of spillages in the Niger Delta should use a different target level to reflect the residential nature of the land, and where the land is a farmland, the agricultural practices, which relies on crude farm implements, with a high level of contact with the soil must be captured.

1.6 The Niger Delta region.

1.6.1 Introduction

The Niger Delta of Nigeria is situated in the Gulf of Guinea, spanning a huge area of land, estimated to be about 70,000 square kilometres, and making up approximately 7.5% of the total land mass of Nigeria. One of the great deltaic regions of the world, it is Africa's largest, and world's third largest delta and mangrove area (UNEP, 2010). It is densely populated, with a population of over 31million from more than 40 ethnic groups spread across Abia, Akwa Ibom, Bayelsa, Cross River, Delta, Edo, Imo, Ondo, and Rivers States of Nigeria. The ethnic nationalities in the Delta Region of Nigeria include the Ibo, Efik, Ijaw, Urhobo, Kalabari, Yoruba, Ogoni, Ibibio, Itsekiri, among so many others. The region is criss-crossed by a network of rivers and creeks, and has a coastal zone that consists of barrier island and beach fronts. It faces the south-east trade winds, which makes for heavy seasonal rainfalls, with only a short period of dry season, making the area one of the largest wetlands in the world. The flora in the area consists mainly of riparian forests dominated by mangrove vegetation in the tidal zone and mixed forests with raffia palms in the freshwater areas. The other ecosystems found in the Niger Delta include freshwater swamps, creeks, estuaries and

barrier islands (Mrabure and Ngene, 2005; Akegbejo-Samson and Omoniyi, 2009). Essentially, the area consists of zones of interaction between freshwater, brackish and marine ecosystems, making it very significant as spawning and nursery ground for several types of fish and crustaceans. The importance of the area is further accentuated by the presence of taxonomically diverse and salt-tolerant trees and other plant species which thrive in the sheltered tropical shores and estuaries

Traditionally, the ecology of the Niger Delta serves as the hub for the economic activities in the area as the natives engage in pelagic and semi-pelagic artisanal coastal fishing, hunting for wild life, subsistence farming in small parcels of land, gathering of wild crops and fuel wood from the mangroves, palm wine tapping, and similar activities (Akegbejo-Samson and Omoniyi, 2009; Gabriel, 2004). The difficult topography and terrain in the Niger Delta have meant that most communities in the area are gathered in nucleated and rural settlements of less than 5000 inhabitants in isolated dry sites within the deltaic swamps. This tends to limit the level of economic activities, and results in poor infrastructural and socio-political developments (UNDP, 2006). Increasingly, the indigenous people in these communities are unable to carry out these traditional trades as a result of degradation and pollution of their environment and the resultant loss of biodiversity and ecosystem functions. As a consequence, after more than 50 years of exploration and production of crude oil in these communities, there is unimaginable poverty and depravation with the residents still living in shacks, with broken canoes, some of highest levels of infant and child mortalities in the world, no access to electricity, poor sanitary conditions, low literacy rates, poor access to health care and one of poorest in the metrics quality of life (Higgins, 2009; UNDP, 2006). For example, two environmental impact assessment reports by Shell (2006b; 2006a) on some of the projects it has ongoing in the Niger Delta [the “Final Report from the Okordia-Rumuekpe Pipeline Replacement Project” and the “Environmental Impact Assessment (EIA) of Rumuekpe OML (22) and Etelebou(OML28) 3D Seismic Survey Final Report] capture the pervasive local poverty that runs through most of the communities in the region. Briefly, about 20 to 35 percent of children under the age of 5 in these communities were reported to be under-, or malnourished, with about 25% showing evidence of stunting as indicated by short height-for-age; 90% of the households rely on hurricane lanterns for lighting, since they are not connected to the national electricity

grid, and firewood was the available cooking fuel to about 66% of the residents; there was exceptionally low level of functional literacy, and in one of the communities with about 5500 residents, there was only one very poorly equipped primary school, and to attend secondary school, the children from this community walk 9 kilometres to the neighbouring community. The average income in these communities was reported to be about 5000 Naira, which is the equivalent of about £20 per month. Infectious and preventable diseases were reported to be endemic, including malaria, typhoid fever, diarrhoeal diseases, measles, acute respiratory infections, chicken pox, and generally low life-expectancy. Room occupancy was about 3 to 7 persons per room, in mostly mud, bamboo and thatched houses. Where those houses are built bricks, it was common to find asbestos roofing or zinc roofing. The residents have been complaining about the rapid rate of corrosion of the galvanised iron roofing sheet (zinc) due to the impact of acid rain from the gas flares common in the area (SPDC, 2006b; SPDC, 2006a; Ekpo and Obia, 2010.). The pattern is common throughout the majority of the communities in the Niger Delta, particularly in the host communities to the oil exploration and production facilities. The United Nations Development Programme (UNDP, 2006) has described the region as suffering from “administrative neglect, crumbling social infrastructure and services, high unemployment, social deprivation, abject poverty, filth and squalor, and endemic conflict...” For several years, the oil companies have been operating without appreciable control or environmental regulation or monitoring guiding their activities and operations (UNDP, 2006; Amnesty International, 2009).

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Figure 1-1 Map showing the Niger Delta oil producing states with map of Nigeria as insert.
(source: NDWG)

1.6.2 Environment and health issues in the Niger Delta

The Niger Delta has been described as the most egregious case of crude oil pollution in the world, with reports of over 6800 oil spillages spanning over more than 50 years. The United Nations Environment Programme (UNEP) report on the environmental assessment of Ogoniland, one of the oil-bearing areas in the Niger Delta, confirmed concerns among the communities, environmentalists and quangos that the extent of contamination of land and water resources in the delta may be truly unprecedented. The report suggests that the pollution is ongoing, and may require more than 30 years, and over £1billion for remediation (EIA, 2013; UNEP, 2011). The volume of crude oil spilled into the environment has been estimated to be the equivalent of one Exxon Valdez tanker oil spill in Alaska, or about 260,000 barrels a year, every year for over 50 years of upstream petroleum industry activities in the area (US DOE, 2010).

The oil and gas industry in the delta operates mostly onshore, sometimes in close proximity to the residence, farm or fishing grounds of the host communities. Essentially, the operational units consist of production wells that are linked through an extensive network of pipelines that transport crude oil to flow stations. At the flow station, crude oil is separated from the associated water, and the associated gas is

recovered, flared or vented. Subsequently, crude oil is transported from the flow stations via larger pipelines to the export terminal. As a result, residents of communities where the wells, flow stations, and/or loading terminal are located are subject to some exposure to petroleum fallout in the course of these schedules required to bring crude from the well to a loading point. This could be by way of gas flaring or venting, waste mismanagement, fugitive emissions, spillages, or even light intrusions from flares (OGAP, 2005).

The Niger Delta is a vast wetland, one of the largest in the world, and comprises a number of ecological zones ranging from the sandy coastal ridge barriers, brackish or saline mangroves, freshwater permanent and seasonal swamp forests, to lowland rainforests. It is subject to tides from the Atlantic Ocean and flooding on the banks of the River Niger and its tributaries. The health of the environment and the lives of the people of the region are intertwined with the health of the overarching water system in the area. The rivers and streams serve as sources of drinking and bath water; fishing and other agricultural activities such as fermentation of cassava, laundry, regattas and religious activities are also carried out in the water bodies. Commonly, the untreated water from streams, rivers and wells serve as drinking water for the communities (Amnesty International, 2009). Anyakora and Coker (2006; 2009) analysed several water bodies in the areas with extensive crude oil production in the Niger Delta, and their findings show that in the areas affected with heavy pollution, the concentration of several carcinogenic and non-carcinogenic PAHs exceeded the World Health Organisation limit values for both recreational and drinking water levels. From their study, there was significant risk of cancer from exposure to water bodies in the places they sampled. Anecdotal reports on the organoleptic properties of the surface and groundwater by residents of the host communities concerning the pollution in their areas are corroborated by the scientific findings of several research papers, and include the observation of oily-sheen on the drinking water, kerosene taste in water meant for drinking, and oily-sheen in surface water bodies that is commonly seen in the area. Due to lack of access to other sources of safe drinking water, the residents of these communities drink, cook, wash their clothes, and use the polluted water for other chores (Amnesty International, 2009; Anyakora and Coker, 2009). The fact that unrefined crude oil has a place in folkloric medicine as an analgesic, for relieving gastrointestinal

disorders, in the treatment of burns and foot rot and leg ulcers (Orisakwe et al., 2000) could blunt their appreciation of the risk posed by the exposure. In essence, there is no perception in most of the residents of these communities to any risk associated with exposure to the hazard associated with crude oil.

The potential human health risks deriving from drinking water quality associated with the operations of the petroleum industry in the Niger Delta could be quite severe and multifaceted. For example, in the report on the environmental assessment of Ogoniland, benzene was found contaminating the drinking water source in Ogale Eleme at levels 900 times higher than WHO guideline (10µg/l) for safety in drinking water (UNEP, 2011). The WHO guideline values have been developed and issued for over 60 years, and are based on international best practices and the risks associated with water consumption. These values serve universally as benchmark for safety in drinking water (WHO, 2004). The UNEP report also highlighted several cases of ground water pollution which were in excess of intervention values going by the Nigerian legislation guiding operations in the petroleum industry, the Environmental Guidelines and Standards for the Petroleum Industry in Nigeria (EGASPIN), which for benzene in groundwater is 30µg/l, and the target value is 0.2µg/l. For example, at Ejama-Ebubu in Eleme Local Government Area, at a site of a huge historical oil spill that occurred more than forty years ago during the Biafran war, and which was described as the most infamous case of oil spillage in the Niger Delta by the UNEP Report, several other spillages have since occurred at that site, and after several attempts at remediation, the site remains heavily contaminated. Also, along Shell Petroleum Development Company (SPDC) pipeline right of way in Ejama-Ebubu community, groundwater pollution that exceeded EGASPIN intervention values was detected at 19 out of 33 sites investigated (UNEP, 2011). There were several other sites in the report where very high levels of hydrocarbons were detected in groundwater which feeds the aquifer the communities tap into as drinking water. In a significant number of sites where the drinking water quality was analysed in the course of the UNEP assessment, petrogenic hydrocarbons have been found at levels that could cause harm.

There are standards for drinking water quality in Nigeria, the Nigerian Industrial Standards (NIS) 554:2207, which was developed by the Federal Ministry of Health

through a multiagency technical committee of stakeholders, and issued by the Standards Organization of Nigeria (SON). The standard contains mandatory limits with regards to constituents and contaminants of water that are either hazardous to health, and/or likely to be objectionable to consumers (SON, 2007). Effectively, the standards for drinking seeks to protect public health consequences of exposure to poor quality drinking, and includes protection of drinking from catchments and source to the its usage by its consumers.

The ingestion of contaminated water could be a primary route of exposure to hydrocarbons, and the Risk Based Corrective Action (RBCA) toolkit is devoted primary to investigating the risks posed by petroleum hydrocarbons in polluted soils through this route and model (Pinedo et al., 2014). The human health risk implications of drinking water tainted with petroleum hydrocarbons, particularly the known human carcinogens such as benzene, and other toxicogenic hydrocarbons like the other BTEX compounds and PAHs found in petroleum are many. It has been suggested that the contribution of environmental exposure to chronic disease risks could be up to 70-90% (Lichtenstein et al., 2000; Rappaport and Smith, 2010). Although the records are poor, the incidence of chronic diseases, especially neoplasm in Nigeria, and particularly the Niger Delta, is on the increase (Omoti and Awodu, 2005).

Benzene, toluene, ethylbenzene and xylene (BTEX) are natural constituents of crude oil, along with a panoply of PAHs. The chronic toxicological effects of benzene derive mainly from its suppressive effects on the bone marrow tissue (Snyder and Kocsis, 1975; Smith, 2010). Benzene is an established haematotoxin with toxic effects on the heamatopoietic system leading to aplastic anaemia, leukopenia, pancytopenia, agranulocytosis, and acute myelodysplastic syndrome or pre-leukaemia (Schnatter et al., 2012; Smith, 2010; Snyder, 2000). It has been estimated that benzene-induced bone marrow suppression occurs in 1 in 10 persons with inhalational benzene exposure of greater than 100ppm (Smith, 1996). Benzene is also a human carcinogen and clastogen, and has been shown to induce both structural and numerical aberrations in human lymphocytes and bone marrow in chronic exposure scenarios, especially in occupational settings (IARC, 1987; IARC, 2012). There are substantial reports linking occupational exposure to benzene and acute myeloid and acute non-lymphocytic leukaemias,

including other lymphohaematopoietic cancers, even at exposure levels that are less than 1ppm (Schnatter et al., 2012; Rappaport et al., 2013).

Other human health impact associated with benzene exposure include the impairment of immune system, which may result from its effect on haematopoiesis following chronic exposure to slightly higher doses (IPCS., 1993). Neurological, reproductive, and developmental morbidities have also been associated with exposure to high levels of benzene, especially in occupational epidemiological studies (Baslo and Aksoy, 1982). Paroxysmal nocturnal haemoglobinuria has also been linked with chronic exposure to benzene. This is a disorder that is caused by accelerated breakdown of red blood cells, and which leads to bleeding into urine especially during sleep, which is the most active period for this malfunction in the body (Aksoy, 1985).

When benzene is ingested in water, it is rapidly and extensively absorbed. Although there are no studies on the absorption profile of benzene through ingestion by mouth in humans, evidence from animal studies shows that at least 90% of benzene was absorbed on oral administration, but in a dose dependent manner (Sabourin et al., 1987). Benzene is distributed throughout the body after exposure, but tends to be found in greater amounts in tissues with high lipid content or those with high perfusion rate. The toxic effects of benzene result from its metabolism by mixed function oxidases in the liver and bone marrow (Smith, 1996; Morgan and Smith, 2002; Snyder, 2004). The activity of the mixed function oxidases are genetically determined, and can also be altered by other chemicals and drugs, so that profound toxicity can be seen at very low levels of exposure in susceptible subjects (Lan et al., 2004).

Exposure to PAHs would also be of concern in the Niger Delta with the high levels of hydrocarbon pollution of drinking water sources and groundwater observed in the area. This was corroborated by UNEP in the Ogoniland Report (2011). However, the levels of PAHs found in the drinking water and groundwater based on the UNEP report was assessed as not remarkable as a risk driver (UNEP, 2011; Linden and Palsson, 2013). Although there have been reports of heavy metal contamination of sediments and surface water in the Niger Delta (Kakulu and Osibanjo, 1988; Kakulu and Osibanjo, 1992), there are none about heavy metals polluting drinking water sources and groundwater. Nevertheless, in places where these surface water bodies serve as source

of drinking water, the possibility exists for ingestion of heavy metals with the potential for risk to human health.

Beyond oil spillages and the hazard it poses to the water quality and the health of the residents who depend on the water and allied resources for their livelihood, there are the more entrenched poor waste management practices, especially operational wastes from the oil and gas industry in the area. The upstream petroleum industry is a heavy waste generating venture, and these are not innocuous wastes. Produced water, drilling fluids and muds, drill cuttings, produced sands; ballast water, well treatment chemicals, sanitary wastes, and other toxic chemicals are intermittently discharged into streams, rivers and the seas, close to the residential, fishing and agricultural grounds in the Niger Delta (UNEP, 2011). Land farming of solid wastes from exploration and production of crude oil, such as spent drilling muds and drill cuttings appears a common practice. Ayotamuno et al., (2002), sampled some discharges and effluents from some wells in the area and found high levels of grease and oil contents, and noted that these were dumped into the watercourses, streams, and on land without pre-treatment. Amnesty International (2009) observed a significant failure in the monitoring, regulation and control of wastes in the oil and gas industry in Nigeria. In Ogoniland, an ethnic nationality of the Niger Delta located in Rivers State of Nigeria, similar findings were made by the United Nations Environment Programme, when they undertook a comprehensive environmental assessment of the area (UNEP, 2011). Among the residents of the communities impacted by the dumping of these effluents and discharges, there is lack of basic information about the hazards associated with the exposure to these discharges, and no information that could inform their behaviour and response. Other studies on the water quality in the Niger Delta region, including studies on the underground water quality, have found that the discharge of effluents and operational wastes have impacted on the quality of water meant for both domestic and industrial purposes, with the potential to pose serious threats to the health of the residents and the environment (Ayotamuno et al., 2002; Osuji and Uwakwe, 2006)). Studies carried out later by UNEP (2011) found that in so many parts of the Niger Delta, especially in Ogoniland, the drinking water from the major aquifer serving some communities was contaminated with benzene at over 900 times the guideline value set for safe drinking water by the World Health Organization (WHO) and United States

Environmental Protection Agency (US EPA). It is suggested that the artisanal practices in agriculture, and fishing in the area, in which hoes, machetes, and shovels are used for tillage of ground, especially by women and children, would create an easy pollutant linkage to the hazardous wastes that are dumped untreated in land farming operations. There are no records of the amount of wastes dumped into these very sensitive ecosystem, nor indeed adequate research into the potential impacts. A joint report by the Federal Ministry of Environment (FMENV) and the Nigerian Conservation Foundation (NCF) estimated that the damage on the ecosystem may be worse than other notoriously impacted regions of the world, including Azerbaijan, Kazakhstan, Siberia and Ecuador (FMENV/NCF., 2006). Corroborating this findings, UNEP (UNEP, 2011) estimates that the damage is ongoing across land and water, and 25 to 30 years may be required to remediate the area they assessed, if prompt measures were, and international best practices adhered to (EIA, 2013). The Niger Delta region is subject to regular pluvial and fluvial flooding due to the intensity of the rains, and its coastal location. This has implications for the health of the ecosystem with regards to the waste management practices, especially the toxic wastes associated with oil and gas industry. Depending on the time of the year and level of segregation through barriers, it is entirely plausible that the floods could sweep the waste down to sensitive areas even before the expected biological attenuation by land farming have run the course of detoxification intended, and could result in levels of human exposure that was unintended (Ogba and Utang, 2008). Analytical reports on the sampling of the sediments from rivers and canals and the soil in the Niger Delta region, particularly from the host communities to the oil producing facilities that emit the effluents have revealed levels of PAHs and other chemicals of concern higher than limit values set for remediation or other intervention (Anyakora et al., 2005; Sojinu et al., 2010). The possibility exists for the leaching of toxic chemicals from the untreated effluents into the aquifers, especially since the water table in the area is not too deep from the surface in the region

One of the most visible impacts of the oil and gas industry in the Niger Delta is the degradation of the landscape and biodiversity. The mangrove swamps are famed as important breeding grounds for several marine fauna. One of the fallouts of the environmental pollution in the Niger Delta, and one with potentially serious human health impact is the tainting of seafood. There is a strong dependence by the indigenous

communities on this ecosystem as a source of protein; by some estimates, fish and other aquatic and marine resources could constitute more than 80% of the protein source in these communities. Several sources of contamination of seafood in the Niger Delta have been identified, ranging from the incessant oil spillages to the dumping and discharges of untreated drilling wastes into the delicate ecosystems in the area (Amnesty International, 2009; Adeyemo et al., 2009; Vincent-Akpu and Chindah, 2009). The common practice in the management of process and operational wastes in the oil and gas industry in the Niger Delta, particularly waste drilling fluid and mud, including drill cuttings in the exploratory phase of the upstream operations is discharge into landfills and burrow pits. Odokuma and Akponah (2008) reported that several cases of drilling fluid plumes trailing downstream from poorly maintained disposal sites are seen around the Niger Delta environment. There are also reports of fish kills due to oil spillages and discharge of untreated operational wastes into water bodies (Amnesty International, 2009; Adeyemo et al., 2009; Benka-Coker and Olumagin, 1996). Due to the seasonal flooding problems in the area, even the wastes that are disposed in pits and landfills are leached into rivers and streams, or into swamps in the mangrove forests that serve as important breeding and nursery grounds for fin and shell fish. The discharge of drilling fluids and drilling muds, including drill cuttings represents a potential source of hazardous chemicals such as surfactants, biocides, trace and heavy metals, PAHs, VOCs, and other chemicals of potential concern for human health into the food chain. The food safety problem may be heightened by the fact that some of these chemicals are not only refractory to biodegradation, but may also bioaccumulate (Amnesty International, 2009; Benka-Coker and Olumagin, 1996). Of particular concern are the tainting of molluscs, crabs, oysters, and other benthic fauna that the women and others without pelagic fishing ability rely on in their fishing and gathering activities, and often are common items on the family menu (Gabriel, 2004; Adeyemo et al., 2009). The sediments and bottom of the water bodies that these organisms live and feed from are repository of the toxic contaminating wastes and chemicals of potential concern for human health risks, especially those chemicals that are not easily biodegraded. It is also not easy to determine what happens at the various trophic levels in the food chain for the refractory contaminants as they are passed from one organism to the one that feeds on it (Briggs, 2003). Wastes disposed into burrow pits and swamp in the non-tidal areas

have been noted to leach into farmlands and into the streams and rivers during seasonal flooding. The contamination of vegetables and fruits, especially those that creep on the ground, and that may end up being eaten by residents without proper processing remains a potential source of impact on health. Even when the crops are washed, traditionally, they are washed in the streams which may be polluted. Again, some of the local staples like cassava are left in the streams and rivers to ferment and leach out noxious chemicals in the making of tapioca, a traditional food processing practice. With the pollution of the streams and rivers, real food safety issues, bordering on exposure to toxicants discharged into the water bodies, or from spillages into them arise. The rural poor with no access to alternative resources are likely to bear a disproportionate burden of the impacts (Briggs, 2003)). With the inadequate environmental regulatory regime in Nigeria, not much is known about the chemical characteristics and properties of the chemicals that may be present in these environments, and the extent of pollution, both historical and current. Issues about environmental pollution and the human burden of disease is novel in Nigeria, as indeed in most developing countries (Vincent-Akpu and Chindah, 2009; Briggs, 2003; Utzinger et al., 2005). The human health effects of contaminated food in the Niger Delta could be heightened by behavioural practices that could be attributed to the pervasive poverty among so many residents in the communities, which is made worse by low level of literacy and poor risk communication in the area. For example, it has been reported that some organochlorine pesticides like Lindane are released into streams and rivers to kill fish commercially, and the women that smoke fish use them to control pests on the fish that are eventually sold in the markets, practices that suggest very poor risk awareness (Ndiokwere, 2004; IPEN, 2006). Against this background, it would seem plausible that fish kills that may be attributable to other environmental pollutants could be harvested and either consumed or sold in its fresh or dried form and that could include fish kills due to oil and gas industry waste and discharges. There is a serious deficit in the regulation of quality and standards of food and food products in Nigeria, especially food produced locally. The National Agency for Food and Drug Administration and Control (NAFDAC) was established by Decree No 15 of 1993, and its main remit is the regulation of imported and locally processed food and drugs, at the federal level. The local authorities at the tertiary level of government see the responsibility as the

administration of the local markets (Omotayo and Denloye, 2002). The area of food hygiene and food quality is, to a very large extent, a private matter.

Heavy metal contamination of food and environmental media in the Niger Delta associated with the upstream petroleum industry operations has also been reported. Ndiokwere and Otalekor (1996) found exceptionally high levels of arsenic, nickel, chromium, iron and lead in vegetation and soil samples around areas of petroleum exploitation and gas flaring in the area. Other workers have found high levels of chromium, cadmium and lead in river sediments, and in benthic and sediment-dwelling fauna commonly used as food in the area, for example periwinkles (*Tympanotonus fuscatus*) and in crabs and sea snails. There are also reports of mercury contaminating fish stock in the area (Davies et al., 2006; Benson et al., 2007). Although the sources of the heavy metal pollution were identified as anthropogenic, point and non point sources including agricultural sources were implicated. Interestingly, however, the highest level of contamination was found around upstream petroleum facilities including flow stations and drilling sites (Agbozu et al., 2007). Järup (2003) identified sea food as a major source of health risk from mercury in communities with high fish consumption. The risk could be accentuated where fishing takes place in polluted fresh waters as it seems to be in the Niger Delta. Pregnant women who consume high quantities of seafood may have their foetus exposed to the risk of neurological deficits and other damages associated with mercury exposure (Dolk and Vrijheid, 2003). In adults, the risks associated with high dietary intake of mercury in fish include cardiovascular disorders, and this has been correlated with fish consumption (Jarup, 2003). The food chain may also be an important exposure pathway for the other metals contaminating the food sources in the Niger Delta. Lead is classified as a 'possible human carcinogen' based on sufficient animal data, and insufficient human data (IARC, 1987). Other evidence suggests a weak association between lead and lung, and stomach cancers and gliomas (Steenland and Boffetta, 2000) Paediatric plumbism has been associated with reduced intellectual ability, encephalopathy, renal tubular damage and nervous deficits. Food, drinking water and soil could serve as important sources of arsenic exposure in polluted areas. The symptoms of intoxication include gastrointestinal upsets, severe disturbances of the cardiovascular and nervous systems, and death in acute incidences. Bone marrow depression, haemolysis, hepatomegaly, melanosis, hyperkeratosis, skin

and lung cancers have also been recorded as a result of arsenic intoxication (WHO, 2001).

Some of the chemicals reported as polluting the environment in the Niger Delta, including the heavy metals, the hydrocarbon fractions, the biocides used as additives in drilling and operational processes, and a host of other wastes have been of potential concern due to their association with congenital anomalies, reproductive deficits and poor pregnancy outcomes (Dolk and Vrijheid, 2003; Nriagu, 2011). In a study in Rivers State, which is one the leading crude producing states in the Niger Delta, which was based on records of incidences between 1984-1987, of 39 cases of children with congenital cleft deformities, the majority (69%) of the cases were from the areas in the state with high concentration of oil wells, gas flares, and similar operations in the oil and gas industry (Datubo-Brown and Kejeh, 1989). In some host communities where serious incidences of environmental pollution from gas flaring and oil spillages have happened, and which has remained poorly remediated, pregnant women are persuaded to leave the area until parturition. This action seems to be supported according by expert opinion that says that oil-related contamination have been associated with negative maternal outcomes, including spontaneous abortion and still-births (Amnesty International, 2009). Although no empirical research-based evidence is adduced linking the environmental pollution to birth defects, it may be too optimistic to take that as evidence of absence of that pollutant linkage (Dolk and Vrijheid, 2003). A number of folkloric practices that could modify risk attitudes have been reported. Among them, the use of crude oil in folkloric medicine in the management of various maladies has been investigated by Orisakwe and others (2000; 2004). In a study on the testicular toxicity of Nigerian bonny light crude oil in male albino rats, Orisakwe and colleagues (2004) found a significant dose-dependent decrease in absolute weight of the testes, epididymal sperm number, and slight to severe degeneration or complete absence of seminiferous tubules. There was an exposure threshold-related necrosis of the seminiferous cells. This finding is important for the reproductive health of the males in the region when they are employed in the clean-up of crude oil spillages, as inadequate personal protective equipment are provided for these tasks, and also for the youths in these communities who engage in acts of sabotage of oil installations, or who otherwise break into well heads to bunker crude oil for local refining, and similar behaviours that may

expose them to intoxication. Against the background of the 10-25% infertility/sub fertility among the adult population in Nigeria, there may be genuine cause for concern, although the majority of the cases have been attributed to infection (Nriagu, 2011).

Gas flaring and venting in the Niger Delta is another major source of environmental pollution with multiple and far reaching health consequences for the residents of region, especially those living proximal to the flare sites or downwind of the fallout plumes. Associated gas, which is the raw natural gas that emerges with crude oil from oil wells, is a mixture of methane and other light hydrocarbons like ethane, propane, butanes and pentanes, including hydrogen sulphide, helium, oxides of nitrogen, and other compounds. There is a site-to-site variation in the composition of associated gas. However, the flaring and venting of associated gas emits a cocktail of air pollutants including some known carcinogens such as the BTEX compounds, PAHs, sulphur dioxide, oxides of nitrogen, toxic heavy metals, black carbon soot, and other particulates. The gas flaring process is often inefficient and variable. The fallout could be a mixture of constituents that range between venting to ideal burning with minimal emissions (Buzcu-Guven et al., 2010). The energy density of the flare gas stream, design of the flare gas system, environmental conditions such as ambient temperature, wind speed and direction all impact on the performance and efficiency of the gas flare system. Up till the year 2006, Nigeria was on top of the list of associated gas flaring nations, emitting 25.5 billion cubic meters of gas according to the World Bank Global Gas Flaring Reduction (GGFR) estimates, and all of that gas was flared in the Niger Delta (Buzcu-Guven et al., 2010). Although the 2009 estimates by the US National Oceanic and Atmospheric Administration (NOAA) show that Russia has overtaken Nigeria as the worst gas flaring nation, the two nations still accounted for an estimated 42% of global associate gas flaring (GGFR, 2010). About 50% of Nigeria's daily gas production is flared (GGFR, 2003).

The pollution of the air and other environmental media through associated gas flaring and venting poses a significant health risk for the residents of the communities close to the gas flares. Among the health effects associated with gas flaring are respiratory illnesses, including asthma, chronic obstructive pulmonary diseases (COPD), chronic bronchitis, blood dyscrasias, cancers, skin eruptions, wheezing, and negative pregnancy

outcomes (Amnesty International, 2009; Buzcu-Guven et al., 2010; Chauhan and Johnston, 2003). Incomplete combustion of the effluent gas has led to deposition of oil droplets on waterways, crops, houses, and on clothes that are hung in the open to dry on clothes line. There are also reports of sooty oil dust collecting inside people's homes, and on the open play areas commonly used for recreation by children (Figure 1-2) (Amnesty International, 2009). In a report by Friends of the Earth (FOE, 2005), women in the communities were shown drying cassava near the horizontal gas flaring sites (Figure 1-3), hoping to utilise the heat generated, oblivious of the toxic exposure that could result. Apart from the extremes of temperature they would be exposed to, they also face the risk of exposure to particulates in respirable air, not only at the perimeter of the flare site, but also at locations downwind of the emission plumes. The children that play around these sites could be at risk from direct ingestion of soil with toxic deposits, dermal contact with contaminated soil, and inhalation of volatile organic compounds, particularly around the flare sites.



Figure 1-2 Gas flaring close to children's playground (FOE, 2009).

Gas flaring and venting in the Niger Delta has a history as old as the petroleum extractive industry in Nigeria. There are communities that have had flares for more than 50 years, or about two generations. This is important not only for historical exposures and the potential health effects, but also for cytogenetic effects that may be stable and persistent in the gene pool into generations, and may impact on the viability and survival of the population.

Other activities and operations in the petroleum industry that contribute to air pollution and impact on the health of the residents of their host communities include fugitive emissions from flow stations, the burning of spilled crude oil, volatilization of light petroleum fractions in spent drilling muds and drill cuttings, discharge of produced water into swamps and streams, and the subsequent vaporization of the entrained petroleum hydrocarbons and other VOCs into the atmosphere, especially with the high ambient temperatures in the region.



Figure 1-3 Woman drying cassava with heat from gas flare. (Ed Kashi, 2008).

1.6.3 The Environmental assessment of Ogoniland by UNEP

The environmental assessment of Ogoniland was undertaken by the United Nations Environment Programme (UNEP) at the invitation of the Government of The Federal Republic of Nigeria in consultation with various stakeholders in the oil and gas industry in the Niger Delta, and Ogoniland in particular. The assessment sought to determine the extent of impacts due to the operations of the industry over a period of over 50 years. Although oil industry operations has been suspended in the Ogoni since 1993, the adverse footprints on the environment with widespread contamination remains.

Ogoniland is located in the south east of Rivers State Nigeria, and covers an area of about 1000Km². The Ogonis are one of the indigenous tribes of Nigeria, and straddle 4 local government areas east of Port Harcourt, namely Khana, Gokhana, Tai and Eleme. However, the traditional administrative of the Ogonis is compromised of 6 kingdoms- Ken-Khana, Babbe, Gokana, Nyo-Khana, Tai and Eleme. Data from the 2006 National Census show the population of Ogoniland to be around 832,000, which is broken down as follows

Eleme	190,884
Gokhana	228,217
Khana	294,217
Tai	117,767

Oil exploration and exploitation commenced in the 1950s in Ogoiland, and extensive production were established during the intervening decades, with about 116 wells drilled, 12 operational oilfields and 5 flow stations located in the area, yielding an output of 185000 barrels/day. Shell Petroleum Development Company (SPDC) Nigeria was the major operator of the concessions in Ogoniland, with most of the facilities located onshore. Unfortunately, the relationship between Shell and the Ogonis has been fractious, and Ogoniland has witnessed recurrent social unrest over concerns related to oil industry operations, petroleum-related contamination, and resource control.

The UNEP assessment was funded by Shell at a cost of over \$10 million, and spanned a period of 14 months. It involved desk reviews, field work and laboratory analyses. In

the course of the assessment, 122kms of pipeline rights of way were surveyed, all known oil spill sites were examined including oil wells and all oil-related facilities, irrespective of its state, abandoned or decommissioned. With the aid of aerial surveillance and reconnaissance, areas of oil pollution were mapped and visited, including locations used by criminal gangs for artisanal refining of petroleum and oil bunkering.

During the assessment, 69 sites were flagged for detailed soil and groundwater analysis. In addition, samples of community drinking water, sediments taken from the creeks, surface water, shellfish and fin-fish, and air were collected through the length and breadth of Ogoniland adjoining areas for analyses. In total, over 4000 samples were analysed, including water samples from 142 groundwater monitoring wells that were specifically drilled for study purposes, while soil samples were extracted from 780 boreholes.

The analytes examined in the assessment included certain groups of hydrocarbons with known adverse impacts, based on reports from previous oil spill assessment and clean-up work. The most important of these are the BTEX compounds and PAHs. In the air quality investigations, VOCs were targeted primarily.

The assessment also carried detailed remote sensing, and reviewed the extant legislation, institutions, oil industry practices and available remediation technologies towards the completion of the study.

1.6.3.1 Main Findings:

The Environmental Assessment of Ogoniland found oil contamination to be widespread and severely impacting multiple components of the environment. Due to the high level of rainfall in the area, delays in cleaning up polluted sites leads oil being washed away, traversing farmlands, and invariably ending up in creeks.

Thematically, the findings were grouped under the following subgroups

Contaminated soil and groundwater:

(a) Extensive pollution of soil, including sediments and swampland from spilled crude oil, although pockets of contamination were from refined products

(b) There is no continuous clay layer across Ogoniland, and as a result, oil spilled in most land areas seeped into the groundwater, sometimes to depths of more than 5 meters.

(c) Most of the spill sites showed the presence of TPH in excess of the standard set in the law governing the operations of the oil and gas industry in Nigeria (EGASPIN).

(d) At significant number of sites tested, the level of groundwater contamination exceeded EGASPIN.

(e) The most egregious case of groundwater contamination was found in Nsisioken-Agbi in Ogale.

Vegetation

(a) Notable impacts on mangroves, which are important spawning ground and nursery for fish. As a result, there is severe impacts on the life cycle of that spawn there, and those that use them as nursery.

(b) The impact of poor soil quality has been low yield and poor quality of harvest especially of root crops like cassava. Also, fire outbreaks sequel to crude oil spills kill vegetation and create crusted earth with poor ability to support vegetation growth.

(c) In some areas of Ogoniland, for example Bodo West, a significant increase in artisanal refining was noted. This bring devastation on the mangrove forest

Aquatic

(a) The surface water throughout the creeks in Ogoniland was found to contain hydrocarbons. The layers of oil found floating on the surface waters varied from thin sheen to thick black, with the highest reading recorded at 7,420µg/L at Ataba Otokroma

(b) The level of pollution has resulted in fishers having to travel further upstream or downstream to make a catch since fish tend to move in search of less contaminated water.

(c) Although there are concern raised by community members about seafood quality due to widespread contamination of the water bodies and fishing grounds, the results of the UNEP assessments show that those fears are not sustained by evidence from the

analyses. However, the fishing sector has suffered as result of the destruction of the common fishing grounds in Ogoniland. Several cases of fish farms and aquaculture businesses located on the creeks that have been devastated as a result of oil spillages were recorded.

1.7 Statement of the problem

One of the fallouts of the BPs Deepwater Horizon or Macondo well blowout and the resultant oil spillage in the Gulf of Mexico is that although so much research has been done, and a lot of knowledge and understanding exist, into the environmental impacts of oil spillages, comparatively, very little is known about the human health effects. The paucity of evidence-based research means that much uncertainty still exists about the potential risks to human health posed by these events. A flurry of research has since been initiated by the National Institute of Environmental Health Sciences (NIEHS) in America. One of these many researches include the Gulf Longitudinal Follow-Up (GuLF) Worker Study, which is a long term study developed to learn about the possible health effects in workers and volunteers involved in the containment and clean-up of the Gulf oil spill. There are still so many other researches and endowments under the Deepwater Horizon Research Consortia funded by the NIEHS that are targeted at identifying personal and community health effects arising from the oil spill. These research efforts are still in progress. Previously, Aguilera et al. (2010) had reviewed the effects of exposure to spilled crude oils on human health, although most of the available reports were on studies carried out as a result of accidents involving super tankers in littoral and marine environments, furthering the quest and desire to understand the human health risks associated with crude oil spillages.

The Niger Delta region of Nigeria has been the site of upstream petroleum industry operations since the mid-1950s. The Delta region has had a tragic history of oil spillages, most of which remains unremediated or under-remediated. There are cases of legacy spillages still contaminating the places people live, work and recreate that have remained for over 40 years. Added to that, there are issues of poor waste management practices and gas flaring and venting, including production oil well fires, artisanal refining of crude oil illegally obtained from compromised oil facilities, poor maintenance of oil industry facilities, very challenging regulatory framework, cultural

and traditional practices, leading to the description of the region as the most oil-polluted place on earth (UNEP, 2011; FMENV/NCF., 2006).

At the request of the Nigerian government, the United Nations Environment Programme (UNEP) conducted a comprehensive assessment of the environmental impact of oil contamination in Ogoniland, one of the ethnic nationalities in Rivers State, Nigeria, and a major oil producing area in the Niger Delta region with a fractious history of oil spillages. In the report from the assessment (UNEP, 2011), it was confirmed that in a significant number of locations, there was serious threat to the health of the residents that could arise from exposures to very high levels petrogenic hydrocarbons in various environmental media. For example, in one of the communities sampled, the residents were drinking water with benzene contents more than 900 times above the WHO guideline for human health attributed to oil pollution that has penetrated into the aquifer that serves as source of water in their wells (UNEP, 2011). Although the UNEP study was limited to Ogoniland, field reconnaissance trips undertaken as part of this research project suggest that this trend may run through a reasonable number of the other communities that are hosts to the upstream petroleum industry in the Niger Delta. A plethora of occupational epidemiological studies of workers in the petroleum and other industries with benzene exposure similar to, or even lower than has been reported in the Ogoniland Report have recorded statistically significant excess of leukaemia, particularly acute myelogenous leukaemia, acute nonlymphocytic leukaemia, malignant lymphoma, and lung cancer (Yin et al., 1996; Vlaanderen et al., 2011). The International Agency for Research on Cancer (IARC, 1987; IARC, 1989) classified benzene as a Group 1 carcinogen (carcinogenic to humans). While some of these cancers are rare outcomes with long latency periods in some cases, immediate and stable changes in the haematopoietic system as well as chemical modifications of the DNA and damage to the chromosome which serve as intermediate biomarkers of intoxication, and sentinel of potential future disease risks could be seen in the peripheral blood and other body tissues. For example, the haematotoxic and immunotoxic effects of even low-grade exposure to benzene could be measured. These outcome measures may also be relevant for other compounds such as PAHs (Wickliffe et al., 2014).

1.8 Research aim and objectives.

The aim of this research is to investigate aspects of health risk associated with the prolonged exposures to environmental contaminants in the Niger Delta that may be related to the operations and activities of the oil and gas industry, and the fallouts of the operations.

Pursuant to this aim, the following tasks shall be carried out:

- Identify communities in the Niger Delta in which petroleum exploration and production takes place, and which have identifiable incidents of crude oil spillages and/or dumping of wastes derived from such operations as study area
- Identify residents and community members who may have had exposure to petroleum through the various pollutant linkages, and have lived in the study area for a period not less than 5 years.
- Determine through oral interviews and structured questionnaires self-reported physical health symptoms among the exposed populations, including questions to identify confounders to potential effects associated with exposure to petroleum hydrocarbons and exploration and production wastes.
- Carry out analysis of blood samples for biomarkers of exposure to major components of petroleum, and other biochemical metrics of physical health effects associated with exposure to these components.

Effectively, this research shall investigate the impacts of the upstream petroleum industry in the Niger Delta from a cross-sectional human biomonitoring and health risk assessment perspective. Within this framework, a battery of biomarkers of damage to the DNA shall be analysed and self-reported health symptoms critically evaluated in the exposed population and matched referent group. The overarching endpoint is the detection of early genetic metrics, and other adverse health symptoms, that may be sentinel of more serious chronic health consequences due to the exposure events. The most important endpoint of these types of exposures is cancer, particularly with chemicals of concern such as the BTEX compounds, PAHs, and heavy metals. Ethnographic inquisition shall also be carried out aimed at situating data collected from

observational, focus group meetings and questionnaire studies within a human health framework, taking cognisance of the importance of quality of life measures as determinants of physical and psychological wellbeing.

1.8.1 Research hypothesis

The residents of the areas of operations of oil and gas industry in the Niger Delta are exposed to crude oil-derived hydrocarbons and other petrogenic contaminants in their environments arising from these operations. This study's main hypothesis is these exposures, including the exposure to spilled crude oil, dispersants used in the containment of oil spillages, the flaring of associated gas, agitations for environmental and economic resources that has put communities at loggerheads with oil companies, places the indigenous people of Niger Delta at a greater risk for developing mental and physical health outcomes. Although an open-ended study design was intended, and no specific health outcomes will be investigated, it was guided largely by health outcomes and complaints from researches that investigated similar exposures related to crude oil spillages and clean-up activities. Accommodation was made for the limitations due to available funds, time, prevalent fragile security situation in the Niger Delta, and what was realistic in the study area.

2 Research methodologies

2.1 Introduction.

Approval for the study protocol was obtained from the Cranfield University Health Review and Ethics Committee. The study questionnaire and methodology, including the invitation to study, which explained the purpose of the study, what was required of the potential respondents, including the measurements and samples to be taken, their rights to withdraw from this study at any stage without prejudice, confidentiality of personal information and measurements through anonymous record keeping, and consent through signed approval (Appendix) were submitted and vetted by the Cranfield Health Ethics Committee. The study questionnaire used for this study was adapted from the questionnaire used for Gulf of Mexico BP oil spill, known as Gulf Long-term Follow-up Study (GuLF Study) (NIEHS, 2010), by the American National Institute of Environmental Health Sciences. The Study questionnaire was piloted on some friends and acquaintances, and on some students at University of Port Harcourt (UNIPORT), in the study area, to ensure that the questions asked would not cause any distress to the potential respondents. Some sections and questions in the questionnaire were modified to reflect and accommodate local knowledge and understanding of disease conditions.

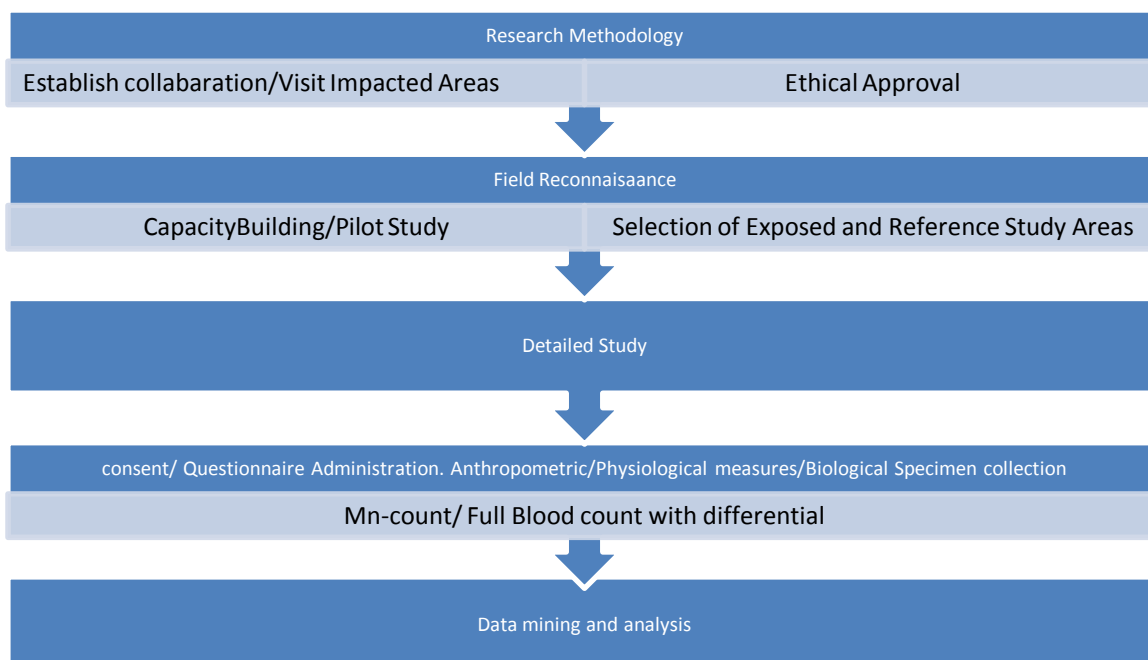
Requests for collaboration and input to the study were made to the Faculty of Pharmaceutical Sciences, University of Port Harcourt, and Faculty of Pathological Sciences, University of Port Harcourt Teaching Hospital. A trip was made to Port Harcourt, Rivers State, in June 2011 to meet with some of the staff of both institutions, and to locate and assess the possible centre for the study in the Niger Delta. At the meetings, it was agreed Professor O.E. Orisakwe, a toxicologist and head of the Department of Experimental Pharmacology and Clinical Pharmacy, who has done a lot of research and is widely published in the area of this research, would be the lead collaborator from the faculty of pharmaceutical sciences UNIPORT, while Dr C.C. Obiorah, a consultant pathologist, senior lecturer and head, Department of Anatomical Pathology, who also runs the Cancer registry in the University of Port Harcourt Teaching Hospital (UPTH), would provide the lead from the teaching hospital. Dr

Obiorah facilitated the obtaining of ethical approval for this study from the UPTH Ethics Committee on the back of the approved study protocol from Cranfield University. The approval to undertake this study was granted by Cranfield Health Ethics Committee based on the approval from the UPTH Ethics Committee and collaboration agreements.

Several focus meetings were held with the aim of building capacity for the study, including seeking to understand and harness the experiences the collaborators, and other relevant university staff have had on crude oil spillages, waste management practices, and health and environment issues in the Niger Delta that may be pertinent to the research topic. Consultations were held with across several departments and faculties of the university, and with practitioners in environmental impact assessment beyond the university. Issues about the prevalence of cancers and the demographics were especially focussed on. There was also the all important issue about security and militarisation in the Delta, and how to prevent coming into harm's way in furthering the research. It was agreed that the Niger Delta would offer a unique challenge since most of the oil and gas activities in the area are carried out onshore or near-shore, with majority of the oil spillages un- or under-remediated. The areas and communities with oil spill-related problems were widespread.

As a result of these meetings, it was agreed that a combination of observational and cross-sectional epidemiological approach will be used to enable investigation into specific hypotheses generated from previous studies of oil spills, and potentially, identify conditions and symptoms that may occur in excess among residents in the exposed communities. It was also agreed that the research on the human health effects in the communities would be best served if this research is not based on *a priori* hypothesis. A flow chart of the research the approach and steps taken in this study is provided in the flowchart below.

Flowchart of Research Methodology



The laboratory capacity and space available for the identified studies were assessed, and it was agreed that it was going to be limiting. After auditing the areas of need, a list of materials, including chemicals and bench top analytical equipments to complement what was available was compiled. Cranfield Health was kind in purchasing those materials and shipping them to Port Harcourt.

2.2 Field reconnaissance

Several other trips were made to the study area aimed at establishing a level of environmental knowledge, understanding the prevalent situation and local concerns and challenges that may be encountered in the study. It was decided that the study would be best served by working with local institutions as a way of enhancing and tapping into local capacity and knowledge, in addition to helping secure the success of study.

A number of communities were identified as potential sampling areas based on the history of oil spillages in them. Based on the knowledge with the study collaborators on

the ground and the outcome of the consultations, a conclusion was reached that so many communities in the Niger Delta were affected, and the pollution issues were spread across a substantial number of oil bearing and oil producing areas of the Niger Delta and beyond. Evidently, everywhere petroleum pipeline transverses in the Niger Delta was potentially a spill site due to poor infrastructural management and maintenance, and sometimes breach by criminals who steal product from these pipelines, regardless of the consequences to themselves and the environment.

Field scouting trips were carried out to some communities on fact finding mission, with the aim of gathering information on the experience the indigenous people and residents have had with oil industry operations and pollution-related issues in their area and the ways they think it may have affected their environment and health. The goal of these scouting trips was to fully apprise the focus groups in these communities of the aim of the study, and to seek their collaboration and support. In the course of these trips and consultations, the primary and public healthcare issues of concern were also noted, and queried in line with their scientific meaning and significance, and the study aim and objectives. Town Hall meetings were held in Ogale, in Eleme Local Government Area (LGA), in Joinkrama in Ahoada LGA, Ogbodo-Isiokpo, Ikwerre Local Government, all in Rivers State, and in Biseni, Yenogoa LGA of Bayelsa State. The visit and meetings were made between March and June 2012. For example, as part of the deliberations and to buttress the seriousness of the challenge they face, in Biseni, the research team was taken to the site of an oil spillage at one of the well heads in the community, it was observed that some areas around the well head still had notable signs of the spill, including areas with poor growth in the vegetation (Figure 2-1.). In every case, access into communities was facilitated and coordinated through a member of the community known to someone in the collaborative research team, or through students of UNIPORT who are natives of the community of interest. This was considered important since there was usually an air of suspicion about strangers coming into these communities to carry out projects related to the petroleum industry in whatever guise. There have been several anecdotal reports of attacks on workers and contractors in the petroleum industry; abductions and kidnapping were also rampant in the area, especially in the years before amnesty was granted to militants in the Niger Delta. As at the time of the field studies, a measure of restiveness was still palpable in some of these communities.

On that basis, it was agreed that the study be approached initially through informal meetings to avoid local conflict. Multiple visits and negotiations were required to ensure that the purpose of the study was understood, including the activities to be carried out, and to invite the input of the community into the study. Trust from the communities in the intentions and aims of the study was considered central to its success, as long as the focus on its scientific integrity was maintained.



Figure 2-1. Well head in Biseni, Yenogoa, and site of oil spill

With the establishment of contacts in the communities, further field trips were conducted and meetings scheduled with community leaders, including the traditional council of chiefs and elders, the women leaders and the youth leadership. These strata of meetings were needed for mobilisation and consensus building, and to understand the different concerns each group may have on the study. These meetings afforded the research team opportunities to ask questions and gather anecdotal evidence that may be unique to these various sectors of residents and demographics in the communities, and to fully explain that the research was purely academic, with no connections or funding from the oil industry. The benefits of the research to those that would volunteer and the

need to have some background human health data in the Niger Delta was emphasised, and questions were raised and answered, as far as was possible. So many of the communities visited were very welcoming to have the research conducted in them. Some of the complaints from the residents of impacted communities included fish kills, kerosene smell in drinking water, rapid rusting of zinc-plated roofing sheets, destruction of farmlands, and the need to row their boats farther afield for any reasonable catch of fish, including poor fish catches. On their personal health, the complaints were about respiratory maladies, including frequent attacks of asthma, pneumonia, skin rashes, irritations in the eyes, coughs and dizziness. These were noted and queried for their relevance to the research theme.

In Ogale, Eleme, after a meeting with the traditional ruler, HRH Godwin Bebe Okpabi, the palace secretary and youth president were detailed to arrange a tour of some parts of the community affected by oil spillage and pollution. The palace secretary gave a narrative of some health issues they had encountered in the community as he understood them, including the feeling that the reproductive health of young females in the community was affected by the exposures. According to his account, the exposure to oil pollution in the community was suspected to be contributory to low fecundity, or uncertainty about the reproductive health of young adults, especially the females. As a consequence, female indigenes were encouraged to marry early or risk not finding a suitor if they delayed beyond a certain age. The other anecdotal symptoms gathered were complaints of malaise, fevers, itchy eyes, and other evidences they claim were more prevalent within the affected communities, suggesting increased morbidity among residents. There were issues of serious pollution of underground and drinking water sources in Ogale. This was highlighted in the Environmental Assessment of Ogoniland Report by the United Nations Environment Programme (UNEP), which is the report on the environmental assessment of Ogoniland (UNEP, 2011). The tour of the community revealed that there were vast areas of the community whose drinking water sources had strong noxious smell of hydrocarbon. It was also observed that the main water sources for household use in Ogale were commissioned by Port Harcourt Refining Company Limited, a subsidiary of the national oil company, Nigerian National Petroleum Company (NNPC) in April 2010 (Figure 2-2 and Figure 2-3). These boreholes were labelled as not fit for use sequel to the Ogoniland Report (UNEP, 2011), which was

released in August 2011. It was also observed that the community had so many hand dug wells in individual compounds, outside those provided by the NNPC, and those were still in use, and were fed by the same polluted underground water



Figure 2-2. Borehole in Ogale Eleme that serves a source of water for household use.



Figure 2-3. Water borehole in Ogale labelled as not fit for use.

In Ogbodo, the pattern of health complaints by the residents at the focus meetings mirrored those recorded in Ogale and Biseni. It consisted of arthritis, fever, malaise, and cough. There were two incidences of oil spillages in Ogbodo from ruptured oil pipeline in 1997 and 2001. The stream that services the community, and a major source of drinking and household water supplies, including a source of income and livelihood for fishermen, and recreation for the youths in the area was affected very badly. Subsequent fire to the oil slick, which burned for many days, made worse the situation for the residents of this community. It could not be established if the fire was an attempt at remediation and to contain the free phase oil on the river. We were told no other form of remediation has been carried to date on the fallout of that oil spill in that community, and this spill incidences happened more than 10 years before the visit to the community. A series of meetings were held in Ogbodo, in the hope that the community could be included in the analytical and laboratory study. This did not materialise in the time frame available for the extramural aspects of this study. There was need for further consultations and explanations on the aim and objective of the research. There was also constraints imposed by the limited funding and materials available for the research,

which meant that it was not possible to take on the whole communities that were considered as deserving of investigation.

Gas flaring was observed to be rampant in the Niger Delta, especially in the communities with producing wells and flow stations. Different flare stacks were observed, some very high in the air, and others on the ground. Still, others were very close to residential areas visited or within them, and you could hear the crackling sound they emitted as they burned. The brightness of the emitted light from some of the continuous flare stacks was such that residents in communities around them would live in constant glare, even at night. No location in the Niger Delta was sacrosanct, including places like children playgrounds (Figure 1-2). As illustrated (Figure 1-3.), some natives, left with a Hobson's choice, have learnt to put the flares to use, and have resorted to drying tapioca with the flame from horizontal flares in their community. The hunters of game and wild animals though, have fared worse, as they complained that the brightness of the flares makes it harder to make a kill in forests that are illuminated at night, as the nocturnal animals are turned away from those areas to more covered areas. The heat of the flares, the crackling noise, and the brightness of the light were complained about as interfering with soundness of sleep, especially by the elderly and more vulnerable residents of the communities visited. Traditional lifestyles, religious and cultural activities, some of which are ritualistic, and carried out under cover of the night were also said to be affected by the bright light from the continuous flare stacks.

It was also observed that security personnel in brand new 4x4 pick-up vans guard the major oil installations, like flow stations, and patrol around the communities, fully armed with guns. The residents said it has not always been this way. Apparently, this was a response to the increased militarisation of the Niger Delta, with the attendant abductions and kidnappings that have become prevalent. The residents report that these security details, a joint patrol of the army, navy, police and other personnel, are detailed to guard the oil companies and their staff, especially the expatriates, and occasionally get involved in dispute and conflict resolution in the more restive communities. These security personnel would also mount road blocks and speed breaks at strategic locations within these communities, and have been said to harass and intimidate the locals. Their presence in some of the more remote and rural communities has been reported to create

a siege mentality among the residents. This feeling was reported to be accentuated by the fact that in the past, some communities in the Niger Delta have been sacked and decimated by the military over protestation against environmental degradation due to the operations of the oil and gas industry within their community, due to agitation for environmental justice.

Furthermore, in the course of the focus meetings, some of the residents complained about incidences of divisions and strife within communities due to the approach of the oil and gas companies to community relations and liaison with them. According to their account, the oil and gas companies tend to rely not on their elected representatives, but what they termed on "powerbrokers", who act more as public relations or security contractors, although residents within the communities, and members of it. They attribute the escalation in violence and militarisation in the area in part to the need for these contractors, who they allege recruit and arm the youths to undertake the surveillance and security of pipelines and other installations within their local environment. However, the ambience around the meeting did change and their tones were hushed when discussing this, creating the impression of that there was a foreboding about discussing this topic. The impression was created that there was an air of suspicion and distrust with members and residents in these communities about moles in their midst.

2.3 Selection of test and reference communities

Ogale in Eleme Local Government Area of Rivers State was chosen as the test community based on the observations made and the evidence available from the UNEP Report on the environmental assessment of Ogoniland (UNEP 2011). From that report, the need for human health risk assessment was urgent. It was decided that there was an overarching need to investigate the potential impact of the pollution on the health of residents of this community, and possibly set a background that would feed into, and instruct studies that may follow. The assessments in the course of the field trips and surveillance, especially the pollution of the community's drinking water sources, suggest that Ogale may have had the most visible impact, and that the need for intervention was urgent. This lent further credence to the need to include Ogale Eleme in the study. The other consideration in choosing Ogale, Eleme as a test community was

the logistics involved in transportation of blood samples for analysis to the laboratory, which was situated at the University of Port Harcourt Teaching Hospital (UPTH). Transportation in and around Port Harcourt can be a huge challenge for sensitive deliveries. Although Ogale Eleme presented some logistic difficulties due to high volume of traffic on the major road that leads to it, including the poor state of the roads required for access to the various villages that would require sampling, it was one of the nearest to UPTH of the Ogoni communities.

Briefly, Ogale is the administrative headquarters of Eleme Local Government Area, Rivers State. The Eleme people are normally grouped together with the Ogoni people, although they claim a different linguistic and ethnographical origin. The population of Eleme Local at the 2006 census was 190,884. The Eleme Kingdom is grouped into two clans: Nchia, to which Ogale and five other communities belong, and Odido clan, which is made up of four communities. Ogale Eleme is located about 20km east of Port Harcourt by road. Ogale Eleme is very well developed, going by the standards of most communities in Nigeria. It benefits from a general hospital, it is electrified, with power supplies connected to the national grid, there are a number of banks and financial institutions located in it, a daily market, some tarred roads, and verges on the popular East-West Road, that transverses the South-South zone of the Niger Delta. The Port Harcourt Refinery Company, a petrochemical plant, and a number of other industries are located some kilometres away, in Alesa Eleme. Ogale is located about 7km from Onne, one of the Eleme communities, and the site of the largest seaport in the Niger Delta. One of the major difficulties encountered in accessing Ogale during the period of the research was that coming from the teaching hospital, there was only one road available to reach Ogale, and it required passing through Port Harcourt, with its unpredictable traffic. Unfortunately, much of that major link road was under construction throughout the period of the study, which made the traffic much worse, especially during the peak traffic periods. Ogale is major satellite town to Port Harcourt, with so many workers in resident in it, and making the daily commute to Port Harcourt.

Rumuche, Emohua Local Government Area of Rivers State was selected as the reference community. It shares so many geographical attributes with Ogale, Eleme, Its location makes it a veritable satellite town to Port Harcourt, just like Ogale, Eleme. It

may be slightly less metropolitan, and certainly lacks the level of industrial development present in Eleme. There are no petroleum installations in Rumuche and, therefore, no history of any spillage known to the community, and it is not located downwind of any known emission plume from the known oil and gas installations or flare stack which means it is not subject to any identifiable far-field exposure. There was the added advantage of easy access to Rumuche, so blood samples could be transported conveniently back to the laboratory. Entry into the Rumuche was facilitated through the Reverend Ebere, the priest at the Baptist Church in the community. Through the assistance of an elder in the church, who was also a chief and confidant of the paramount ruler of Emohua, Nnenwe-Eli, the research team met with the council of chiefs. The aim of the research was explained to them, including the need for the potential benefit the research could avail the community in providing a baseline data on the health status of a cross-section of the community. The study information sheet and invitation to study was provided to the council, and questions and concerns that were raised were addressed. It was further explained to them that study was based on voluntariness of participation and any data provided, including, personal details provided was going to be handled with anonymity to except by use of encrypted identification number. The confidentiality requirements underpinning the study was also elaborated. It was explained that the outcome of the project and data it would afford could be a useful reference and baseline for the community, and a snapshot of the health status of a cross-section of the community, but the other benefit was for the respondents and the community in the sense of having contributed to understanding how the activities of the oil and gas industries could be affecting the health of the residents and indigenes of the Niger Delta.

Rumuche, Emohua Local Government Area, is located about 15km southeast of Port Harcourt, Rivers State. Emohua is among the four local government areas that make up the Ikwerre ethnic nationality of Rivers State. The others are Obio/Akpor, Port Harcourt and Ikwerre. The population of Emohua, according to the 2006 census is 201,901 (NPC, 2006), and it is located on an area of 831km² (321square miles) It is also electrified and on the national grid, has a central access road that is tarred, and verges on the East West Road. It is not far from Emohua General Hospital, and is about 7km away from UPTH, and 5km from Choba, the permanent site of University of Port Harcourt. It does not

benefit from the level of industrialisation and commercial activities seen in Ogale, Eleme. There are no banks or similar financial institutions located in Rumuche.

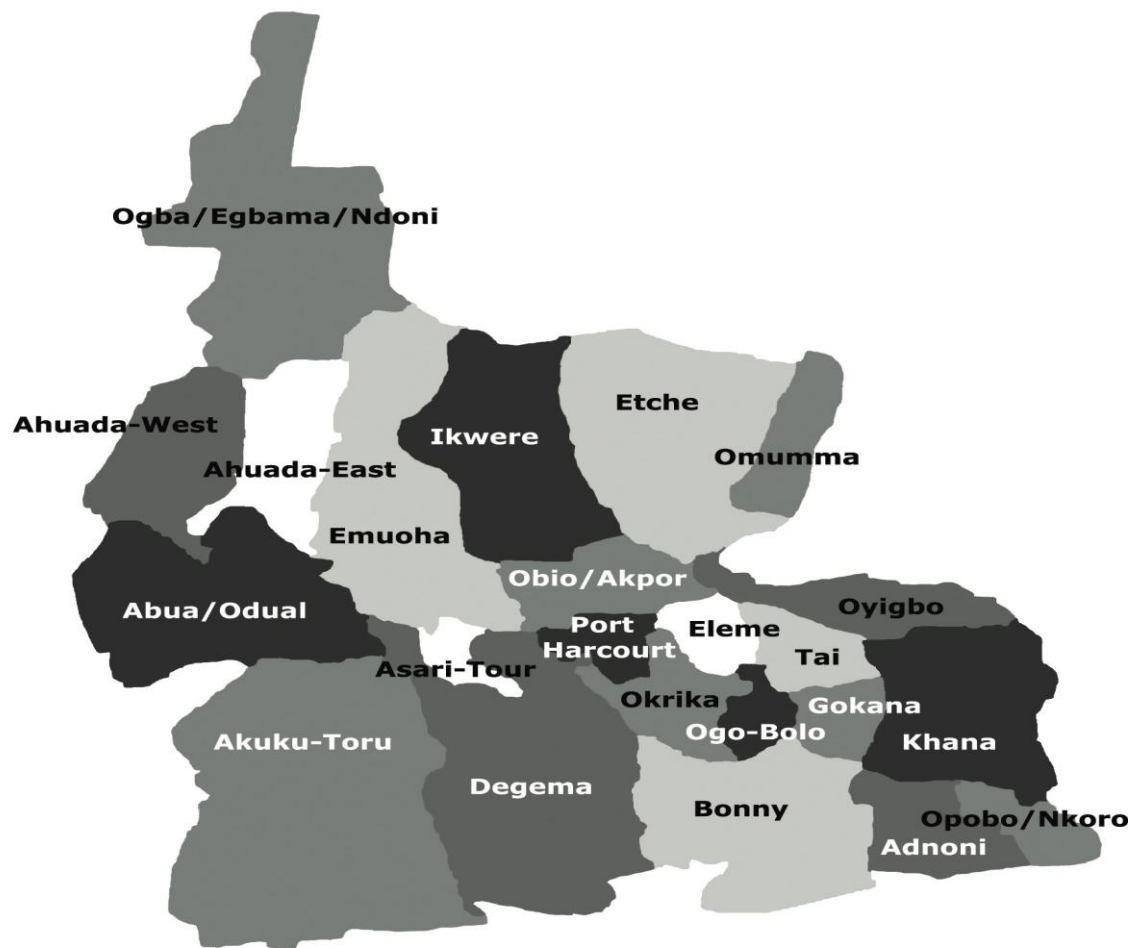


Figure 2-4 Map of Rivers State showing the local government areas

2.4 Mobilisation and enlightenment.

With the selection of the test and reference communities, active and targeted enlightenment programmes were carried out to ensure the creation of the awareness required to carry through the research in these communities. At further town hall meetings with the different focus groups in these communities, especially the traditional ruling council, the women's leadership, the youth leadership, and the community development committees, further emphasis was laid on the potential benefits of the data the study would generate as baseline health record for the study communities, and the

potential benefit for those that would volunteer in availing themselves of the benefit the preliminary physiological tests that the study would afford them. At each of these focus group meetings, the study information sheet was provided, including the invitation to study. The inclusion and exclusion criteria were explained to these community leaders, who were entrusted with the responsibility spreading the word and bringing these details to the potential volunteers from the communities. The local youths were also engaged for mobilisation and further enlightenment of their community residents, while the traditional rulers authorised that the traditional method of mobilisation and enlightenment through the town crier be deployed in addition, when necessary.

To enable effective communication and avoid distrust, primary healthcare workers resident in the sampled communities and who were proficient in speaking the local dialects were recruited as assistants for field studies at least one week prior to the commencement of the field sampling. In subsequent meetings with the study assistants, they were made familiar with the sampling protocols and ethical requirements underpinning the study. In recruiting the field sampling assistants, steps were taken to engage at least one community nurse with proficiency in phlebotomy. All the assistants were trained on the administration of informed consent and the structured questionnaire. A pilot sampling was carried out on one of the study facilitators, with efforts made to simulate the expected condition in the field. The lapses identified were corrected and the sampling methodology standardised.

2.5 Field sampling.

The field studies and sample collection took place in December, 2012. Community centres were chosen a few days prior the commencement of sampling. The community centres were advised to be the best place for the sampling, as opposed to house calls, for reasons of hygiene, and in difference to cultural practices that border on privacy, especially with regards to adult males visiting with married women in matrimonial homes. The sampling was carried out in the mornings, so it may be that those residents with weekdays work commitments outside these communities were not afforded the opportunity to participate in the research. In most cases, the town hall or the village square was cordoned off to generate shelter and ensure privacy when administering the questionnaire. Chairs and tables were rented and provided for the volunteers and the

facilitators to seat and write. A day before the commencement of the sampling in each community, there was further mobilisation through the town crier to ensure the awareness was refreshed in potential volunteers about the scheduled sampling, including the time and place. Some of respondents helped to spread the word about the sampling to their neighbours and family members, and the youths, especially in Ogale, were actively involved in creating awareness about the research in the villages and mobilising volunteers, as the sampling got underway.

2.5.1 Selection of volunteers.

On the day of sampling, every potential participant that reported to the venue was provided with the study information sheet (Appendix), which outlined in brief the purpose of the study, the type of information required to answer the questionnaire (Appendix), provisions made to guarantee the confidentiality of personal information provided by the volunteer, including the results of laboratory investigations and tests, the importance of participation in the study, and the contacts of the study facilitators, in the event there was need for further clarifications or concerns. The study information sheet also contained details relating to the voluntariness of participation in the study, and that there would be no penalties for not participating. It also stated clearly the understanding that each volunteer reserved the right to withdraw their consent at any stage of the study, without prejudice. Each potential participant was allowed reasonable time to familiarise themselves with the study information sheet at the study centre, and if they chose, they were availed the salient points by a field study assistant who was knowledgeable enough to interpret it in the local dialect. After this, those still willing to participate in the study were prequalified in line the exclusion criteria in the study guideline, by crosschecking for details stated below:

- Age- must be 18 years or older
- Open only to non-smokers
- Residence in the study community of at least 5 years
- Residents who have not lived in the community for up to 5 years, but have been involved in oil spill clean-up activity
- Not open to pregnant women

- Not open to those currently employed or were previously employed as workers in the oil and gas industry, including oil field services, who may have the possibility of occupational exposure.

In Ogale Eleme, there was oversampling of the residents in the villages closest to the areas identified in the UNEP Ogoniland Report (2011) as the most heavily polluted, and where the source of water for drinking and household use were identified as heavily polluted. These groups and areas were prioritised on the basis of the potential exposure to the risk under study arising from their proximity to the spillages and contamination. These villages are Agbii (under which Nsisioken falls), Ekpangbala, Alueken, Aluebo, and Ejii, all in Ogale. To ensure continued cooperation and support in all aspects of the research throughout the period of the field study, close engagement was maintained with several community organisations, representatives, and advocacy groups, including the religious and cultural leaders. These groups served as important links in making the study more interactive, and facilitated an understanding of the issues and concerns that arose in the course of the study, and how best to address them. This way, trust was built in the residents of the community in the research and helped in mobilising the volunteers to participate in the study, including projecting a feeling of relevance and benefit to the community.

2.6 Administration of informed consent and study questionnaire.

Each volunteer to the study was allowed time to read through the study information on passing through the prequalification step, and was further informed that the study was entirely voluntary, and each participant had the right to withdraw from the study at any point, and there would be no penalties attached. Then, the volunteer still willing to participate in the study was asked to give their consent in writing by signing the informed consent form provided. The form was countersigned and archived. Subsequently, the structured study questionnaire was administered on the study participant, and information about their age, gender, occupation, diet, alcohol consumption, personal and family medical history, housing, exposure to environmental and indoor pollutants through the burning of fossil fuel and inhalation of second hand cigarette smoke, medication use, and a host of demographic details, including

involvement in the cleanup of oil spills were collected (Appendix). The field study staff were oriented and supervised on questionnaire administration, with the aim of harmonising the interpretation and translation of diseases and symptoms in the questionnaire and harmonising them with those self-reported by the respondents.

The study questionnaire was adapted from the GuLF Study questionnaire, with selections made based on suitability of the questions for the study objectives, the burden on the study subjects, and the practicality for this study. The sections of the GuLF Study questionnaire used were those on basic enrolment, and aspects of respiratory health. The sections bordering on follow-up studies and mental health were not included. The administration of questionnaire and sampling in Ogale, Eleme-, and Rumuche, Emohua-Local Government Areas, Rivers State took place concurrently between the 4th and 22nd of December, 2012.

2.7 Anthropometric and physiological measurements.

Each study participant was weighed (in kilogram) with a digital laboratory scale(Salter[®], UK) with 0.1kg division and 150kg maximum weight, which was placed on a flat surface on the ground. Shoes were removed before mounting the scale for measurement. The standing height was measured (in meters); their waist circumference (in centimetres) was also measured. The height was measured with a metal tape with the respondent standing on a flat concrete surface close to a wall with shoes removed. The height was measured to the nearest 0.1centimeter, while the waist circumference was measured (to the nearest 0.1cm) with a cloth tape measure at the uppermost lateral border crest(ilium), that is the natural indentation of the waistline, with belts removed. Each measurement was taken in replicates, and the average value was recorded for analysis by one of the field study assistants or any other member of the study team.

The blood pressure and pulse measurements were collected by one of the study assistants or a member of the study team knowledgeable in taking the measurements, which most of the time was a medical doctor from UPTH. The respondent was seated for at least 5minutes in a chair with a back rest with right arm barred and supported at heart level. The upper arm cuffed and the stethoscope applied lightly over the brachial artery pulse, proximal to the cubital fossa, and below the bottom edge of the cuff. The cuff was inflated to 30mm Hg above palpable systolic blood pressure, and gently

deflated at a rate of about 2-3mm Hg/second. The first appearance of sound was then defined as systolic blood pressure, while the disappearance of sound was taken as diastolic blood pressure. Both systolic and diastolic blood pressure reading were measured and this determination was done twice with at least two minutes intervals. The lower of the two readings was recorded as the blood pressure. A clinical aneroid sphygmomanometer(Accoson[®] UK) and stethoscope were used for measuring the blood pressure. All the measurements were taken in a seated position. The blood pressure, the weight and waist circumference measurements were made available to the study participants although no clinical interpretation was possible. However, where the blood pressure measurement was recorded as high (>140/90mm Hg), the participant was advised to contact their healthcare provider or a community healthcare facility for additional evaluation and possible interpretation. This was necessary since the residents in the communities under study, and a large number of the respondents to the study, included many without access to medical care, and this study may have provided the initial insight into some potential risk in health condition the volunteer may be exposed to. It was agreed that not to encourage them to seek medical care and clinical assessment and further evaluation where the outcome of the measurements suggested so would have amounted to a mishandling of the main reason this study was undertaken.

2.8 Blood collection.

All the equipments for use in blood collection was prepared in advance.

After the administration of the health study questionnaire,each volunteer was further required to consent to having blood sample collected after explaining the procedure and reason for collecting the blood. With the granting of consent to collect blood, a tourniquet was applied above the intended site of venepuncture, which is the median cubital vein. Care was taken to ensure that the application of the tourniquet did not cause pain to the volunteer. Then about 6ml of blood was collected after the cleansing of the skin with an alcoholic swab by a sampling assistant qualified as a phlebotomist or a medical doctor with the study team. The blood was divided into two vacutainers[®], one 5ml heparinised for cytogenetic studies, and another 5ml EDTA bottle for haematological screening. Each bottle was labelled with the unique identification

number assigned to each participant, and was blinded to avoid bias through the process of analysis. With the blood in the sample bottle, mixing was achieved by gently inverting the bottle a few times, with care taken to avoid vigorous shaking. The blood bottles were then placed in the holder and kept in the cool container with wet ice. At the end of each sampling day, usually between 8am to 12noon, the cool box with ice was transported to the teaching hospital, and analysed.

2.9 Haematological screening

The blood samples in EDTA vacutainers® were subjected to red cell, white cell, and platelet counts, white blood cell differential, haematocrit and red cell indices. All samples were analysed within 12 hours of collection using the Sysmex® laboratory haematological autoanalyser type KX-21N, which measured 19 haematological parameters.

2.10 Cytokinesis-block micronucleus test.

2.10.1 Reagents set up

RPMI 1640 culture medium was prepared by weighing out 2g RPMI 1640 powder (Sigma-Aldrich) and transferring into a labelled conical flask containing 950ml of distilled water at room temperature, and stirred gently. Then 2g of sodium bicarbonate powder was transferred into the labelled flask with gentle stirring. In each instance, traces of powder were rinsed into the flask. Then, the pH of the solution was adjusted to 7.0-7.4 with either 1N HCl or 1N NaOH as required.. The volume was made up to 1litre with more distilled water, and the flask was closed and stored in a refrigerator until used.

Instant foetal bovine serum (FBS) (lyophilized powder) (Sigma-Aldrich) was rehydrated by adding 50ml distilled water with sterile pipette to the tube containing 3g of the powder with gentle agitation to yield 50ml solution of ready to use FBS, which was stored at 2-8°C until used.

Phytohaemagglutinin (PHA) solution (Sigma-Aldrich) was prepared by removing the vial containing 45mg of the freeze-dried extract from the freezer and allowing to attain room temperature on the sink. The rubber cap was sterilised with ethanol, which was allowed

to evaporate. Subsequently, 20ml of sterile isotonic saline was pipetted into a 50ml Falcon[®] tube, the seal on the vial containing PHA was vented with a 25G needle and a 0.22µm hydrophobic filter to break the vacuum. Using another sterile 10ml syringe and needle, 5ml of the sterile saline was withdrawn from the Falcon tube and injected into the vial with gentle agitation to dissolve the PHA. About 5ml of the dissolved PHA solution was withdrawn with the same syringe, and transferred to a labelled sterile 50ml Falcon tube. Another 5ml of sterile isotonic saline was injected into the vial to rinse out the rest of the PHA from the vial and then withdrawn into the labelled 50ml Falcon tube. The remaining 10ml of sterile isotonic saline was then added to the labelled Falcon tube to yield a 20ml solution of PHA, which was aliquoted into sterile tubes and stored at 4°C until used.

Cytochalasin-B (Cyt-B) (Sigma-Aldrich), a 5mg solid in a vial was dissolved in 8.3ml of dimethylsulphoxide, to yield a solution of 600µg/ml as follows: The vial containing Cyt-B was removed from the refrigerator and allowed to reach room temperature, without removing the seal. After that, the sealing rubber was sterilized with ethanol and allowed to evaporate. Then the seal was vented with a 25G needle and 0.22µm hydrophobic filter to release vacuum. With the use of a 5ml syringe and needle, 4ml of the 8.3ml of DMSO was injected into the vial, with gentle agitation to mix, then the dissolved Cyt-B was withdrawn from the vial into a labelled sterile TV10 tube, which had been labelled previously. Then the rest of DMSO, 4.3ml was aspirated into the syringe and injected into the vial, mixed gently, and withdrawn again into the labelled TV10 tube. Aliquots of the Cyt-B solution were dispensed into sterile tubes and stored in a freezer until used.

2.10.2 Whole blood culture

After preparing the reagents, the culture medium was prepared by in a sterile glass by the addition of 90ml of RPMI 1640 medium containing L-glutamine with 10ml of 10% foetal bovine serum (FBS), and 1ml of sodium pyruvate solution.

Typically, 0.5ml of whole blood was withdrawn after gently shaking the blood sample bottle to mix, with a micropipette into the culture medium in a culture tube with lid. Then, phytohaemagglutinin (PHA) was added to the medium to stimulate mitosis at a concentration of 30µg/ml of the culture medium. The whole blood culture was then

incubated at 37°C with loose lids in a humidified atmosphere containing 5% carbon dioxide for 44 hours after PHA stimulation.

After 44 hours of PHA stimulation and incubation, cytochalasin-B (cyt-B) was added to block cytokinesis at a concentration of 6µg/ml, and the culture tube was mixed by shaking gently to ensure uniform distribution of Cyt-B in the medium. 24 hours post cytokinesis block, the lymphocytes were harvested.

To harvest the lymphocytes after incubation, the tube containing the medium was centrifuged gently (300g) for 5 minutes, and the supernatant discarded. After this, the cells were subjected to hypotonic treatment to enable the lysis of red blood cells. 1ml of ice-cold potassium chloride solution (0.075M) was used for the hypotonic treatment, after which the suspension was centrifuged for 8 minutes. The supernatant was removed and a fixative, consisting of methanol: acetic acid (3:1) was added slowly with gentle agitation to prevent the cells from clumping. The cells were further centrifuged at 300g for 8 minutes, and the supernatant discarded. This was repeated twice with further changes of the fixative solution, then cells were re-suspended gently. Then using a Pasteur pipette, two drops of the suspension were dropped onto a clean glass slide labelled with a number that identifies the participant, but blinded to analytical team by labelling with a predetermined identification number, and allowed to dry for 10 minutes.

When the slides had dried for 10 minutes, they were dipped in a coplin jar containing methanol for 30 seconds, then transferred to another jar filled with buffered Wright-Giemsa stain for 3 minutes, after which they were rinsed with distilled water and allowed to dry on an absorbent paper napkin before the application of Depex mounting media and covering with a coverslip.

The slides were coded and randomized to avoid distinguishing the groups. They were examined at 400X magnification using a Leitz Laborlux microscope (Ernst Leitz Weitzlar, Germany). At least 1000 binucleate lymphocyte cells (those that one mitotic division) examined, with at least 500 cells binucleate from each of the duplicate culture per sample. The sum of the count for the two slides was recorded.

2.11 Statistical analyses

Simple descriptive statistics were used to characterise the demographics of the study population. Qualitative data were cross tabulated in a 2 x 2 table and chi square tests were carried to check for differences between the exposed and referent groups. Some quantitative measures were re-coded into binary variables and subjected to chi square analysis. For quantitative variables, the means for the groups were calculated with standard deviations, and the student's t-test was used to analyse for the equality of means. For the cytokinesis block micronucleus assay in peripheral blood lymphocytes, the results were explored for normality using the Kalmogorov-Smirnov test. Skewness and kurtosis were accepted at an upper magnitude of ± 1 or lower as normally distributed. To examine the unique contribution of age, cooking with firewood and gender in the explanation of micronucleus count in peripheral blood lymphocytes (Ceppi et al., 2011), a two stage hierarchical multiple linear regression was conducted with micronucleus count as the dependent variable. Age of respondents, cooking with firewood, and gender, with a dummy variable created for the gender, were entered as model 1 of the regression to control for potential confounding effects. Selected white and red blood cell parameters were entered as model 2, and the hierarchical was performed. An examination of correlations revealed that no independent variables were highly correlated. The collinearity statistics (Tolerance and variance inflection factor, VIF) were all within acceptable limits, and the assumption of multicollinearity was assumed to have been met. An examination of the Mahalanobis distance scores indicated no multivariate outliers. Standardised residual and scatter plots indicated the assumption of normality, linearity and homoscedasiticity were met as there was reasonable consistency of spread through the distributions. Also, a logistic regression analysis was conducted to adjust for the effects of potential confounders on selected binary respiratory health outcomes between exposed and reference respondents. All the analyses were performed with SPSS version 22.0 (SPSS Inc., Chicago). Significance was accepted at $p < 0.05$.

3 Results

3.1. Field reconnaissance trips and observational studies.

3.1.1 Water

It was observed that there was no pipe-borne water available to the majority of the communities visited in the course of this study. The commonest source of water for use were wells, the majority of which were shallow hand-dug in design that were covered with a ring with a hole at the centre (for example disused car tyres) through which water was drawn with a bucket tied to a rope in an upward pulling action. The depths of these wells varied depending on location and season of the year. The wells in the more coastal communities yielded water very close to the surface, particularly in the rainy and wet seasons, while the wells further inland may have to be dug 10 metres or more deep before water can be accessed. The more affluent households would have motorised rig-drilled boreholes installed, with electric water pumps that would serve in transferring water from these boreholes to overhead storage facilities, from which the water is distributed through pipes for domestic usage. In some communities, like Ogale in Eleme Local Government Area of Rivers State, most boreholes have hand operated mono-pumps, instead of the electric water pumps. In some communities, these water sources are located centrally, and would be used by a number of households. In Port Harcourt, the capital city of Rivers State, the observation was that most homes were also not connected to any central public potable water source, but boreholes and hand-dug wells were the major source of water for everyday use. Most cities and urban areas in the Niger Delta, and indeed the federation were no different from Port Harcourt, but were reliant on private wells for water. The streams, rivers and other bodies of water in the communities of the Niger Delta serve as valuable sources of water for domestic and recreational purposes. It was observed that a proportion of residents of the more rural areas of the Niger Delta did not have even the basic hand-dug wells. These residents still had to go down to the streams to fetch water, and relied on rain-harvest or water impoundments for their needs. For these residents and natives, the water resources served as a major source of livelihood. In the communities with oil spill incidences, and those with active petroleum exploration and production activities, a common complaint

was that water from their wells, the rivers and streams, had an oil sheen on the surface when the water was left standing for some time. In Joinkrama, Ahoada Local Government of Rivers State, and Biseni, Yenogoa Local Government of Bayelsa, the narrative was that water drawn from the wells around the areas would be used for general domestic purposes, but not for drinking. The residents would buy sachet water brought in from other areas for drinking. Rain water harvest was a common practice in most rural communities of the Niger Delta, and the water captured served for various domestic uses, including drinking. However, the reports obtained during the field studies from the residents suggested there was suspicion and distrust in the quality of the rain water harvest, due mostly to the attribution of quick rustiness of zinc roofing to acidity of rain water in the area, which they claimed was due to gas flaring common in the area.

In Ogale Eleme, there was a community water scheme consisting of some boreholes with hand operated mono-pumps in most cases, but in other cases submersible pumps. The scheme was commissioned in April, 2010, as a corporate social responsibility undertaken, by the Port Harcourt Refining Company Limited, a subsidiary of Nigerian National Petroleum Company (NNPC) Limited, the Nigerian national oil company. Unfortunately, the water from these boreholes were seen labelled as not fit for use for any purpose as a result of the findings and recommendations of UNEP (2011). In the course of the field studies, and on various trips with the youths from Ogale, the issues and concern about the water supply from these wells were demonstrated and made clear. When water was pumped out from the wells, it had a foul smell of petroleum that was quite heavy. This was observed at several wells and locations in the community, although the intensity of the smell varied. It could not be ascertained how long the community had been with the problem of this polluted water, although there was anecdotal evidence of incidences of oil spillages, the last major one of which was said to have been recorded in 2005 in an area that was described as mainly residential. The spill was recorded to be due a breach in an NNPC pipeline conveying refined petroleum products, presumably from the neighbouring refinery in Eleme, according to the residents that witnessed the incidence. The oil was said to have saturated a significant land area, and the residents had resorted to scooping the oil to sell to desperate motorists, and to earn a living from it. It was also observed that although all the mono-

pump wells in Ogale bore the label of unfit for use, and water was brought into the community by water tankers from Port Harcourt by Rivers State Government as an emergency relief, some of the wells were still in use. Children could still be seen fetching water from some of them, or bathing with water fetched from the pumps.

3.1.2 Occupation

The majority of the residents in the communities visited in the course of this study were engaged in farming either as a major occupation, or as a hobby on part-time basis, especially those that had other employments and engagements outside the communities. Some residents were traders, while others worked as employees of private and public organisations. However, the farming practices observed were mainly subsistent and un-mechanised, normally with the use of crude implements like hoes, machetes, shovels and the like. There was no evidence suggesting the use of pesticides and herbicides, although occasionally, fertilizers, mainly the mineral fertilizers such as nitrogen, phosphate and potassium (NPK) were used for improving yield. Fishing was another occupation that was reported as commonly practised in these communities, mainly the artisanal and pelagic fishing, using non-motorised wooden boats. Shell fish, like periwinkles, oysters, cockles, and crabs were also collected by women and children from the marshes and intertidal zones, sometimes close to the residential areas, especially for the coastal dwellers. The gathering of wild crops, fruits, snails, dead timber as firewood, either for use in the household or for sale, was also observed to be common, especially with younger residents and women. Hunting and trapping of wild animals and games like antelopes, rabbits, and grass-cutters, also known as the greater cane rat, and other game animals was practised, particularly by the male residents.

3.1.3 Waste management

There were no organised waste management practices or sites identified anywhere in the areas visited during the field study, including Port Harcourt. There were waste dump and collection sites in Port Harcourt city, but these were open areas and public spaces where un-segregated wastes, mainly household wastes, were dumped in an unregulated and uncontrolled manner. These sites were emptied intermittently, and the wastes trucked to huge disused burrow pits, that serve as land fill sites. These land fill sites are

not lined, and there were no sorting or segregation of wastes at these sites. What was left of the wastes after scavengers had made their pick of resalable items, were normally burnt, or left to the elements. Waste management in most cities in Nigeria is a Public-Private Partnership (PPP) initiative as this guarantees dynamism, access to finance, knowledge of technology, managerial efficiency and entrepreneurial spirit that is often lacking in government and bureaucratic setup. However, there is still a very low uptake of sustainable waste management practice even in the cities.

The rural communities were not served in the manner of the cities, as there were no lorries that came round to collect household wastes. Neither were there any waste collection or dump sites for household wastes. Historically, the communities in the Niger Delta have relied on composting for waste management. The waste generated by most homes were putrescible green, innocuous and biodegradable wastes, and were collected into farms and allowed to decay, and contribute to enriching the soil. The idea of harmful and toxic wastes may therefore be novel to the residents of these communities.

Anecdotal accounts suggest that industrial wastes from the oil and gas industries in these communities were dumped in burrow pits scattered around the length and breadth of the Niger Delta, mostly in disused lateritic pits, which are plots of land from where laterite had been extracted and used for road construction. There were several of these legacy waste sites identified in the course of this study dotting these communities. From the account of the residents, fly tipping of industrial wastes, including petroleum industry effluents and wastes was common. While this field study lasted, so many areas in the Niger Delta suffered severe flooding. It was understood that in flood events that occur frequently in the area, wastes from these impoundments were often mobilised, and chemicals leached into surrounding residential areas, agricultural land and aquaculture spaces with potential for human health impact. Besides, the infiltration of flood water into the landfill sites could also lead to significant liquid contaminants (leachate) seeping from the sites, and posing risks to biodiversity and public health.

3.2 Study population/demographics.

The distribution of the study population by age and gender is summarised in Table 3-1 below. The average age of the respondents from the exposed community was 39.7 years (range, 18-86; median, 36), which was significantly lower than the mean age of 45.7 years calculated for the referents (range 18-90 years; median, 47) ($p = 0.002$).

In the exposed community, about 40% of the respondents were aged 18 to 30 years, whereas the proportion for the reference respondents was slightly under 30%. A disproportionately lower percentage (21.5%) of respondents from the exposed community were aged 56 years or older at sampling compared to the respondents from the reference area (37.3%). A chi square analysis supported the hypothesis that there was statistically significant difference in the distribution of respondents within groups by age ($p < 0.001$).

Table 3-1. Distribution of respondents by gender and range of age in exposed and reference communities and chi-square

Age group (Years)	Exposed			Reference		
	Male(%)	Female(%)	Total (%)	Male(%)	Female(%)	Total(%)
≤30	59 (23)	45 (17.6)	104(40.6)	15 (13.6)	19 (17.3)	34 (30.9)
31-45	17 (6.6)	52 (20.3)	69 (26.9)	5 (4.5)	12 (10.9)	17 (15.4)
46-55	9 (3.5)	19 (7.4)	28 (10.9)	6 (5.5)	12 (10.9)	18 (16.4)
≥56	10 (3.9)	45 (17.6)	55 (21.5)	18 ((16.4)	23 (20.9)	41 (37.3)
Total (N)	95(37.1)	161(62.9)	256	44(40)	66(60)	110
Mean(SD)	34	43	39.7(16.4)	46	46	45.7 [§] (17.5)
Median	28	42		49	47	
Range	67	68		72	61	

§ $p = 0.002$, the total mean age for exposed significantly lower than for reference respondents.

The majority of the respondents sampled were of the female gender, with over 60% of the total respondents. In the exposed area 62.8% and in the reference 60.4% of the respondents sampled were female. However, between the reference and exposed communities, there was no statistically significant difference in the overall distribution by gender ($p = 0.659$). There were disparities in the age distribution of the women within

the exposed and reference population. Over 60% of the female respondents from the exposed area were aged 45 years or younger at sampling. The proportion for the reference community was 47% for women aged 45 years or younger at sampling. For the age range 56 years or older, the proportion of women from the exposed area was 28% as against about 35% recorded for the reference area.

There was a higher ratio of men aged 45 years or younger from the exposed community who responded to sampling at a total of 80%. In contrast, the ratio of male respondents from the reference community aged 45 years or younger was about 45%. In the highest age range of 56 years or older, the proportion of male respondents was 11% from the exposed community, whereas about 41% of those who responded from the reference community fell within that age range.

Table 3-2 below shows a summary of some anthropometric measurements in the respondents sampled from the exposed and reference communities. The average height of the respondents from the exposed area (160 cm) and those from the reference (159 cm) was not significantly different ($p = 0.591$). The mean height calculated for female respondents from both the exposed and the reference areas was the same at 156cm, whereas for male respondents, the mean height was 167cm for the exposed and 164cm for the reference. Neither values achieved significant statistical difference. Similarly, there was no statistical difference in the average weight measured for exposed respondents (60 kg), although the value was slightly lower than the mean for the referents (62 kg) ($p = 0.191$). In both communities, the average weight for men was higher than the average for women. However, the mean body mass index (BMI) was significantly higher in the referents (24.7 kg/m^2) compared with the exposed (23.5 kg/m^2) ($p = 0.027$). This was mainly due to the low BMI calculated in men from the exposed area, who were also significantly younger in age. The mean waist circumference (girth) for the respondents was 89.1cm for the exposed and 89.4cm for the referents. There was no significant difference in the waist circumference calculated.

Table 3-2 Mean biometric measures with standard deviation for female and male respondents with p-value for t-test for equality of means in the exposed and reference communities

	Exposed			Reference		
	Male Mean	Female Mean	Total Mean(SD) [§]	Male mean	Female Mean	Total Mean(SD) [§]
Height (cm)	167	156	159.8(10.4)	164	156	159.2 (10.9)
Weight(kg)	63	59	60.2 (11.5)	66	60	62.0 (13.7)
BMI(Kg/m ²)	22.6	24.0	23.5 (4.4)	24.9	24.6	24.7 (5.2)*
Girth (cm)	91	85	89.1 (10.7)	89	90	89.4 (15.0)

[§]Based on population means for exposed and reference respondents *P< 0.05

Further selected baseline demographic characteristics of the study respondents from the exposed and reference communities are summarised as shown in Table 3-3 below. As evidenced from the table, 62.8% of respondents in the exposed community used firewood for cooking, against 82% in the reference community, which was significantly different ($p < 0.001$). There was a high proportion of respondents in the exposed community that reported cooking with kerosene (52.1%). This was significantly higher than the proportion of the respondents from the reference area (26.1%) ($p < 0.001$). The proportion of respondents who cooked with cooking-gas was 10.5% in the exposed community and 8.1% in the reference area. There was no statistically significant difference in the use of liquefied petroleum gas for cooking between the respondents from the two communities ($p = 0.771$). However, as shown in Table 3-3 there was only a marginal difference in the proportion of respondents from the exposed and reference communities who reported inhalation of smoke, either from their own cooking or their surroundings, as a nuisance, with 37.6% in the exposed and 45.9% in the reference ($p = 0.133$). The majority of those who reported smoke inhalation as nuisance were females in both sample areas, with 63.9% in the exposed area and 62.7% in the reference, which accords with the cultural roles with women regarded as caretakers and home managers in these traditional societies.

Table 3-3 Proportion of respondents in exposed and reference communities for different cooking practices

Cooking method	Exposed			Reference		
	Yes(%)	No(%)	Total	Yes(%)	No(%)	Total
Firewood	162(62.8)	96(37.2)	258	91(82) [§]	20(18)	111
Kerosene	134(52.1) [§]	123(47.9)	257	29(26.1)	82(74.9)	111
Gas	27(10.5)	230(89.5)	257	9(8.1)	102(91.9)	111

[§] p<0.001 significantly higher proportion of respondents used cooking method.

Although smoking was one of the exclusion criteria for participation in this study, non-smokers who self-reported exposure to passive or nuisance tobacco smoke in the exposed area was 26.4% of the study respondents, while the proportion in the reference area was 29.7%. Statistically, there was no significant difference in the exposure to passive smoking between the two group of respondents (p= 0.505). There was unsurprisingly more females from the exposed area who complained of inhalation of passive smoke in the exposed area (57.4%) compared with 39.4% in the referent respondents who self reported this complaint, since the respondents from the exposed area were younger in age, and may have age-related variations in lifestyle, with nuisance smoke inhalation arising from social interactions.

Alcohol consumption was dichotomised into alcohol consumption or no alcohol consumption due to the small percentage of respondents recorded as moderate or heavy drinkers in both the exposed (11 as moderate; none as heavy) and reference (4 as moderate; none as heavy) population. As shown in Table 3-4, 29.7% (44.7% female, 55.3% male) of the respondents from the exposed area and 36.9% (39% female and 61% male) responded "Yes" to alcohol consumption, but no statistically significant difference was achieved between the two areas.

Table 3-4 Proportion of respondents and their gender in the exposed and reference communities who responded to smoke inhalation and alcohol consumption questions

Variable	Exposed			Reference		
	Male(%)	Female(%)	Total(%)	Male(%)	Female(%)	Total(%)
Cooking smoke Inhaled						
Yes	35(36.1)	62(63.9)	97(37.6)	19(37.3)	32(62.7)	51(45.9)
No	61(37.9)	100(62.1)	161(62.4)	25(41.7)	35(58.3)	60(54.1)
Total			258			111
Passive smoking						
Yes	29(42.6)	39(57.4)	68(26.4)	20(60.6)	13(39.4)	33(29.7)
No	67(35.4)	122(64.6)	189(73.6)	24(31.6)	52(68.4)	76(70.3)
Total			257			109
Alcohol consumption						
Yes	42(55.3)	34(44.7)	76(29.7)	25(61)	16(39)	41(36.9)
No	52(28.9)	128(71.1)	180(70.3)	19(27.1)	51(72.9)	70(63.1)
Total			256			111

3.3 Self-reported health effects

A summary of self-reported respiratory health effects, particularly cold, catarrh and fever blisters, common cough and cough with phlegm, with outcomes from cross-tabulation and chi-square analysis with p-values is presented in Table 3-5 below. The respondents from the exposed sampling community reported a marginally higher prevalence of cold, catarrh, or stuffy nose, with 72.1% reporting having had a case

within one year of the sampling, compared with 70.4% in the reference sampling area ($p = 0.739$). However, the mean of the number of cold, catarrh or stuffy nose episodes self-reported by respondents from the exposed sampling community was significantly higher than the mean of the episodes for the respondents from the reference study area (2.95 versus 1.84; $p = 0.003$).

Table 3-5 Numbers and percentages of respondents with "Yes" and "No" response to coughs and cold symptoms plus mean of years and standard deviation

Health variable	Exposed		Reference	
	Yes	No	Yes	No
Cold, catarrh or stuffy nose				
Number (%)	186 (72.1)	72 (27.9)	76 (70.4)	32 (29.6)
Mean No. of episodes(SD)	2.95 (2.36) **		1.84 (1.67)	
Cough				
Number (%)	109 (42.2)	149(57.8)	51(47.2)	57(52.8)
- $\geq 4x/day \geq 4days/week$.				
Number(%)	85(32.9) *	173(67.1)	22(20.4)	86(79.6)
- On waking up.	67(26)*	191(74)	17(15.7)	91(84.3)
Number(%)				
- All day and night				
Number(%)	70(27.1)	188(72.9)	20(18.5)	88(81.5)
+Phlegm(Morning)				
Number(%)	64(24.9)	193(75.1)	6(224.1)	82(75.9)
+Phlegm(All day)	59(22.9)	199(77.1)	22(20.4)	86(79.6)
Number(%)				
+Phlegm(≥ 3 weeks)				
Number(%)	39(15.1)	219(84.9)	11(10.2)	97(89.8)
Duration(years) of Cough+phlegm		2.95[2.56]		2.11[2.47]
(≥ 3 weeks)[SD]				

** $p < 0.001$, * $p < 0.05$, * $p < 0.05$; Significantly higher prevalence compared with reference

Among the respondents self-reporting cold, catarrh or stuffy nose, a trend in the prevalence in relation to cooking method was noticed (Table 3-6 below). Sixty percent of those who reported cold, catarrh and stuffy nose used firewood as cooking fuel in the exposed area, while the proportion was higher in the reference area at 81%. The proportion of those who self-reported cold, catarrh or stuffy nose and also used kerosene as fuel was 54% in the exposed respondents and 31% in the referents.

However, the prevalence was much lower in the respondents who used gas as cooking fuel, at 9.1% in the exposed and 9.4% in the reference community. There was no significant association between cold, catarrh and stuffy nose and cooking methods within the exposed respondents ($p= 0.169$ for firewood; 0.307 for kerosene; and 0.214 for gas). In the reference respondents sampled, there was also no significant association between the methods of cooking and cold, catarrh or stuffy nose, except in those who cooked with kerosene ($p= 0.968$ for firewood; 0.039 for kerosene; 0.612 for gas).

The prevalence rate of self-reported cough in the exposed community was 42.2%, and 47.2% in the reference respondents; but statistically, no difference was achieved between the two populations ($p= 0.382$). Within the cohorts that self-reported cough, 70% of them in the exposed community cooked with firewood, 42% cooked with kerosene, and 12% reported cooking with gas. In the reference community, the ratios recorded for common cough and cooking methods were 82% for firewood, 28% for kerosene, and 7.8% for gas. The proportion of respondents in the exposed community that self-reported cough 4 to 6 times day for about 4days or longer a week was 32.9%, while the prevalence in the reference community was 20.4%, which supports the supposition that a higher prevalence of cough was associated with the exposure ($p= 0.017$). The prevalence of self-reported cough on waking up in the morning in the respondents sampled from the exposed community was 26% compared with 15.7% in the reference samples, which was statistically significant ($p= 0.034$). With a prevalence rate of 27.1% in the exposed and 18.5% in the reference, there is no support for the hypothesis that there is a significant difference in the prevalence of cough throughout the day and rest of the night between the respondents from the exposed and reference communities ($p= 0.081$). There was a marginally higher prevalence of cough with phlegm self-reported in the respondents sampled from the exposed community (24.9%) compared to the prevalence (24.1%) in the reference community ($p= 0.867$). Again, the percentage of respondents that self-reported cough with phlegm throughout the day was not significantly different between the exposed and reference samples (22.9% versus 20.4%; $p= 0.600$). For self-reported episodes of cough with phlegm lasting longer than 3 weeks, the prevalence rate was 15.1% in the exposed respondents and 10.2% in the reference, but difference failed to achieve statistical significance ($p= 0.210$). The self-reported average length (years) over which a respondent had cough with phlegm that

lasted longer than 3 weeks in the exposed (2.95) was higher than the mean for the reference respondents (2.11), but failed to achieve statistical significance ($p=0.387$).

Table 3-6 Numbers and percentages of respondents with "Yes" response to cold/catarrh and their self-reported cooking methods

Cooking method	Exposed		Reference	
	Yes(%)	No(%)	Yes(%)	No(%)
Firewood	112(60.2)	74(39.8)	62(81.6)	14(18.4)
Kerosene	101(54.3)	85(45.7)	24(31.6)	52(68.4)
Gas	22(11.8)	164(88.2)	5(6.6)	71(93.4)

Table 3-7 presents a summary for self-reported number of episodes of a respiratory disease variables over the year in which data was collected, or the duration in years over which a respondent has suffered with the variable (disease) and, where appropriate, the age of the respondent at first diagnosis. The prevalence of cold sores and/or fever blisters on the lips self-reported by the respondents from the exposed community was 38%, and 31.5% in those respondents from the reference community (Table 3-6), but this was not statistically different ($p=0.237$). The total number of episodes of cold sores and /or fever blisters from the exposed and reference communities was averaged, and the mean for each group was compared. As shown in Table 3-6 below, the mean value for the exposed (2.8/year) was significantly higher than the mean number of episodes in the reference community (1.18/year) ($p<0.001$). The association of cooking methods with cold sores and/or fever blisters on the lips was not significant in the exposed and reference respondents sampled, with 64% of those who had a positive self-report to this disease variable also cooking with firewood in the exposed, the proportion was 88% in the reference community (Table 3-7). The proportion of respondents who had cold sores and/or fever blisters and cooked with kerosene was 49% in the exposed and 23.5% in the reference area, while for those who cooked with gas, the ratio was 7.1% and 11.8% in the exposed and reference communities respectively, ($p=0.697$ for firewood, 0.400 for kerosene, and 0.394 for gas in the exposed; 0.221 for firewood, 0.700 for kerosene, and 0.241 for gas in referents).

Table 3-7 Numbers and percentages of respondents with "Yes" and "No" response to cold sores or fever blisters plus mean of "Yes" and standard deviation including trend of symptom with cooking methods.

Cold sores or fever blisters	Exposed		Reference	
	Yes(%)	No(%)	Yes(%)	No(%)
Number	98(38)	160(62)	34(31.5)	74(68.5)
Mean no. of episodes (SD) for Yes	2.80(2.56)		1.18(0.72)	
Cooks with firewood	63(64)		30(88)	
Cooks with kerosene	48(49)		8(23.5)	
Cooks with gas	7(7.1)		4(11.8)	

Table 3-8 below shows some selected statistical parameters on self-reported symptoms related to airflow obstruction. The difference in the ratio of the respondents that self-reported wheezing or whistling sound in the chest in association with a cold was not statistically significant, but fewer proportion of respondent in the exposed community reported having this symptom compared with the reference respondents (20.2% versus 27.%; $p= 0.111$). There was a lesser percentage of respondents in the exposed area that self-reported wheeze apart from cold compared with the proportion that self-reported from the reference community (15.9% versus 24.1%), although this also failed to achieve statistical significance ($p= 0.065$). For the symptom "Does your chest sound wheezy or whistling most days or nights", the prevalence rate recorded in the respondents as "Yes" was 12.1% for the exposed samples and 20.8% in the reference community, which was significantly lower ($p= 0.033$). As evidenced from Table 3-8, the mean duration (in years) of attack wheeze or whistling self-reported in the exposed (2.10 years) was lower than the mean self-reported by the referent respondents (2.73 years), but failed to achieve statistical significance ($p= 0.317$). However, those respondents from the exposed area that self-reported wheeze were having their attacks at significantly younger average age (30.65 years) compared with the age of onset in the reference respondents (48.53 years) ($p= 0.002$).

Table 3-8 Numbers and percentages of respondents with "Yes" and "No" response to wheeze in exposed and reference communities plus mean of years and standard deviation

Wheeze	Exposed		Reference	
	Yes(%)	No(%)	Yes(%)	No(%)
-with cold	52(20.2)	206(79.8)	30(27.8)	78(72.2)
-apart from cold	42(15.9)	217(84.1)	26(24.1)	82(75.9)
- most day/night	31(12.1)	226(87.9)	22(20.8*)	84(79.2)
Duration in years of - (SD)		2.10(1.64)		2.73(2.88)
Age of first attack-(SD)		30.65(16.84)		** 48.53(15.83)

*P<0.05; **p< 0.01, reference group value is significantly higher than exposed.

As shown in Table 3-9 below, the frequency of self-reported shortness of breath associated with wheeze or whistling in the chest in the respondents from the exposed community was 10.5% compared with 12.3% self-reported in the reference samples, but the difference failed to achieve statistical significance ($p= 0.102$). Nevertheless, the mean age in years at which the first episode of wheeze that was associated with dyspnoea was registered was 30.65 years in the respondents from the exposed community, which was significantly lower compared with 48.53 years for respondents from the reference community ($p= 0.002$). There was a significantly lower fraction of respondents from the exposed area that reported needing treatment for dyspnoea compared with the proportion from the reference community (9.4% versus 17.8%; $p= 0.24$). The frequency of dyspnoea on mild exertion, such as hurrying up a level surface or walking up a slight hill, was self-reported at 17.1% in the exposed and 27.8% in the referent respondents, which shows a statistically significant difference ($p= 0.02$). There was a significantly lower proportion of the respondents from the exposed area that self-reported walking slower on a level surface than their peers due to breathlessness compared to the proportion in the reference respondents (15.1% versus 27.1%; $p= 0.007$). There was a significantly lower proportion of respondents from the exposed community that self-reported dyspnoea while walking at own pace on a level surface compared with the respondents from the reference community was observed (12.8% versus 24.1%; $p= 0.008$). Again, the prevalence of self-reported dyspnoea with minor exertion, like becoming breathless after waking about 100 yards, or after a few minutes on a level surface, was 9.8% and 21.3% respectively in the exposed and reference respondents, which achieved statistical significance ($p= 0.003$). The respondents whose

response was affirmative to being too breathless to leave their house, or dyspnoeic while getting dressed or undressing, "severe dyspnoea" was 7.5% in the exposed and 16.7% in the reference communities, which showed statistically significant differences ($p= 0.009$).

Table 3-9 Numbers and percentages of respondents self-reporting "Yes" and "No" to dyspnoea

Dyspnoea-	Exposed		Reference	
	Yes(%)	No(%)	Yes(%)	No(%)
-With wheeze	27(10.5)	230(89.5)	18(12.3)	90(87.7)
-Needed therapy	24(9.4)	232(90.6)	*19(17.8)	88(82.2)
-Up slight hill	44(17.1)	214(82.9)	*30(27.8)	78(72.2)
-Slows down	39(15.1)	219(84.9)	**29(27.1)	78(72.9)
- On level surface	33(12.8)	224(87.2)	**26(24.1)	82(75.9)
-With minor exertion	25(9.8)	231(90.2)	**23(21.3)	85(78.7)
Severe dyspnoea	19(7.5)	234(92.5)	**18(16.7)	90(83.3)

* $p < 0.05$, ** $p < 0.01$; significantly higher prevalence rate referents than in exposed area.

As summarised and illustrated in Table 3-10, 15.7% of the respondents from the exposed community self-reported episodes of chest illness that led to stoppage of work compared to 17.6% in the reference respondents, but there was no statistically significant difference achieved in the proportions ($p= 0.664$). The prevalence of phlegm associated with chest illness self-reported in the respondents sampled was 11.2% in the exposed and 6.5% in the reference communities, but this also failed to achieve statistical significance ($p= 0.171$). The ratio of respondents who self-reported having had a chest illness before the age of 16 years was 5.1% in the exposed and 1.9% in the reference communities, which was not statistically significant ($p= 0.155$). There was no statistical difference in the prevalence of attack of pneumonia self-reported in the respondent sampled from exposed and reference communities (9.4% and 10.4%; $p= 0.769$). For sinusitis, no statistical difference was also achieved in the prevalence self-reported between the exposed and reference respondents (7.7% and 12.3%; $p= 0.179$). However, there was a significantly higher prevalence of constant dizziness self-reported in the exposed respondents compared with the proportion in the referents (17.2% versus 7.5%; $p= 0.019$).

Table 3-10 Numbers and percentages of respondents with "Yes" and "No" response to other chest illness and dizziness

Health variable	Exposed		Reference	
	Yes(%)	No(%)	Yes(%)	No(%)
Chest illness	40(15.7)	214(84.3)	19(17.6)	89(82.4)
stopped work				
Phlegm with chest illness	28(11.2)	223(88.8)	7(6.5)	101(93.5)
Lung illness before 16yrs	13(5.1)	242(94.9)	2(1.9)	106(98.1)
Attack of pneumonia	22(9.4)	213(90.6)	11(10.4)	95(89.6)
Attack of sinusitis	18(7.7)	215(92.3)	13(12.3)	93(87.7)
Constant dizziness	*40(17.2)	193(82.8)	8(7.5)	98(92.5)

*p= 0.019; significantly higher prevalence in exposed.

There were other analyses carried out and tables prepared that looked at the self-reported respiratory health issues against cooking methods in the appendix. The results are not presented because no significant associations were found, and to avoid the trap of multiple testing that may not contribute to any meaningful associations.

3.4 Haematological screening.

3.4.1 RBC parameters

The summary of red blood cell (RBC) count indices is shown in Table 3-11 below. The mean absolute RBC count in the exposed respondents was 4.66×10^{12} /litre compared to 4.50×10^{12} /litre for reference respondents. The difference in the mean count failed to achieve statistical significance ($p = 0.053$). There was also no significant difference in the mean haemoglobin measure between the exposed (12.54g/dl) and reference respondents (12.31g/dl) ($p = 0.237$). Neither was there any statistically significant difference in the mean platelet count in the exposed (207.46×10^9 /l) and the reference respondent (210.79×10^9 /l) ($p = 0.680$). There were statistically significant negative correlations achieved between the mean RBC count and average micronucleus counts in both the exposed (-0.372 , $p < 0.001$) and reference (-0.331 , $p < 0.01$) respondents sampled. The correlation between average micronucleus count and the mean haemoglobin measure trended the same pattern with a negative correlation factor of -0.467 , $p < 0.001$ in the exposed and -0.308 , $p < 0.01$ in the reference respondents.

Table 3-11 Means and standard deviations of selected red blood cell (RBC) parameters in respondents

Variable	Exposed N=161(SD)	Reference N=95(SD)
RBC count (x 10 ¹² /l)	4.66(0.61)	4.5(0.63)
Haemoglobin (g/dl)	12.54((1.63)	12.31(1.71)
Platelet count (x 10 ⁶ /l)	207.46	210.79
Haematocrit (%)	39.41(4.58)	38.43(4.89)

As evidenced from Table 3-12, there was no significant differences in the absolute RBC count across the sampled ages between the exposed and reference respondents, with 43% having their count below normal, and 49.7% within normal in the exposed compared to the proportion for the reference, 53.4% and 38.6% respectively (p= 0.248). The value for haemoglobin measured in the respondents shows that 35.4% in the exposed was below normal compared with 44.7% in the reference community, which was not statistically different (p= 0.143). No statistically significant difference was recorded for the haematocrit between the exposed (39.41%) and reference (38.43) respondents, p= 0.111.

Table 3-12 Results of selected Red Blood Cell count parameters against range of age in exposed and reference respondents

	RBC range x 10 ¹² /litre					
	Exposed			Reference		
	<u>≤4.4</u>	<u>4.5-5.5</u>	<u>≥5.6</u>	<u>≤4.4</u>	<u>4.5-5.5</u>	<u>≥5.6</u>
≤30	18	35	7	14	13	4
31-45	25	13	3	8	5	1
46-55	7	11	0	7	5	5
≥56	14	15	1	18	11	1
Total(%)	64(43)	74(49.7)	11(7.4)	47(53.4)	34(38.6)	11(7.6)
Mn count(SD)	25.5(8.3)	20.9(8.4)	15.0(5.2)	18.3(5.3)	15.7(4.1)	14.3(5.3)
Haematocrit	35.5(3.2)	41.6(3.1)	46.0(2.4)	34.6(2.6)	41.6(3.0)	46.2(2.4)
	Haemoglobin g/dl					
	<u>≤12</u>	<u>12-18</u>		<u>≤12</u>	<u>12-18</u>	
≤30	15	49		9	23	
31-45	18	26		8	8	
46-55	6	15		9	6	
≥56	18	14		16	15	
Total	57(35.4)	104(64.6)		42	52	

3.4.2 WBC count and differential

A summary of the mean and standard deviation values of selected full blood count indices in sampled respondents is presented in Table 3-13 below. The mean white blood cell (WBC) count in respondents sampled from the exposed community ($4.73 \times 10^9/\text{litre}$) was significantly lower than the mean count in those sampled from the reference community ($5.68 \times 10^9/\text{litre}$) ($p < 0.001$). Table 3-13 also shows that the mean value of the absolute count of lymphocytes, in the differential count, of $2.32 \times 10^9/\text{litre}$ in the respondents sampled from the exposed community was significantly lower than the mean value for the respondents sampled from the reference community ($2.60 \times 10^9/\text{litre}$) ($p = 0.006$). The mean of the mixed white blood cell count, which is the absolute count of basophils, eosinophils, and monocytes (middle cells) in whole blood for the respondents sampled from the exposed community ($0.37 \times 10^9/\text{l}$) was also significantly lower compared with the mean value for the respondent sampled from the reference community ($0.57 \times 10^9/\text{l}$) ($p = 0.031$). The mean count of neutrophils was $2.09 \times 10^9/\text{l}$ in the respondents from exposed compared to $2.43 \times 10^9/\text{l}$ in those sampled from the reference community. The difference approached statistical significance ($p = 0.057$). There was a significant negative correlation between WBC count and micronucleus count in the respondents from the exposed (-0.279 , $p < 0.001$) and in those from reference (-0.178 , $p < 0.05$) areas.

Table 3-13 Means and standard deviations, plus results of student t-test of selected white blood cell count parameters in respondents

	Exposed	Reference
WBC count ($\times 10^9/\text{l}$)	4.73(1.28)	[†] 5.68(1.71)
Absolute count of lymphocytes($\times 10^9/\text{l}$)	2.32(0.69)	* [†] 2.60(0.93)
WBC middle cell count($\times 10^9/\text{l}$)	0.37(0.46)	*0.57(0.45)
Neutrophils (absolute count($\times 10^9/\text{l}$))	2.09(0.97)	2.43(0.81)

[†] $p < 0.001$, *[†] $p = 0.006$; * $P = 0.031$

The summary of the results for the transformation of selected full blood count parameters into normal, below normal or above normal range using the haematology laboratory benchmark of University of Port Harcourt Teaching Hospital (UPTH), which is a major tertiary referral centre in the sampled area, Rivers State, against range of age

in the exposed and reference respondents and chi-square analysis is shown in Table 3-14 below. From the table, the proportion of respondents with WBC counts below normal range was 28% across all ages in the exposed, which was significantly higher than 9.6% in the reference community ($p= 0.001$). Remarkably, about 64% of the respondents with WBC counts below normal range in the exposed community were aged 45 years or younger at sampling, compared with about 22% for the referent community. The micronucleus count in peripheral blood lymphocytes in the respondents from both the exposed and reference areas were higher in those whose WBC count values were below normal compared to those within normal range. The average neutrophil count in both groups was higher in those within normal WBC range compared with those below normal.

Table 3-14 Results of selected White blood cell count parameters against range of age in exposed and reference respondents

Age group	WBC $\times 10^9/l$					
	Exposed			Reference		
	≤ 3.9	4-10.8	≥ 10.9	≤ 3.9	4-10.8	≥ 10.9
≤ 30	15	49	0	1	30	1
31-45	14	30	0	1	15	0
46-55	5	16	0	2	13	0
≥ 56	11	21	0	5	25	1
Total(%)	45 (28)	116 (72)	0	9 (9.6)	83 (88.3)	2 (2.1)
Mean Mn	26.4	20.8 (7.7)		21.2 (4.5)	16.6 (5.0)	17.5 (0.7)
count(SD)	(9.1)					
Neutrophils(SD)	1.4 (0.4)	2.4 (1.0)		1.4 (0.4)	2.5 (0.8)	3.0 (0.0)

Mn= Micronucleus.

3.5 Cytokinesis-block micronucleus test.

The mean values for the total number of micronuclei in 1000 binucleate cells in cultured human peripheral blood lymphocytes, including the distribution across range of age, are shown in Table 3-15 below. The average number of micronuclei per 1000 binucleated cells in peripheral blood lymphocytes sampled in the respondents from the exposed community was 21.1, while the mean for the reference respondents was 17.1. The difference in the average counts supports the hypothesis that the mean micronuclei count is significantly higher in the exposed compared with the reference respondents

($p < 0.001$). The trend of higher mean micronuclei count in binucleate peripheral blood lymphocytes in the cytokinesis-block micronucleus assay in respondents from the exposed community compared with those from the reference was observed across the range of age. In all cases, statistical significance was achieved in comparing the difference between the mean counts, except in the age range 46-55 years, where the difference approached significance ($p = 0.057$).

Table 3-15 .Table of micronucleus count per 1000 binucleate cells in peripheral blood lymphocytes across age groups in respondents

Age group	Exposed	Reference	t-test	p-value
	Mean;SD (N)	Mean;SD (N)		
≤30	16.5; 6.1 (104)	12.6; 3.6 (33)	3.396	0.001
31-45	23.3; 8.1 (67)	17.2; 3.7 (16)	2.940	0.004
46-55	22.8; 6.1 (28)	19.6; 4.0 (17)	1.953	0.057
≥56	26.6; 7.5 (55)	20.14.0 (37)	4.798	<0.001
Total	21.1; 8.1 (256)	17.1; 7.5 (104)	4.68	<0.001

The relationship between micronucleus count in 1000 peripheral blood lymphocytes, WBC and RBC ranges in the exposed and reference respondents is summarised and illustrated in Table 3-16 below. Across the samples, respondents with RBC and WBC counts below normal range had higher micronucleus counts. The mean micronucleus count in the exposed for respondents whose RBC count was $4.4 \times 10^{12}/l$ or lower was 25.5 compared to 18.3 for the same group in the reference area. For those in the next RBC range, $4.5-5.5 \times 10^{12}/l$, the mean micronucleus count was 20.9 and 15.7 cells in the exposed and reference areas respectively; while the mean for those with RBC count was 5.6 or more, the mean count was 14.7 and 14.3 in the exposed and reference respondents. The relationship between micronucleus count and range of WBC was that the mean count in the exposed area for the respondents with their WBC count equal to or below $3.9 \times 10^9/l$ was 26.7, compared to 20.6 for the reference area; whereas the count for those with their WBC count in the normal range ($4.0-10.8 \times 10^9/l$) was recorded at 20.6 in the exposed and 16.6 in the reference areas.

Table 3-16. Summary of Micronucleus count in 1000 peripheral blood lymphocytes across range of WBC and RBC in respondents

RBC Range X 10 ¹² /l	WBC Range x10 ⁹ /l							
	Exposed				Reference			
	≤3.9(N)	4-10.8 (N)	≥10.9 (N)	Total (N)	≤3.9 (N)	4-10.8 (N)	≥10.9 (N)	Total (N)
≤4.4	30.8(22)	22.6(41)		25.5(63)	21.6 (5)	17.9 (40)	17(1)	18.3(46)
4.5-5.5	23.6(19)	19.9(54)		20.9(73)	19(3)	15.3 (30)	18(1)	15.7(34)
≥5.6	11.5(2)	15.8(16)		14.7(18)		14.3(7)		14.3(7)
Total(N)	26.7(43)	20.6(104)		22.4(147)	20.6 (8)	16.6 (77)	17.5(2)	16.9(87)

3.6 Oil spill clean-up activities

In the exposed community, 15 respondents reported participation in oil spill clean-up or the scooping of oil from a breached pipeline. As illustrated and summarised in Table 3-17 below, the mean age of these respondents was 31.2 years (range 20-68years). There were three females, 32, 33 and 60 years old respectively, and 12 male, average age, 28.6 years. It could not be established fully if the oil leakage was refined petroleum product or crude oil, nor the exact place they had participated in the oil spill clean-up, although the assumption was that it was within or around their community, Ogale-Elеме. There were reports of leakage of refined petroleum product from a pipeline from The Port Harcourt Refinery, which is located in Elеме, close to the area sampled as exposed, although crude oil leakage from oil wells located in the area had also been reported. Some of the respondents reported that they had "scooped" oil, which could mean they just helped themselves in the presence of a spill for pecuniary benefits, and not necessarily participated in any remedial activities. This is a common practice at oil spill sites in the Niger Delta.

All the respondents that reported participation in activities related to oil spillages also self-reported very significant respiratory symptoms, ranging from cold-sores and fever blisters, stuffy nose and catarrhal effusion, to wheeze and dyspnoea. Most of these respondents complained of dizziness. The mean micronucleus count within this cohort

was 18.3 per 1000 binucleate cells in peripheral blood lymphocytes, which was higher than the mean count (16.5) for their range of age in the exposed, but the difference failed to achieve statistical significance. Out of the 15 respondents that reported involvement in oil spill clean-up activities, the full blood count metrics were available for 5. One of the 5 whose blood count was available, male of 23 years, had very low WBC count, $3.3 \times 10^6/\text{dl}$. The rest of the blood count parameters were not remarkable, although the respondent had other complaint of severe breathlessness, attack of wheeze and had suffered from attack of bronchitis before he was 19 years of age. Another respondent, female 33 years old at sampling, complained of frequent fevers at night.

Table 3-17 The age, gender, selected respiratory complaints, selected blood count parameters, and micronucleus count in 1000 binucleated peripheral blood lymphocytes for respondents from the exposed area who reported participation in oil spill events

Sex, age		Respiratory symptoms					Blood count				Mn Count
	A	B	C	D	E	F	RBC	Hg	Plt	WBC	
M, 20	+		+								15
F, 60			+	+	+	+					23
M, 44	+			+		+					26
M, 30	+		+	+	+		4.37	12.5	187	4.0	14
M, 23	+			+		+	4.87	13.5	93	3.3	20
M, 38	+	+									20
M, 27	+	+		+	+	+					24
M, 48	+	+	+		+	+	4.75	14.2	251	5.1	28
F, 32	+						5.14	15.2	157	4.3	21
M, 24	+	+	+	+							18
M, 25	+	+									23
M, 20	+	+									8
M, 21	+			+	+	+					18
M, 23	+	+	+	+	+	+					12
F, 33				+	+	+	5.2	15.2	174	5.0	15

A= Cold/catarrh; B= Cold sores/fever blisters; C= Cough; D= Wheeze; E= Dyspnoea; F= Dizzy spells
RBC count x 10¹²/l; Hg =g/dl; Plt count x 10⁶/l; WBC count x 10⁹/l

A two model hierarchical multiple linear regression was conducted with micronucleus in 1000 binucleated peripheral blood lymphocytes as the dependent variable. To control for potential confounders, the continuous variable, age, the binary explanatory variables,

cooking with firewood and gender (which were dummy coded), were entered at stage one, with the blood count parameters WBC, RBC, Hgb, haematocrit, platelet and lymphocyte counts entered as independent predictors, while controlling for the effects of the confounders. The results for the exposed and reference respondents were compared as summarised in Table 3-18 below.

Table 3-18 Summary of Hierarchical Regression Analysis for Variables predicting Micronucleus count in peripheral blood lymphocytes in exposed and reference areas.

Variable	B (C.I)	SE B	β	t	B (C.I)	SE B	β	t
Model 1	Exposed N = 104				Reference N = 93			
Constant	10.94 (7.95, 13.92)	1.53	.	7.23***	7.15 (4.69, 9.62)	1.24		5.77***
Age	0.22 (0.15, 0.30)	0.04	.45	5.98***	0.20 (0.15, 0.24)	0.02	.69	8.89***
FireWood	0.97 (-3.41, 1.48)	1.24	-.06	-0.78	-1.03 (-3.08, 1.02)	1.03	-.08	-1.00
Gender(F)	3.08 (0.71, 5.45)	1.20	.19	2.57*	3.08 (1.58, 4.58)	0.76	.30	4.08***
Model 2								
Constant	44.64 (31.90, 57.39)	6.45		6.92***	10.93 (2.62, 19.25)	4.18		2.62*
Age	0.20 (0.14, 0.28)	0.04	.41	5.87***	0.20 (0.15, 0.25)	0.02	.70	8.59***
Firewood	-1.30 (-3.55, 0.96)	1.14	-.078	-1.14	-1.04 (-3.13, 1.06)	1.05	.08	-0.99
Gender(F)	0.16 (-2.73, 3.05)	1.46	.01	0.11	2.27 (0.47, 4.07)	0.90	.22	2.51*
WBC Count	-0.31 (-1.34, 0.72)	0.52	-.05	-0.60	0.43 (-0.26, 1.13)	0.35	.15	1.24
RBC count	-0.17 (-3.88, 3.53)	1.88	-.01	-.09	0.59 (-2.31, 3.50)	1.46	.08	-0.41
Hgb	-0.21 (-2.78, 2.30)	1.27	-.04	-0.17	0.27 (-1.66, 2.20)	0.97	.09	0.28
Hct	-0.47 (-1.61, 0.67)	0.58	-.27	-0.82	0.24 (-1.10, 0.62)	0.43	-.23	-0.56
Platelets	0.01 (-0.03, 0.00)	0.01	-.10	-1.54	0.00 (-0.10, 0.01)	0.01	.03	0.32
Lymphocytes	-1.93 (-3.89, 0.03)	0.99	-.17	-1.95	-1.25 (-0.01, -0.23)	0.63	-.23	-2.00*
*p < .05; **p < .01; ***p < .001								

In the exposed, age, cooking with firewood, and female gender contributed significantly to the regression model, $F(3,155) = 18.69$, $p < .001$) and accounted for 27% of the variation in micronucleus count. Adding the blood count parameters to the regression in model 2 explained another 16% of the variation micronucleus count, and this change in R^2 was significant, $F(9, 149) = 12.23$, $p < .001$). In the reference respondents, the contribution made by the demographic, potentially confounding variable to the regression model was also significant $F(3, 89) = 35.03$, $p < .001$), and accounted for 54% of the variance. The overall model with the blood count parameters was also significant, with $F(9, 83) = 12.59$, $p < .001$), and explained 58% of the variance in the regression model. However, the change in R^2 failed to make any significant contribution to the regression model ($p = .332$). Again, in the overall model (2) for the exposed, the only significant independent predictor of micronucleus count was age, accounting for 7.8% of the variance in the model ($p < .001$). Age ($\beta = .71$), gender ($\beta = .22$), and absolute count of lymphocytes ($\beta = -.23$) were significant contributors to the overall model (2) in the variation of micronucleus count in the reference respondents with ($p < .001$, $p < .05$, $p < .05$) respectively.

Table 3-19 below summarises the outcome of binomial logistic regression analysis conducted to predict some self-reported categorical health variables in the exposed and reference areas: Cold/catarrh/stuffy nose, Cold sores/fever blisters, Cough, and Wheeze with cooking with firewood, age, micronucleus count, white blood cell count, red blood cell count and gender as predictor variables.

For cold/catarrh/stuffy nose, overall, the model was significant, $\chi^2(6) = 7.06$, $p = .591$; Nagelkerke $R^2 = .063$ for the exposed, and neither for the reference $\chi^2(6) = 7.74$, $p = .397$; Nagelkerke $R^2 = .117$. None of the explanatory variables was a significant predictor in the exposed and reference areas. The model was also not significant in predicting cold sores/fever blisters in the exposed, $\chi^2(6) = 7.61$, $p = .268$; Nagelkerke $R^2 = .065$ and reference areas $\chi^2(6) = 7.21$, $p = .302$; Nagelkerke $R^2 = .110$. However, in the exposed respondents, RBC count was significant as an independent variable in predicting cold sores (OR .80, $p < 0.05$). The overall model was not significant in predicting cough in the exposed respondents $\chi^2(6) = 6.59$, $p = .360$; Nagelkerke $R^2 = 0.055$, but for the reference respondents, it was significant $\chi^2(6) = 16.54$, $p = .011$.; Nagelkerke $R^2 = 0.226$.

Of all the predictor variables, only WBC count was a significant predictor, $p < 0.05$, with an odds ratio of 0.69. The overall model was insignificant in predicting wheeze in the exposed, $\chi^2(6)=3.76$, $p = .710$; Nagelkerke $R^2 = 0.04$, but was in the reference respondents $\chi^2(6)= 12.74$, $p = .047$; Nagelkerke $R^2 = 0.19$, although no independent variable yielded significant predictor power.

Table 3-19 Summary of Logistic Regression Predicting Respiratory (Health Yes or No)

Exposed					Reference					
Independent Variable	β	Odds Ratio	95% CI		p	β	Odds Ratio	95% CI		p
Cold/Catarrh/Stuffy Nose										
Firewood	-0.19	0.83	0.36	1.93	.666	-.53	0.59	0.16	2.17	.428
Age	-0.01	0.99	0.96	1.02	.362	.05	1.03	0.99	1.07	.215
MN Count	0.05	1.05	1.00	1.11	.064	.02	1.03	0.89	1.18	.731
WBC Count	0.25	1.29	0.93	1.79	.135	.12	1.12	0.84	1.50	.443
RBC Count	0.50	1.62	0.80	3.43	.176	.37	1.44	0.59	3.56	.425
Gender	0.18	1.19	0.48	2.95	.701	-.86	0.42	0.12	1.45	.171
$\chi^2(6)=7.06$, p = .591; Nagelkerke R ² = .063					$\chi^2(6)=7.74$, p = .397; Nagelkerke R ² =.117					
Cold sores/Fever Blisters										
Firewood	0.20	1.22	0.55	2.72	.627	1.20	3.33	0.74	14.98	.117
Age	0.01	1.01	0.99	1.04	.400	-0.40	0.96	0.92	1.00	.055
MN count	0.03	0.98	0.93	1.03	.334	0.13	1.14	0.99	1.31	.072
WBC Count	0.15	0.86	0.65	1.15	.321	0.08	1.08	0.83	1.42	.565
RBC Count	0.80	2.22	1.05	4.68	.037	0.19	1.21	0.51	2.90	.669
Gender	0.71	2.04	0.80	5.20	.136	-0.41	0.67	0.20	2.29	.519
$\chi^2(6) = 7.61$, p= .268; Nagelkerke R ² = .065					$\chi^2(6)= 7.21$, p= .302; Nagelkerke R ² = .110					
Cough										
Firewood	0.01	1.01	0.48	2.14	.971	0.41	1.51	0.41	5.54	.533
Age	0.00	1.00	0.97	1.02	.765	-0.04	0.96	0.92	1.00	.062
MN Count	-0.04	0.96	0.92	1.01	.134	-0.08	0.93	0.81	1.06	.282
WBC Count	-0.01	0.99	0.76	1.29	.931	-0.37	0.69	0.50	0.96	.030
RBC Count	-0.17	0.86	0.44	1.65	.641	0.12	1.13	0.49	2.64	.777
Gender	0.73	2.078	0.91	4.74	.083	0.40	1.50	1.47	4.77	.496
$\chi^2(6)= 6.59$, p= .360; Nagelkerke R ² = 0.055					$\chi^2(6)= 16.54$, p= .011.; Nagelkerke R ² = 0.226					
Wheeze										
Firewood	-0.71	0.49	0.18	1.34	.166	-0.95	0.39	0.07	2.27	.293
Age	0.02	1.02	0.98	1.05	.381	-	0.98	0.94	1.02	.343
						.002				
MN Count	0.02	1.02	0.96	1.09	.490	-0.09	0.91	0.79	1.06	.215
WBC Count	0.02	1.02	0.72	1.47	.899	-0.23	0.79	0.60	1.05	.106
RBC Count	0.01	1.01	0.42	2.45	.987	0.30	1.35	0.52	3.51	.541
Gender	0.11	1.12	0.37	3.39	.846	0.11	1.11	0.314	3.94	.870
$\chi^2(6)=3.76$, p= .710; Nagelkerke R ² = 0.04					$\chi^2(6)= 12.74$, p= .047; Nagelkerke R ² = 0.19					

4 Discussion

4.1 Introduction

The field observational studies and evidence gathering carried out in selected communities in the Niger Delta show that there are several locations where the residents may be at significant risk of exposure to hazardous chemicals due to exploration and production activities of the oil and gas industry. All environmental media-air, land and water- in the delta are potential source or pathway in the pollutant linkage. The toxicants would include the natural constituents of crude oil, including the BTEX compounds, PAHs, heavy metals, and a myriad other harmful chemicals used in the exploration and production of crude oil. The Oil and gas industry in Nigeria has been in operation for almost 60 years, and has been the main base of the Nigerian economy. The environmental footprint and the consequent human health effects are potentially multi-generational. It is noteworthy that the petroleum industry has been the heartbeat of the economy of Nigeria, with a huge chunk of the export earnings coming from it. As a result of the centrality of this industry to the nation's economy, the major policy thrust of the government has been to increase output, however the regulatory framework to control for the environmental impacts of the increased production has not been commensurate, but has lagged behind. For a long time, the laws that governed the operations in the oil and gas industry that are made at the federal government level, were never reviewed. The enforcement of these laws has always been derogated to the central government, at centres far from where the operations take place. Unfortunately, whereas those communities that are host and proximal to oil and gas exploration and production have largely been bereft of the benefits of the resource that is domiciled with them, but distributed at the centre- the seat of government, the consequences and fallouts of the operational failures remain with the residents of the oil-bearing communities.

This study was aimed at investigating the potential risk to physical health, including psychological health issues in residents and community members of the Niger Delta that could be associated with over 50 years of the operations of the oil and gas industries in

the region. The data and other evidences from laboratory investigations, questionnaires administration, field and observational studies that were carried out may be supportive of plausible significant risk to human health from exposure to benzene, polycyclic aromatic hydrocarbons (PAHs), heavy metals, particulates, and other potentially carcinogenic chemicals in various environmental media, but detailed exposure assessment and pollutant linkage will be required to establish this. It was discovered that several cultural practices and traditions of the natives and residents would be at cross purpose with, and potentially engender an aversion to, appropriate risk perception and risk attitude. This would make exposure to petrogenic toxicants in the environmental media easier, and could detract from seeking appropriate mitigation of potential health fallouts or blunt the association of these outcomes to the exposures. Over the many years -and after long periods- of exposure to environmental despoliation and loss of ecosystem functions, with the attendant poverty among the residents, mental health issues may have arisen in the form of post traumatic stress disorders (PTSD). The rise in militancy, increase in sabotaging of oil pipelines and other petroleum industry infrastructure, artisanal refining of petroleum and so many other ills plaguing the Niger Delta, it is thought, may be symptomatic of this PTSD and related psychiatric outcomes.

4.2 Laboratory Studies

A significantly higher count of micronuclei in binucleate cells of cultured peripheral lymphocytes was found in the respondents from the exposed area in the cytokinesis-block micronucleus assay. The cytokinesis-block micronucleus frequency assay in peripheral blood lymphocytes has been validated in cancer screening as predictive of cancer risk (OECD., 2010). It has been reported that an elevated frequency of micronuclei in peripheral blood lymphocytes is associated with the early events in carcinogenesis (Bonasi et al., 2007; Garaj-Vrhovac et al., 2008). Although a significantly higher frequency of micronuclei in binucleate lymphocytes was found in the respondents sampled from exposed area compared with the frequency in the reference community, the age and gender distribution of the respondents sampled suggest that this finding is counterintuitive. Micronuclei frequency in population studies has been found to be positively correlated with age. It is also found to be higher in female gender than male (Fenech and Bonassi, 2011). The hierarchical regression

modelling performed also showed that age and gender were significant predictors of micronucleus count in this study, in both the exposed and reference respondents. Age contributed the most to the model in both populations to micronucleus count. Age and gender were the only significant explanatory variables contributing to the hierarchical multiple regression model. The respondents from the exposed area were younger in age, with an average age of 40 years, compared with the mean age of about 46 years for the reference. They also had more than 60% of the female respondents under 45 years of age, as opposed to 46% in the reference population; and for the oldest age bracket, the exposed had even fewer female respondents compared with the referents (28% versus 40%). These factors should favour a lower count in population studies with the micronucleus assay, but they had a poorer outcome. Unfortunately, this could have serious health implications as increased frequency of micronuclei in peripheral blood lymphocytes is not only predictive of cancer risk in humans, but has also been associated with obesity, diabetes, and cardiovascular diseases risks (Andreassi et al., 2011). Further, to control for the potential confounding effects of age, female gender and cooking with fossil fuel (with the attendant exposure to indoor air pollution), and to achieve comparability across the MN count for exposed and reference a hierarchical multiple regression analysis was performed, with the potential confounders as independent predictor variables in the first block, and selected blood parameters as explanatory predictor variables of micronucleus count in peripheral blood lymphocytes (Ceppi et al., 2011; Mustapha et al., 2011; Umoh et al., 2013). The results show that controlling for possible confounding effects of age, gender and cooking firewood, statistically significant impact changes in micronucleus count in peripheral blood lymphocytes could be independently predicted in the exposed respondents by the selected blood parameters- WBC count, RBC count, haemoglobin measure, haematocrit, platelet count, and lymphocyte count - included in the model, but not in the referent respondents. It has already been seen that there were significant differences in the blood count parameters, especially the white blood cell count and differential between the respondents sampled from the exposed and reference sampling areas, with the exposed respondents presenting poorer white cell count parameters. It could be inferred that the evidence from the hierarchical multiple regression analysis, which controlled for the potential confounding effects of age, gender and cooking practice, i.e.

cooking with firewood, lends credence to the hypothesis that the exposures in the exposed area is associated with adverse effects on white cell count and differential parameters, and to higher micronucleus count in peripheral blood lymphocytes.

A correlation has also been found between increased frequency of micronucleus in peripheral blood lymphocytes and sperm abnormalities, infertility, pregnancy loss, pre-eclampsia and intra-uterine growth restriction in humans (Migliore et al., 2006; Fenech, 2011), and also with neurodegenerative diseases (Migliore et al., 2006); (Migliore et al., 2011). The potential for human health risks in line with these research findings could be inferred. For over a century, mechanistic studies have been carried out and empirical evidences accumulated which support a causal link between chromosomal abnormalities and cancer and other diseases with chromosomal breaks and loss as the underlying deficit. The cytokinesis-block micronucleus assay serves as a means for quick assessment of baseline chromosome damage (Fenech, 2000) However, the small sample size in these studies limits drawing a conclusion. In a number of communities visited during the field and observational studies, anecdotal reports of poor reproductive health effects were made by some residents, including an aversion to female family members not getting married and raising families early, an attempt, it would seem, to exploit the most productive period for procreation, probably necessitated by unusual poor fecundity and other maternal health outcomes observed in females when reproduction is delayed. Poor pregnancy outcomes, especially spontaneous abortion, have been found associated with living in the proximity of fields among women in the Amazon Basin of Ecuador (San-Sebastian et al., 2002).

It has also been reported that there is an increasing trend in the pattern of leukaemia in Nigeria, and a higher prevalence of lymphoid malignancies were recorded in the areas of the Niger Delta with oil and gas operations (Omoti and Imiere, 2006; Omoti et al., 2012). In one of their studies which spanned the period 1996 to 2010, the records of admission for 1081 haemato-oncology patients at University of Benin Teaching Hospital, a tertiary referral health centre in Edo State, in the Niger Delta, were analysed. One remarkable observation in this study was that there was about 67% greater proportion of these cases from Delta State, which has a higher preponderance of oil installations compared to the number from Edo State, where the hospital is located,

although both states are in the Niger Delta. The risk of lymphoid malignancies was adjudged to be higher in the geographical areas with more oil and gas installations. When they looked at the trend over time, there was on the average, 84% more cases recorded in the last five year period (2006- June 2010) under study relative to the first five year period (1996-200).

The full blood count and differential count analyses showed there were significant cytopenias recorded, especially in the white blood cells and differentials in the exposed area compared with the reference population. This was remarkable for the mean white blood cell counts and in the differential count. Significant differences were recorded for mean lymphocytes count, the mixed white blood cell count, which includes the basophils, eosinophils and monocytes in absolute counts. The difference in the mean count of neutrophils also approached significance. The white blood cells are the major mediators of the immune system in humans, and are targeted by immunotoxic agents. A major known myelotoxic effect of benzene, a chemical of concern in crude oil spillages, is leukopenia, or depression of white blood cell count (Schnatter et al., 2012; WHO, 2000; Gailbraith et al., 2010), although there is uncertainty regarding the most sensitive blood parameters affected by it (Schnatter et al., 2010). It has been reported that the cytopenias due to chronic exposure to benzene, particularly aplastic anaemia, leukopenia, agranulocytosis, pancytopenia, and myelodysplastic syndrome are caused by bone marrow depression (Schnatter et al., 2010). In another study, D'Andrea et al., (2013) investigated the health effects among the residents of Louisiana who were exposed in the aftermath of the Gulf oil spill, and encompassed in their findings was a lower platelet count in those exposed compared with the referents. Using the haematology reference range for white blood cell (WBC) count for University of Port Harcourt Teaching Hospital (UPTH) as a benchmark, it was found that more than 28% of the respondents from the exposed community had total WBC count below normal, compared with 9.6% for the reference area, which showed significant difference between them, statistically. Judging by pattern of age distribution between the two study populations, the results obtained should have favoured the respondents from the exposed community, since they were significantly younger in both their mean age, and the subset under 45 years of age. Some white blood cell count parameters decrease with increasing age, including absolute count of lymphocytes, eosinophils, and the predictors

of the outcome of acute myeloid leukaemia (MacKinney, 1978; Appelbaum et al., 2006). Taken together, these results strengthen the hypotheses that the exposures to petroleum-derived hydrocarbons due to the operations of the oil and gas industries in the exposed community and from the crude oil spillages that results, including the other environmental pollutants that could result, has plausible impacts on the health of the residents of the areas with these exposures, particularly their haematological health. Although the evidence from this study, especially the haematological analysis would not stretch far enough to draw a conclusion because of the cross-sectional design, when it is added to the evidence provided by the report on the environmental assessment of Ogoniland (UNEP, 2011) on the extent of contamination found in one of the exposed community that was sampled, Ogale Eleme, principally the finding that benzene was found in their drinking water sources at concentrations 900 times greater than the WHO guideline value, it would seem safe to say that the evidence is strong enough to serve as a sentinel for the need to carry out more detailed human health risk assessment and other studies. Although there was a measure of convergence in the release of the UNEP Ogoniland Assessment Report and the preliminary stages of this study, efforts were made at early stages to see if this study could be situated within the UNEP assessment, but no replies were received to so many emails to the facilitators of the UNEP Ogoniland study. There were logistic and financial hindrances to studying for biomarkers of benzene exposure in humans alongside the other remits of the study.

4.3 Self-reported health effects

Among the self-reported health effects, there was no significant difference in the prevalence of cold, catarrh or stuffy nose in the two population sampled, but the respondents from the exposed community who reported having cold or catarrh or stuffy nose, had it for a significantly longer period of time, or more frequently, compared with those who responded from the reference community. The same trend was also noticed for the prevalence of cold sores or fever blisters on the lips, for which there was no significant difference, but the respondents self-reporting this in the exposed area, had a significantly higher and/or longer frequency and duration of it. Another respiratory health variable self-reported was cough. Although there were no statistically significant difference in the prevalence of cough, either as a result of irritation of the airways, or

productive of phlegm between the test populations, the proportion of respondents who had cough persisting for longer than 4 days a week was remarkably higher in those from the exposed area.

The combination of cold, or catarrh, of duration longer than a week, coughing and breathing difficulty, have been reported as symptomatic of benzene exposure, and are portends of immunological deficits (ATSDR, 2000). These symptoms have also been reported in exposures to PAHs, which have been found in many areas with crude oil pollution and gas flaring in the Niger Delta (ATSDR., 2009; UNEP, 2011). The results for self-reported dyspnoea, wheeze, and apnoea with exertion, showed a lower prevalence in the exposed population. However, the mean age of first attack of shortness of breath was found to be significantly lower in the exposed population, suggesting that those who reported experiencing shortness of breath were experiencing it at a much earlier age compared with those in the reference area. Although these are subjective respiratory measures, whose perception and interpretation are subjective and variable, they are also affected by age, sex, body weight, physical conditioning, attitude and emotional motivation (Mukerji, 2000), which may limit their utility in weight of evidence calculations. It must be stated that the answers to the questionnaires were not obtained in clinical conditions, and this could limit the interpretation of these findings. However, they add to the weight of evidence suggesting there may be a relationship between the exposures in the areas of the Niger Delta experiencing environmental stressors due to the operations of the upstream oil and gas industries and poor health metrics in the residents of those communities, especially respiratory well-being. The potential confounders to these results were evaluated. Significantly more respondents from the reference population reported cooking with firewood, 82% compared with about 62% in the exposed population. However, although more of the respondents from the reference community complained of nuisance smoke inhalation from cooking with firewood, the fraction was of no statistical significance. The more rural location of the reference community could be a reason for the greater reliance on firewood as fuel for their cooking. Another explanation could be the absence of the oil and gas industry in that community, and the enduring legacy of traditional ways of life, which is sustainable and supportive of ecosystem functions. So, the forests around the reference community, devoid of the presence of oil and gas industry operations and consequent degradation,

are still yielding firewood, enough not to warrant the need for other cleaner energy sources for cooking. However, the cooking practices and other lifestyle habits could potentially modify the effects of the environmental exposure (Schnatter et al., 2010), and the proportion of residents in the Niger Delta that are still reliant on firewood for cooking, especially in the rural communities is high. The use of biomass fuel, such as firewood is associated with exposure to high levels of indoor air pollution, and with high attributable annual mortality (Haines et al., 2007; Hosgood et al., 2010). The combination of outdoor air pollution due to the activities of the oil and gas industry, poor indoor air quality due to poverty and traditional cooking practices in the Delta region would have plausible adverse respiratory health impact. Exposure to air pollution due to burning of biomass fuel sources have been studied among 521 fishermen, and among 1,397 children aged 7-14 years in the Niger Delta. The results showed a significantly higher prevalence of chronic respiratory health outcomes among the fishermen compared to control (OR 8.7; CI 14.7-16.3; $p < 0.001$) attributable to exposure to smoke from firewood that is burned as fuel for drying fish (Umoh et al., 2013). A non-significant positive association was found between the use of firewood and coal for cooking resulting in indoor air pollution with phlegm, compared with the use of cooking gas in the study of children aged 7-14 years (Mustapha et al., 2011). The logistic regression modelling of some respiratory health outcomes in this study with cooking with firewood, age micronucleus count, white blood cell and red blood cell counts and gender as explanatory predictor variables failed to show these independent variables as predictors of cold/catarrh/stuffy, cold sores and fever blister, common cough and wheeze in the exposed respondents, but succeeded in showing significant predictor power for wheeze ($\chi^2(6) = 12.74$, $p = .047$; Nagelkerke $R^2 = 0.19$) and common cough ($\chi^2(6) = 16.54$, $p = .011$; Nagelkerke $R^2 = 0.226$) in the reference respondents.

4.3.1 Non-drinking uses of water

The centrality of the water bodies in the Niger Delta to the lifestyle of residents in the area means that other domestic uses of these waters would be potential portals of exposure to the contaminants in the water. Domestic activities like laundry, food processing, dishwashing, and various other activities in households that require the use of water could lead to exposure through inhalation, ingestion or dermal absorption of

toxicants, especially the volatile organic compounds that have been found as contaminants of water bodies in the Niger Delta. One aspect of lifestyle in the Niger Delta that is dependent on water, and that could be of significant importance in pollutant linkage, is the traditional practice of processing cassava (*Manihot esculenta*) into various end products utilised as food in the Niger Delta, and several other parts of West Africa. Certain varieties of cassava produce the cyanogenic glucosides, linamarin and lotaustralin, which undergo hydrolysis by the endogenous enzyme, linamarase, to form hydrogen cyanide. The hydrogen cyanide so formed has been implicated in certain chronic toxic outcomes in human and animal cohorts that consume poorly processed cassava over prolonged periods (Hahn and keyser, 1985; Hahn, 1988). One of such toxic manifestations in human populations is tropical ataxic neuropathy (Hahn, 1988). The traditional method of processing cassava in the Niger Delta include immersion in streams over a period of 3-5 days for fermentation and to enable the reduction of the levels of hydrogen cyanide forming intermediates. Processed cassava in its various forms, is a major source of food in Nigeria, and especially so in the Niger Delta. Although the water quality in the Niger Delta has changed through pollution, the practices that may cause exposure to the pollutants and could be a significant source of exposure to the pollutants in the water are not diminished. Other foods that are processed traditionally by immersion in streams in the Niger Delta include maize, in the processing of a traditional fermented corn meal, "akamu" or "ogi" that is used by the natives as breakfast cereal, and as a popular infant formula. In the processing of maize into cornmeal, the maize is steeped in water for about 3 days to ferment, then milled and sieved to remove the bran. The slurry is then allowed to settle, and the supernatant gently decanted, leaving the cornmeal behind. The water often used is the one from the streams, where traditionally the processing is carried out, and a good part of this water is retained in the cornmeal. It would be prudent to expect that with the water bodies yielding high detectable contaminants levels, and the residents and natives continuing with the traditional food processing habits, risks to their health due to the inherent exposure could be realised. The dermal, inhalational and oral routes could be recruited, and unfortunately, the most vulnerable members of these communities, children and women, are the ones involved in filling these traditional food processing roles.

From a human health risk assessment perspective, it is important to note that in line with the hierarchical organisation of most traditional societies, especially in Africa, and the resultant distribution of roles, women and children in most households are the ones that perform the role of fetching water from the streams, preparing the food consumed, washing of dishes after meals, doing the laundry, often by the waterside, and are involved in so many other menial chores that would expose to water. When children go to fetch water, they do so from the most accessible point, regardless of quality of the water fetched. They wade in the water most times, wetting themselves including their clothes, and are thus exposed the most where the water is contaminated with petrogenic hydrocarbons. Unfortunately, petrogenic contamination has been reported commonly in the Niger Delta (UNEP, 2011; Linden and Palsson, 2013). Traditionally, when the children, and sometimes the women and other adults go to the streams, they would swim and bath, since the water they bring home is hardly adequate for the several other domestic uses. Conceptually, the residents of the Niger Delta that engage in these activities would be exposed to hydrocarbons in the water bodies via inhalation and dermal routes, and possibly by ingestion.

4.4 Limitations of the study

The lack of quantitative exposure assessment data to environmental contaminants limits association of self-reported health complaints and laboratory findings to any set of environmental fallouts.

The lack of background health records, including the huge popularity of alternative medical practices among the indigenous people of the Niger Delta, created a problem in understanding previous medical history, and how that could relate to health complaints that were self-reported.

This study was unable to analyse data on urine sampling because of equipment and manpower problems. The results gathered were not coherent enough for any meaningful interpretation. Surely, results of another biological sample would have added strength to the findings.

The interpretation of the human health and demographic variables was a major limitation of this study. For example, most local dialects in the Niger Delta would have

limited vocabulary to define the various respiratory symptoms the study questionnaire sought to capture. "Wheeze or whistling" in the chest could be a vague term, and it is not clear the respondents would have a common understanding of that phrase. This could lead to misclassification error with the possibility for attenuated risk estimates.

The mobilisation for the study in the exposed community was driven mainly by the youth leadership, and the result was that more young male respondents were sampled compared to the reference community that was more town-crier driven, which is in line with the traditional way of mass mobilisation in the rural Niger Delta. It is not clear how that may have affected the representativeness of the samples from the two communities, and the potential effect on the results.

There were limitations due to the extra-mural nature of this study, and the need to rely on some facilities that belonged to a third party. That meant that some sensitive analysis could not be carried as and when due. However, because the sampling of the reference and exposed communities were done simultaneously, the effect on the findings should cancel out. Again, because the laboratory studies were carried out in the Niger Delta, there was no room for the level of iteration on outcomes and findings that would have brought about a better refinement to the research otherwise. Time and materials were also very constraining. A mobile field laboratory, and greater reliance on held-held analytical kits with data storage capacity could have served the study better by way of confidentiality, retrieval of data, and analyses. The reliability of some data were compromised due to long traffic snarls leading to occasional storage of biological materials longer than was appropriate and above viable temperatures.

4.5 Recommendations for further studies

The Niger Delta is a vast area, and supports a huge and diverse population of flora and fauna. Much can be gained from a more systematic and widespread environmental assessment, especially within those geographical and linguistic expressions that are

unable to muster the persuasion available in Ogoniland. So many communities have had potentially worse environmental mishaps than was recorded in Ogoniland, and are living the consequences. A delta-wide environmental assessment would serve everyone well. Along with this, there would also be need to conduct a long-term systematic epidemiological study into the potential human health effects the pernicious environmental pollution of the Niger Delta could be having on the residents who suffer the exposure over the nearly 60 years of oil and gas industry operations

There are several tertiary health institutions and university teaching hospitals in the Niger Delta. A reasonable number of them maintain cancer registry. It may be that a structured interrogation into the prevalence and trend of cancers and other disease pattern in the Niger Delta compared with other regions would reveal a trend that would lead to further research hypotheses related to the environmental health challenges in the Niger Delta. A case control study design in which patients that have developed diseases are identified and their previous exposure to potential environmental contaminants is compared with appropriate control without the disease, and the odds ratio is computed to determine the incidence of disease, after adjusting for confounders.

The Niger Delta would benefit from an ethnographic research into the way the cultural habits and practices of the indigenous people may be affecting the health of the residents of the area, including how the gap in the modern economic activities and traditional lifestyle can be accommodated or bridged.

On the human health risk assessment, the Niger Delta would benefit from detailed anthropometric and physiologic measurements of residents living in proximity to the impacted areas, including their heart rate and blood pressure measurements. Detailed pulmonary function tests, including spirometry data collection would be required in the assessment of obstructive lung disease when added to physical symptoms and self-reported medical history information.

An enhanced analyses of biological specimens would be required in future research. The specimens would include greater varieties of blood samples for metals analysis, such as analysis of antimony, mercury, chromium, copper, cadmium, manganese, selenium, calcium, arsenic, and magnesium. Urine analysis for glucose, protein and other basic chemistry would also be required. Toenails clipping would be required for

further analysis of metals, including hairs clipped close to the root for metals and cortisol.

A home environment sampling targeted at providing some information about the living conditions of respondents and enable a better characterization and control of potential confounders based on residential exposures would also be required. This would help in teasing out potential exposures related to incessant oil spillages and other fallout of the activities of the oil and gas industry in the area. Attention to the potential confounding effects of molds, dust mites and other endotoxins and allergens on pulmonary functions would then be kept in focus. A swiping of various areas in rooms and collection of vacuumed dust would be recommended. An analysis of domestic water samples for volatile organic chemicals and heavy metals, including the analysis potable water is also recommended in further studies. This would be useful in determining if there is active and ongoing exposure to petrogenic volatile organic compounds.

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5 Conclusion

The oil and gas industry have caused proven environmental degradation in the Niger Delta of Nigeria. The risk to human health that may be associated with these environmental pollution has been assessed. The findings of this research suggest that the communities that are host to petroleum industries in the Niger Delta may be paying a very high price — risk to their health due to the lack of international best practices and unsustainable manner the industry has operated in the almost 60 years of exploration and exploitation of crude oil in the area.

The exposure to toxicants occur via all environmental media- air, soil, water; and through all known routes-dermal, inhalation, oral. The respiratory, circulatory, immunological, reproductive, and indeed every system in the body are potentially affected. This study found evidence of depressed white blood cells and differential count, suggesting potential compromised immunity. When added to the self-reported health effects, which included higher prevalence rate of episodes of various respiratory deficits, cold sores and fever blisters, and other anecdotal evidences, a picture of plausible immunotoxicity is painted. These findings are typical of exposure to benzene and PAHs, and have been confirmed in several studies, especially in occupational benzene exposure, and studies on crude oil spillages. The results from the cytokinesis-block micronucleus assay lends further credence to the risk the residents and indigenous people of the Niger Delta face, especially those living in proximity to oil and gas installations. Significantly higher counts were recorded for the respondents from the exposed community in the micronucleus assay. Micronucleus frequency in peripheral blood lymphocytes is accepted as a predictive biomarker of cancer risk. When the age of the respondents is taken into consideration as a potential confounder of the micronucleus assay, the observed significantly higher frequency of micronucleus cells appears counterintuitive, and more remarkable. There is a positive correlation between age and micronucleus frequency, and the respondents from the exposed area were significantly younger than the referents.

The petroleum industry has been operating for close to 60 years in the Niger Delta, and has contributed immensely to the economy of Nigeria and the progress of its people, including the welfare and quality of life of the majority of Nigerians. However, the

regulatory framework for controlling the operations in the industry has been weak, and lacking in sustainability. As a result, a disproportionately high exaction has been placed on the indigenous people and the ethnic nationalities whose homes are in the Niger Delta. The toll has ranged from economic to social, and from cultural to spiritual. There has been severe impact on ecosystem functions. This has resulted in the economic emasculation of the majority of the natives who depend on subsistence farming, fishing, hunting and foraging for wild crops for sustenance. The social impact has been at both personal and community level. Some residents have been driven into pariah status by the overarching need to earn a living, sometimes outside the ethos and mores of their community, while communities have wrangled over boundaries and right to oil-derived revenue and royalties accruing from the geographical location of petroleum installations. The cultural and traditional ways of life of the indigenous people of the Niger Delta, from culinary to celebratory, are no longer supported as a result the damages and risks attributable to environmental pollution. Even the traditional religious practices are not spared as sacred forests and water bodies come under sacrilege in the bid to explore and develop oil fields.

The conflicts, deprivation, and environmental despoliation in the Niger Delta, the community agitations and opposition against the perceived injustice with the resultant militarisation, has had plausible mental health consequences, including anxiety-depressive disorders, post-traumatic stress disorders, and a host of other psychological effects.

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Appendix

Table A. 1 Percentages of respondents with "yes" or "no" answers to health variables against their cooking practices in exposed and reference communities

Health variable	Cooks with firewood				χ^2	p
	Exposed		Reference			
	Yes(%)	No(%)	Yes(%)	No(%)		
	162	96	91	20	13.26	<0.001
Cold/catarrh						
Yes	112(60.2)	74(39.8)	62(81.6)	14(18.4)		
No	50(69.4)	22(30.6)	26(81.3)	6(18.8)		
Total	162	96	88	20		
χ^2	1.892		0.002			
p	0.169		0.968			
Cold sores/fever blisters						
Yes	63	35	30	4		
No	99	61	58	16		
χ^2	0.151		1.500			
p	0.697		0.221			
Coughs						
Yes	70	39	42	9		
No	92	57	46	11		
χ^2	0.165		0.049			
p	0.685		0.825			
Coughs on waking up.						
Yes	42	25	13	4		
No	120	71	75	16		
χ^2	<0.001		0.336			
p	0.984		0.562			

Table A. 2 Percentages of respondents with "yes" or "no" answers to health variables against their cooking practices in exposed and reference communities.

Health variable	Cooks with firewood			
	Exposed		Reference	
	Yes	No	Yes	No
Coughs rest of day/night				
Yes	43	27	16	4
No	119	69	72	16
χ^2	0.076		0.036	
p	0.782		0.850	
Cough +phlegm in the morning				
Yes	40		24	2
No	121		64	18
χ^2	0.001		2.660	
p	0.978		0.103	
Cough +phlegm ≥ 24 hrs				
Yes	37	22	19	3
No	125	74	69	17
χ^2	<0.001		0.436	
p	0.989		0.509	
Cough +phlegm >3weeks				
Yes	26	13	9	2
No	136	83	79	18
χ^2	0.295		0.001	
p	0.587		0.976	
Wheeze +cold				
Yes	37	15	28	2
No	125	81	60	18
χ^2	1.950		0.867	
p	0.163		0.049	
Wheeze apart from cold				
Yes	31	10	24	2
No	130	86	64	18
χ^2	4.104		2.660	
p	0.128		0.103	
Wheeze most days +nights				
Yes	24	7	20	2
No	138	88	67	17
χ^2	3.130		1.473	
p	0.077		0.225	

Table A. 3 Percentages of respondents with "yes" or "no" answers to health variables against their cooking practices in exposed and reference communities.

Health variable	Cooks with Firewood			
	Exposed		Reference	
Dyspnoea +Wheeze	Yes	No	Yes	No
Yes	19	8	17	1
No	142	88	71	19
χ^2	0.769		2.405	
p	0.380		0.121	
≥2 Episodes of dyspnoea				
Yes	18	6	17	0
No	142	89	70	20
χ^2	1.702		4.646	
p	0.192		0.031	
Dyspnoea requiring therapy				
Yes	18	6	18	1
No	141	89	69	19
χ^2	2.936		2.741	
p	0.230		0.098	
Dyspnoea up slight hill				
Yes	30	14	26	4
No	131	82	62	16
χ^2	0.1291		0.740	
p	0.524		0.390	
Slower than peers due to dyspnoea				
Yes	26	13	24	5
No	136	83	63	15
χ^2	0.295		0.055	
p	0.587		0.814	
Dyspnoea on level surface				
Yes	24	9	21	5
No	138	86	67	15
χ^2	1.526		0.012	
p	0.217		0.915	
Dyspnoea with mild exercise				
Yes	17	8	21	2

No	144	87	67	18
χ^2	0.310		1.869	
p	0.578		0.172	
Health variable	Cooks with firewood			
	Exposed		Reference	
Disabling dyspnoea	Yes	No	Yes	No
Yes	12	7	13	5
No	147	87	75	15
χ^2	0.001		1.227	
p	0.977		0.268	
Work stopped due chest illness				
Yes	27	13	16	3
No	134	80	72	17
χ^2	0.346		0.114	
p	0.556		0.736	
Phlegm with chest illness				
Yes	18	10	7	0
No	139	84	72	20
χ^2	0.041		1.701	
p	0.840		0.192	
Attack of bronchitis				
Yes	13	7	3	0
No	147	87	85	19
χ^2	0.038		0.666	
p	0.846		0.414	
Constant dizziness				
Yes	31	9	8	0
No	113	80	78	20
χ^2	5.041		2.012	
p	0.025		0.156	

Health variable	Cooks with kerosene			
	Exposed		Reference	
Cold sore/fever blisters	Yes		No	
Yes	48	50	8	26
No	87	73	20	54
χ^2	0.709		0.148	
p	0.400		0.70	
Regular cough				
Yes	59	50	14	37
No	76	73	14	43
χ^2	0.709		0.117	
p	0.400		0.700	
Cough about 4-6X/day>7days				
Yes	47	37	6	16
No	88	85	22	64
χ^2	1.688		0.872	
p	0.430		0.026	
Cough on waking up				
Yes	36	31	3	14
No	99	92	25	66
χ^2	0.072		0.720	
p	0.789		0.396	
Cough day/night				
Yes	39	31	6	14
No	96	92	22	66
χ^2	0.442		0.212	
p	0.506		0.645	
Cough +phlegm in the morning				
Yes	39	25	5	21
No	96	97	23	59
χ^2	2.416		0.799	
p	0.120		0.371	
Cough +phlegm all day				
Yes	35	24	4	18
No	100	99	24	62
χ^2	1.501		0.863	
p	0.221		0.353	

Table A. 4 Percentages of respondents with "yes" or "no" answers to health variables against their cooking practices in exposed and reference communities.

Health variable	Cooks with kerosene			
	Exposed		Reference	
Cough +phlegm >3weeks	Yes	No	Yes	No
Yes	23	16	3	8
No	112	107	25	72
χ^2	0.814		0.012	
p	0.367		0.914	
Wheeze with cold				
Yes	23	29	8	19
No	112	94	20	61
χ^2	1.711		0.012	
p	0.191		0.913	
Wheeze apart from cold				
Yes	17	24	7	19
No	117	99	21	61
χ^2	3.144		0.018	
p	0.078		0.894	
Wheeze most days/nights				
Yes	16	15	3	19
No	119	107	24	60
χ^2	0.012		2.048	
p	0.913		0.152	
Wheeze +dyspnoea				
Yes	12	15	1	17
No	122	108	27	63
χ^2	0.716		4.667	
p	0.397		0.031	
≥2 attacks of dyspnoea/year				
Yes	11	13	1	16
No	121	110	27	63
χ^2	0.373		4.305	
p	0.541		0.038	
Dyspnoea required therapy				
Yes	11	13	3	16
No	123	107	25	63
χ^2	2.723		1.288	
p	0.256		0.256	

Table A. 5 Percentages of respondents with "yes" or "no" answers to health variables against their cooking practices in exposed and reference communities

Health Variable	Cooks with Kerosene			
	Exposed		Reference	
Dyspnoea up slight hill	Yes	No	Yes	No
Yes	24	20	5	25
No	111	102	23	55
χ^2	1.188		1.854	
p	0.552		0.173	
Slower than peers due to dyspnoea				
Yes	16	23	6	23
No	119	100	22	56
χ^2	2.352		0.618	
p	0.125		0.432	
Dyspnoea on level surface				
Yes	15	18	5	21
No	119	105	23	59
χ^2	0.678		0.799	
p	0.410		0.371	
Dyspnoea with little exercise				
Yes	10	15	3	20
No	123	108	25	60
χ^2	1.586		2.525	
p	0.208		0.112	
Disabling dyspnoea				
Yes	12	7	4	14
No	121	113	24	66
χ^2	0.924		0.154	
p	0.336		0.694	
Chest illness stopping work				
Yes	19	21	3	16
No	112	102	25	64
χ^2	0.316		1.234	
p	0.574		0.267	
Phlegm with chest illness				
Yes	15	13	1	6

No	117	106	27	74
χ^2	0.012		0.528	
p	0.912		0.467	

Table A. 6 Percentages of respondents with "yes" or "no" answers to health variables against their cooking practices in exposed and reference communities

Health Variable	Cooks with kerosene			
	Exposed		Reference	
Attack of bronchitis	Yes	No	Yes	No
Yes	9	11	0	3
No	124	110	28	76
χ^2	0.472		1.094	
p	0.492		0.296	
Constant dizziness				
Yes	17	23	1	7
No	105	88	27	71
χ^2	1.882		0.862	
p	0.170		0.353	

A.1 Study Information sheet

A Health Risk Assessment of the Petroleum Industry in the Niger Delta.

The purpose of this document is to provide you with the information you may find useful in making a decision to volunteer as a participant in this study. Should you have need still for any more information, please contact one of the investigators on the telephone numbers provided below.

Introduction

The Niger Delta of Nigeria has been described as one of the most petroleum polluted places in the world. There are reports of more than 6800 oil spillages spanning more than 50 years of petroleum exploration and production in the area. In addition to the

spillages, for a long time, there was unregulated discharge of petroleum industry wastes, gas flaring, and other activities likely to cause harm close to the places people live in the area. Some members of the communities have been involved in clean up of petroleum spillages, sometimes without adequate protection equipments.

The recent environmental assessment by United Nations Environment Programme (UNEP) in Ogoniland confirmed the widespread nature of pollution of the environment in the area, but has very little information in an organised way about the potential health effects of these pollutions. This could be a cause of fear and frustration.

This study will look at residents and members of the host communities living in close proximity to, and most likely to be affected by the effects of oil spillages and petroleum derived wastes through their food, water and air. It will look at those who may have been involved in clean up of oil spillages, but are not employed directly by the oil companies, and the kind of equipment used for the job to understand if this has any effects on their health. The study will seek to find out how the health of these people compares with the health of members of another community that do not have any petroleum industry operations or oil spillages close to them. It is expected that this research will identify if these types of exposure lead to some health problems, and what those problems could be. This will be done carefully and scientifically, so that it will provide valid and important data on health and probably inform policy decisions on health services in the area. The findings will also provide the community and residents with vital knowledge that may shape future response to incidences, including a change of attitudes and mindsets.

Recruitment Criteria

Every resident of the community over 18 years of age who is a non-smoker, is eligible to participate in this study. You will be expected to have lived in the study area for at least 5 years, in the last 10 years, or to have spent cumulatively at 5 years of residence in the last 10 years in the study area, or to have been involved in the clean-up of petroleum spillage or similar incidences. Pregnant women, workers in the oil and gas industry, and children under the age of 18 years will not be included in the present study.

What you will be required to do

If you decide to take part in this study, you will be asked to do the following:

Before the start of the study, you will be asked to sign a consent form to indicate that you have chosen to take part in the study of your own free will, and that you understand that you can withdraw from the study at any time without your rights being affected. Then you will have some questions asked about you, including your age, where you live, the kind of work you do, your diet, and other personal information.

Some measurements will be made of you, including your height, weight, waist measure, heart rate and blood pressure. A medical person may examine your mouth and skin to check for any signs that may suggest any ill health.

You will be asked to provide a sample of urine and to have a little blood taken from your body to be tested in the laboratory.

The results of some of the tests will be made available to the study's subjects, understanding that no interpretation is possible by the study's investigators. However, all results of the tests will be reviewed by a qualified medical practitioner who may want to contact you at a later date.

Potential Benefits

All study participants may benefit from the positive feeling associated with participating in a study of the community health effects associated with the upstream petroleum industry and oil spillages in the Niger Delta. Added to this, the knowledge gained from the study may affect the way business is carried out in the future, and help improve the quality of life of future generations.

Potential Risks

The procedures and questionnaire used for this study present minimal risks to the study participants. The questionnaire is of the type commonly used in studies of this nature, and proven to cause only mild and temporary discomfort, including answering questions that touch on sensitive health topics and some personal experiences that are uncomfortable to talk about. The volunteer is, however, free not to talk about any experience they find uncomfortable, and to end the interview at any time. There may

also be temporary discomfort from the process used for drawing blood, and pain from the needle. No adverse effect is expected from the volume of blood to be drawn.

Confidentiality

The information you provide, and all the other personal information about you shall be used only for research purposes, and your personal information and data from our measurements and tests shall not be traceable to you. Random volunteer numbers are used to identify all persons in a way that protects your privacy, and no personal information from you will be passed to a third party. The results obtained from this study shall form part of Emmanuel Amadi's PhD at Cranfield University, and may be published in peer-reviewed journals.

Contact details of investigators

C.E.Amadi

Dr T.P. Brown

081 6535 8080

+441234 758279

Email: c.e.amadi@cranfield.ac.uk

t.p.brown@cranfield.ac.uk

Dr C. C. Obiorah

Prof. O.E. Orisakwe

07030473512

08068533281

Christopherobiorah@yahoo.com

eorish@yahoo.com

A.2 INVITATION TO PARTICIPATE IN STUDY

Dear Resident,

This letter is an invitation to participate in a research study on the potential short-term and long-term health effects associated with the activities of the petroleum industries in the Niger Delta. We are studying how oil spillages, gas flaring and venting, and the management of other wastes associated with oil exploration and production may be affecting the health of residents of communities like the one you live in.

This study will give you the opportunity to share your experiences. Much can be learned by comparing the health of residents in communities like yours with that of other communities that are without oil industries operations in them.

Participation is voluntary. There is no penalty for not participating.

If you agree to participate, we will come to your house or your cottage hospital to ask you questions about your health, your usual work, your family, and activities relating to clean-up of oil spillages. Additionally, clinical measurements including your blood pressure, heart rate, weight and height will be taken. You will also be required to provide a sample of blood and urine for analysis in the laboratory. This process will take about 30 minutes to 40 minutes, and only one visit is required.

Your help is extremely important to the success of this study and the understanding of how the health of residents of communities that are hosts to the petroleum industries in the Niger Delta may be affected by their activities.

The information you share will be kept private, and none of your measurements will be traceable to you, since all samples and measurements, including the questionnaire

are labeled with special code number instead of your name. The enclosed study information sheet gives more details about the study.

If you have any further questions, you can contact the investigators at the phone numbers given below.

C.E .Amadi

081 6535 8080

Email: c.e.amadi@cranfield.ac.uk

Dr C. C. Obiorah

07030473512

Christopherobiorah@yahoo.com

Dr T.P. Brown

+441234 758279

t.p.brown@cranfield.ac.uk

Prof. O.E. Orisakwe

08068533281

eorish@yahoo.com

A.3 INFORMED CONSENT FORM

Volunteer Identification Number for this study:

Title of Project: *A Health Risk Assessment of the Petroleum Industry in the Niger Delta*

Name of Researcher: *C.E. AMADI*

(Please tick box)

1. I confirm that I have read and understood the information sheet that has been provided for the study named above. I can confirm that I have been given opportunity to ask questions regarding the study, and that they have been answered to my satisfaction. ☐
2. I understand that my participation in this study is entirely voluntary, and I am free to withdraw from the study at any time without giving any reason. ☐
3. I understand that data (results) acquired during this study may be looked at by authorized individuals (project supervisors) from Cranfield University and their collaborators from University of Port Harcourt but will not be traceable to me and may be used in a peer-reviewed article. I give my consent for these individuals to access my data. ☐

4. I agree to take part in the above-mentioned study.



.....
.....
Name of volunteer Date Signature

.....
.....
Researcher Date Signature

Email: c.e.amadi@cranfield.ac.uk

Email : t.p.brown@cranfield.ac.uk

Email : christopherobiorah@yahoo.com

Email: eorish@yahoo.com

A.4 STUDY QUESTIONNAIRE

A Health Risk Assessment of the Petroleum Industry in the Niger Delta. Study Questionnaire

By C.E. Amadi

Supervisor: Dr T.P. Brown¹.

Collaborators: Dr C.C. Obiorah²

Prof. O.E. Orisakwe³

¹ Lecturer, Cranfield Health, Cranfield University, Cranfield, Bedfordshire, MK43 0AL

² Department of Morbid Anatomy, University of Port Harcourt Teaching Hospital, Port Harcourt, Rivers State.

³ Faculty of Pharmacy, University of Port Harcourt, Rivers State.

DEMOGRAPHIC INFORMATION

NAME OF COMMUNITY

PARTICIPANT'S IDENTIFICATION NUMBER:

DATE:

HEIGHT (centimetres {cm})

.

WEIGHT (Kg)

.

WAIST CIRCUMFERENCE (cm)

.

BLOOD PRESSURE

./.

PULSE RATE

ACCOMODATION

HAVE YOU ALWAYS LIVED AT THIS ADDRESS?

☐ Yes ☐ No

IF YES, HOW LONG?

.

IF NO, WHERE DID YOU LIVE BEFORE MOVING TO THIS ADDRESS?

HOW LONG DID YOU LIVE AT THAT ADDRESS?

HOW MANY ROOMS ARE THERE IN THIS HOUSE?

F HOW MANY PEOPLE LIVE IN THIS ACCOMODATION?

COOKING PRACTICES

WHERE IS THE KITCHEN IN THIS HOUSE?

DO YOU COOK WITH a. FIREWOOD

☐ Yes☐ No

b. KEROSENE

☐ Yes☐ No

c. SAW DUST

☐ Yes☐ No

d. GAS

☐ Yes☐ No

DO PEOPLE INSIDE THIS HOUSE COMPLAIN OF SMOKE FROM THE

KITCHEN? ☐ Yes ☐ No

HOW OFTEN?

PASSIVE SMOKING IN THE HOUSE

DOES ANYBODY WHO LIVES OR COMES HERE SMOKE CIGARETTES,

CIGARS OR PIPES IN THIS HOUSE? ☐ Yes ☐ No

HOW MANY PEOPLE SMOKE IN YOUR HOUSEHOLD? ☐

HOW MANY CIGARETTES ON THE AVERAGE ARE SMOKED INSIDE THIS

HOUSE IN A DAY? ☐

DOES ANYONE HERE USE SNUFF? ☐ Yes ☐ No

IF YES, WHO AND HOW OFTEN? ☐

AT YOUR WORK OR BUSINESS, DOES ANYONE SMOKE AROUND YOU SO

THAT YOU CAN SMELL THE SMOKE? ☐ Yes ☐ No

DID YOU EVER SMOKE OR USE SNUFF? ☐ Yes ☐ No

IF YES, WHEN DID YOU START, AND WHEN DID YOU STOP?

(ONLY 2 YEARS AND OVER SINCE CESSATION IS RELEVANT).

ALCOHOL CONSUMPTION

DO YOU DRINK ALCOHOL MORE REGULARLY THAN JUST ON FESTIVE

OCCASIONS SUCH AS CHRISTMAS, WEDDINGS ETC? ☐ Yes ☐ No

IF YES, PLEASE TELL ME HOW OFTEN?

RARELY
ABOUT ONCE EVERY 3-4MONTHS
ABOUT ONCE EVERY 2 WEEKS
SEVERAL TIMES A WEEK

AT WHAT AGE DID YOU START DRINKING?

ON AVERAGE HOW MUCH DO YOU DRINK A WEEK?

OCCUPATIONAL HISTORY

PLEASE TELL ME THE TYPE OF JOB YOU DO, INCLUDING THOSE YOU DO ON PART TIME BASIS.

DO YOU FARM? ☐ Yes ☐ No

DO YOU USE ANY CHEMICALS SUCH AS DDT, LINDANE AND OR THE LIKE TO CONTROL WEEDS, OR INSECTS, OR ANY OTHER PESTS ON YOUR

FARM? ☐ Yes ☐ No

DO YOU WORK AS A COMMERCIAL FISHERMAN, EITHER PART-TIME OR

FULL-TIME, OR SEASONALLY? ☐ Yes ☐ No

HAVE YOU EVER STOPPED FISHING DUE TO OIL SPILLAGE, OR DUE TO

FISH DYING IN THE WATER? ☐ Yes ☐ No

HAVE YOU EVER USED CHEMICALS SUCH AS DDT, LINDANE, OR

SIMILAR CHEMICALS TO KILL FISH? ☐ Yes ☐ No

HAVE YOU EVER BROUGHT FISH HOME FOR YOUR YOURSELF AND
FAMILY, OR SOLD FISH THAT WAS FOUND DEAD IN THE WATER?

☐ Yes ☐ No

DO YOU GATHER SNAILS, OR CRABS, PERIWINKLES, COCKLES ETC

FROM THE AREA? ☐ Yes ☐ No

DO YOU USE ANY OF THE ABOVE (H) AS FOOD IN YOUR HOUSEHOLD?

☐ Yes ☐ No

DO YOU EAT SMOKED FISH OR MEAT REGULARLY IN YOUR MENU

☐ Yes ☐ No ? WHAT ABOUT SUYA? ☐ Yes ☐ No

WHAT IS THE USUAL SOURCE OF DRINKING WATER FOR YOUR
HOUSEHOLD?

WHAT ABOUT FOR COOKING AND BATHING?

DO YOU GO SWIMMING IN THE LOCAL STREAMS/RIVER?

☐

Yes

☐

No

WHERE DO YOU GET WATER FOR WASHING CLOTHES AND KITCHEN
UTENSILS?

PERSONAL HEALTH

ARE YOU CURRENTLY USING ANY MEDICINE FOR ANY REASON?

☐ Yes

☐ No

(Please collect your medication so that I can see what you are taking and record it)

ARE THERE ANY OTHER MEDICATIONS (INCLUDING HERBAL

PREPARATIONS) THAT YOU ARE TAKING? ☐ Yes ☐ No

(Record reported medicine name/condition)

WERE YOU GIVEN THE(SE) MEDICINE(S) BY A DOCTOR OR CHEMIST

AFTER CHECKING YOU? ☐ Yes ☐ No

WHAT DID YOU COMPLAIN ABOUT THAT MADE THEM GIVE YOU THIS
MEDICATION?

THE FOLLOWING QUESTIONS ARE ABOUT COLDS AND CATARRH AND
COUGHS

DURING THE PAST ONE YEAR HAVE HAD COLD OR CATARRH OR

STUFFY NOSE? ☐ Yes ☐ No HOW MANY EPISODES? ☐

WHAT ABOUT COLD SORES OR FEVER BLISTERS ON YOUR LIPS?

☐ Yes ☐ No HAVE MANY EPISODES? ☐

DO YOU USUALLY HAVE A COUGH? ☐ Yes ☐ No

DO YOU USUALLY COUGH AS MUCH AS 4-6X A DAY, 4 OR MORE DAYS A

WEEK? ☐ Yes ☐ No

DO YOU USUALLY COUGH AT ALL ON GETTING UP OR FIRST THING IN

THE MORNING? ☐ Yes ☐ No

DO YOU USUALLY COUGH AT ALL DURING THE REST OF THE DAY OR

AT NIGHT? FOR HOW LONG HAVE HAD THIS COUGH?

☐ Yes

☐ No

DO YOU USUALLY BRING UP PHLEGM AT ALL ON GETTING UP OR FIRST

THING IN THE MORNING?

☐ Yes

☐ No

DO YOU USUALLY BRING UP PHLEGM AT ALL DURING THE REST OF THE
DAY OR AT NIGHT? HOW LONG HAVE YOU HAD PROBLEM WITH

PHLEGM?

☐ Yes

☐ No

HAVE YOU HAD PERIODS OR EPISODES OF COUGH AND PHLEGM

LASTING AT LEAST 3WEEKS OR MORE EACH YEAR?

☐ Yes

☐ No

FOR HOW LONG HAVE YOU HAD AT LEAST ONE SUCH EPISODE PER
YEAR? ☐

DOES YOUR CHEST EVER SOUND WHEEZY OR WHISTLING WHEN YOU
HAVE A COLD? ☐ Yes ☐ No

DOES YOUR CHEST EVER SOUND WHEEZY OR WHISTLING
OCCASIONALLY APART FROM COLD? ☐ Yes ☐ No

DOES YOUR CHEST SOUND WHEEZY OR WHISTLING MOST DAYS OR
NIGHTS? ☐ Yes ☐ No

FOR HOW LONG HAS THIS BEEN? ☐

HAVE YOU HAD AN “ATTACK” OF WHEEZING THAT MADE YOU FEEL
SHORT OF BREATH? ☐ Yes ☐ No

HOW OLD WERE YOU WHEN YOU HAD YOUR FIRST ATTACK?

HAVE YOU HAD 2 OR MORE SUCH EPISODES?

☐ Yes☐ No

HAVE YOU EVER REQUIRED MEDICINE OR TREATMENT FOR THESE
ATTACKS? ☐ Yes ☐ No

IN THE PAST YEAR, HOW MANY ATTACKS HAVE YOU HAD?

DO YOU HAVE SHORTNESS OF BREATH WHEN HURRYING ON A LEVEL
SURFACE OR WALKING UP A SLIGHT HILL? ☐ Yes ☐ No

DO YOU EVER HAVE WALK SLOWER THAN PEOPLE OF YOUR AGE ON A

LEVEL SURFACE BECAUSE OF BREATHLESSNESS?

☐ Yes

☐ No

DO YOU EVER HAVE TO STOP FOR BREATH WHEN WALKING AT YOUR

PACE ON A LEVEL SURFACE?

☐ Yes ☐ No

DO YOU EVER HAVE TO STOP FRO BREATH AFTER WALKING ABOUT 100

YARDS OR AFTER A FEW MINUTES ON A LEVE SURFACE?

☐ Yes

☐ No

ARE YOU TOO BREATHLESS TO LEAVE THE HOUSE OR DO YOU GET

BREATHLES WHEN DRESSING OR UNDRESSING?

☐ Yes

☐ No

HOW LONG HAVE YOU HAD TROUBLE WITH BREATHLESSNESS?

☐

DURING THE PAST YEAR, HAVE HAD ANY CHEST ILLNESS THAT KEPT

YOU OFF WORK, INDOORS AT HOME OR IN BED?

☐ Yes☐ No

DID YOU PRODUCE PHLEGM WITH THE CHEST ILLNESS? ☐ Yes

☐ No

HOW MANY SUCH ILLNESSES WHERE YOU HAD INCREASED PHLEGM
HAVE YOU HAD THAT LASTED A WEEK OR MORE IN THE LAST YEAR?

☐

DID YOU HAVE A LUNG PROBLEM BEFORE THE AGE OF 16 YEARS?

☐ Yes

☐ No

HAVE YOU EVER HAD ATTACKS OF BRONCHITIS?

☐ Yes

☐ No

WAS IT CONFIRMED BY A DOCTOR?

☐ Yes

☐ No

AT WHAT AGE WAS THIS ATTACK?

ARE YOU STILL SEEING A

DOCTOR FOR THIS CONDITION?

☐ Yes

☐ No

WHAT ABOUT PNEUMONIA?

☐ Yes

☐ No

HAVE YOU EVER HAD ANY OTHER CHEST ILLNESS?

☐ Yes

☐ No

PLEASE SPECIFY.

WHAT ABOUT SINUSITIS OR SINUS PROBLEM?

☐ Yes

☐ No

WHAT ABOUT CONSTANT DIZZINESS?

☐ Yes

☐ No

HAVE YOU HAD ANY OTHER HEALTH PROBLEM THAT WE DID NOT DISCUSS?

FAMILY MEDICAL HISTORY

THESE NEXT QUESTIONS ARE ABOUT YOUR FAMILY, THAT IS THOSE RELATED TO YOU BY BLOOD, INCLUDING YOYR FATHER, MOTHER, BROTHERS AND HALF-BROTHERS, SISTERS AND HALF-SISTERS, BUT NOT YOUR INLAWS AND WIFE.

HOW MANY BROTHERS DO YOU HAVE, INCLUDING THOSE THAT ARE DECEASED?

AND HOW MANY SISTERS?

HAS ANY MEMBER OF YOUR FAMILY EVER BEEN TOLD THEY HAVE ASTHMA BY A DOCTOR? ☐ Yes ☐ No IF YES, WHICH RELATIVE?

WHAT ABOUT CHRONIC LUNG CONDITION SUCH AS CHRONIC BRONCHITIS OR EMPHYSEMA? ☐ Yes ☐ No IF YES, WHICH RELATIVE?

WHAT ABOUT HYPERTENSION OR HIGH BLOOD PRESSURE? ☐ Yes

☐ No

WHAT ABOUT HEART ATTACK? ☐ Yes ☐ No

WHAT ABOUT STROKE OR BRAIN ATTACK? ☐ Yes ☐ No

WHAT ABOUT DIABETES OR HIGH BLOOD SUGAR? ☐ Yes

☐ No

WHAT ABOUT CANCER? ☐ Yes ☐ No IF YES, PLEASE TELL

ME WHICH RELATION AND THE TYPE OF CANCER.

WHAT ABOUT RHEMATOID AND OSTEO ARTHRITIS?

☐

Yes

☐

No

OIL SPILL CLEAN-UP RELATED TASKS

HAVE YOU EVER BEEN INVOLVED IN THE CLEAN-UP OF OIL SPILLAGE?

☐ Yes

☐ No

IF YES, WHEN?

☐☐☐☐

COULD YOU TELL ME WHAT HAPPENED, AND THE ROLE YOU PLAYED?

DID YOU USE GLOVES OR ANY OTHER PROTECTIVE COVERS WHEN YOU

DID THIS JOB?

☐ Yes

☐ No

HOW OFTEN DID YOUR BODY OR ANY CLOTHES YOU WORE BECOME

WET OIL OR CHEMICAL DURING THIS JOB?

☐

WHAT ABOUT YOUR SHOES OR YOUR LEGS?

☐

DID YOU NEED TO BURN THE OIL AS PART OF THE CLEAN-UP ACTIVITY?

☐ Yes

☐ No

IF YES, WOULD SAY YOU INHALED THE SMOKE FROM THE BURNING

OIL? ☐ Yes ☐ No

**FOR CONFIDENTIALITY, THIS PAGE WILL BE STORED
DIFFERNTLY FROM YOUR RESPONSE TO THIS SURVEY.**

SURNAME

FIRST NAME

DATE OF BIRTH

SEX

ADDRESS: