Greenpeace Research Laboratories, University of Exeter, UK

NMVOC characterisation and exposure risk in two oil and gas producing regions

1 INTRODUCTION

- Oil industry operations often occur in close proximity to populated areas.
- Many oil production sites are sources of health-relevant air pollutants.
- Emission sources include from vehicles, equipment, leaks, vents and flares.
- Iraq and Nigeria are among the world's largest flaring countries.
- Settlements often lie adjacent to oil production sites.
- The number of people living within 5 km of a flare is estimated to be:
  - 3.0 million in Iraq and,
  - 2.5 million in Nigeria (Binietoglou et al 2023).
- Living near oil industry facilities in these regions has been associated with adverse health impacts including cancers (Onyije et al 2021) and childhood respiratory illness, fever, and low weight (Almi and Gibson 2022).
- Air quality data are severely lacking in the study regions.
- Security and logistical limitations make monitoring for air pollutants difficult.
- Yet, these regions are home to large populations who are potentially affected by oil industry emissions, and other air pollutant sources.
- This work presents;
  - The results of field studies which measured concentrations of a range of VOC species in southern Iraq during summer 2021 and winter 2022, and in the Niger Delta during December 2023.
  - An assessment of exposure risk using satellite observations of oil and gas flaring, combined with local population data in Nigeria.

Nigeria 2023

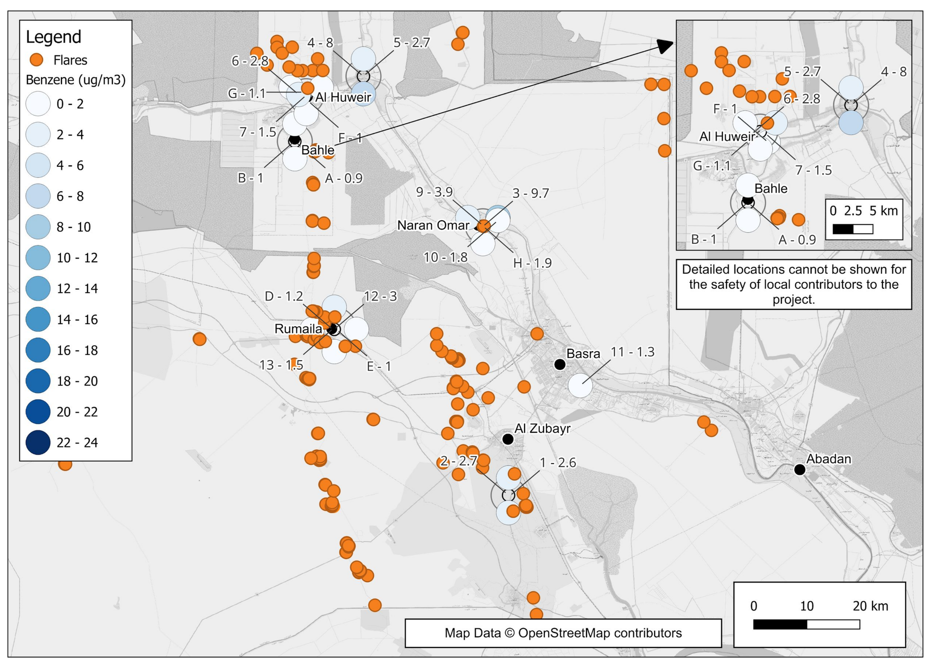
2 FIELD AND LABORATORY METHODS

- Thermal desorption tubes were used to sample ambient air.
- Sampling locations were between 100 m and 10 km of oil and gas industry sites where active flares could be observed.
- Iraq: 41 diffusive samples from 20 locations, each exposed for two weeks during two field campaigns (summer or winter).
- Nigeria: nine hand-pumped five-litre samples from three locations during one field campaign.
- VOCs collected on the sorbent tubes were analysed using gas chromatography-mass spectrometry (GC-MS).

3 RESULTS

- A diversity of VOCs species were identified in samples from Iraq and Nigeria.
- In Iraq
  - benzene concentrations from the 2-week diffusive samples were between 0.9 - 9.7 µg/m^3.
  - the highest recorded VOC concentrations were at residential locations ~100 m from active flares.
- In Nigeria
  - benzene concentrations in the 5-litre samples were between 0.6 - 22.5 µg/m^3
  - the highest VOC concentrations were in built-up environments and at locations adjacent to oil industry sites.

Southern Iraq

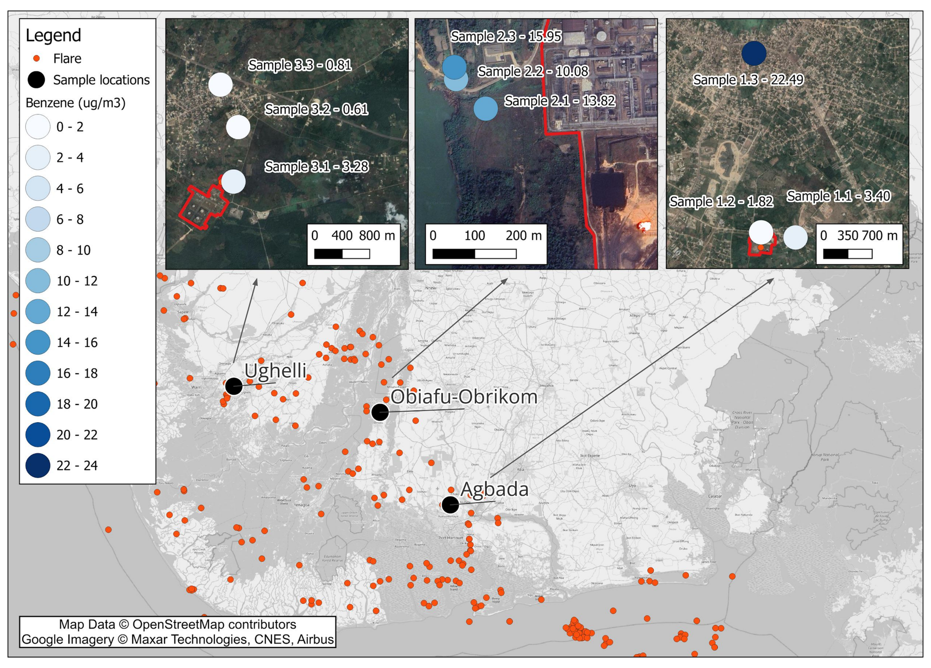


Sample site	Benzene	Toluene	Ethyl benzene	m&p-Xylene	o- Xylene
Summer 2021					
A	0.9	3.8	1.3	3.8	1.4
B	1.0	3.3	1.0	3.1	1.4
C	Lost	Lost	Lost	Lost	Lost
D	1.2	5.0	1.4	4.2	2.2
E	1.0	3.0	1.4	4.4	2.1
F	1.0	1.9	1.0	3.0	1.1
G	1.1	2.4	2.4	2.4	2.4
H	1.9	6.9	1.9	6.6	2.8
Winter 2022					
1	2.6	3.0	0.6	1.1	0.6
2	2.7	4.2	0.9	2.1	1.0
3	9.7	22.3	3.8	12.7	5.0
4	8.0	17.4	3.7	11.5	5.3
5	2.7	6.0	1.6	4.4	1.9
6	2.8	5.5	1.2	1.2	0.6
7	1.5	2.3	0.2	0.1	0.2
8	Lost	Lost	Lost	Lost	Lost
9	3.9	3.3	0.3	0.6	0.4
10	1.8	2.3	0.3	0.7	0.4
11	1.3	4.3	2.0	6.9	2.8
12	3.0	6.6	1.8	4.9	2.4
13	1.5	5.1	2.1	6.7	3.0
µg/m3					

Map: Sampling locations, benzene results and flare sites.

Table: 2-week diffusive sample results for sampling locations

Niger Delta



Site name	Sample site	Benzene	Toluene	Ethyl benzene	m&p-Xylene	O-Xylene
Agbada	1.1	3.4	7.2	1.6	2.5	1.1
Agbada	1.2	1.8	4.5	1.8	4.0	1.7
Agbada	1.3	22.5	72.0	17.1	26.4	11.4
Obiafu-Obrikom	2.1	13.8	24.9	3.0	8.7	3.3
Obiafu-Obrikom	2.2	10.1	15.4	1.9	5.9	2.4
Obiafu-Obrikom	2.3	16.0	30.9	2.6	6.7	2.1
Ughelli	3.1	3.3	5.2	0.6	0.7	0.2
Ughelli	3.2	0.6	0.7	0.1	0.1	<0.06
Ughelli	3.3	0.8	1.7	0.3	0.3	0.1
µg/m3						

Table: 5-litre pumped sample results

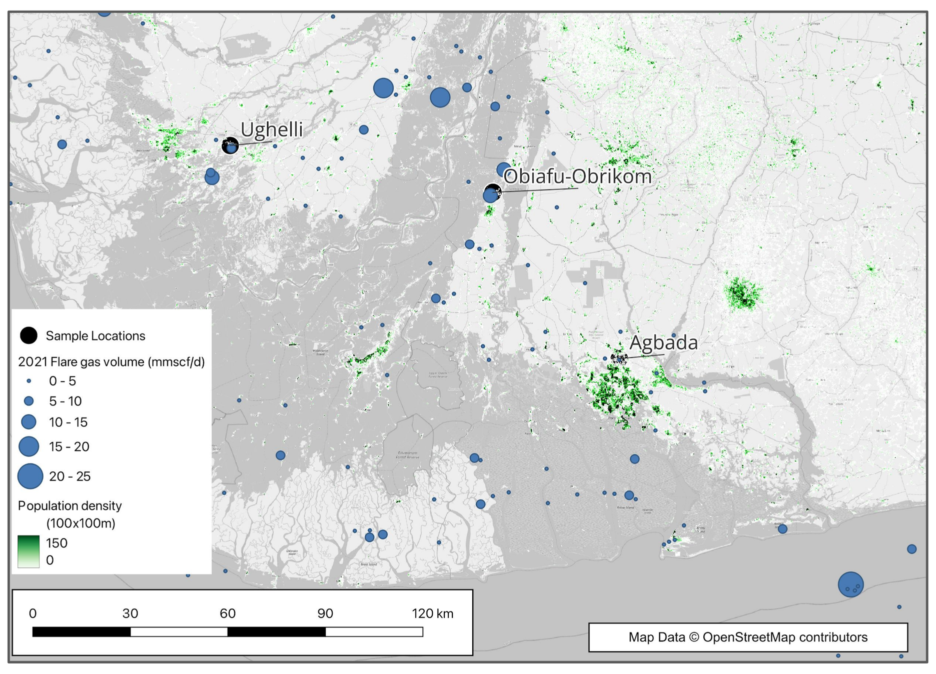
Map: Sampling locations, benzene results and flare sites.

4 EXPOSURE RISK ANALYSIS

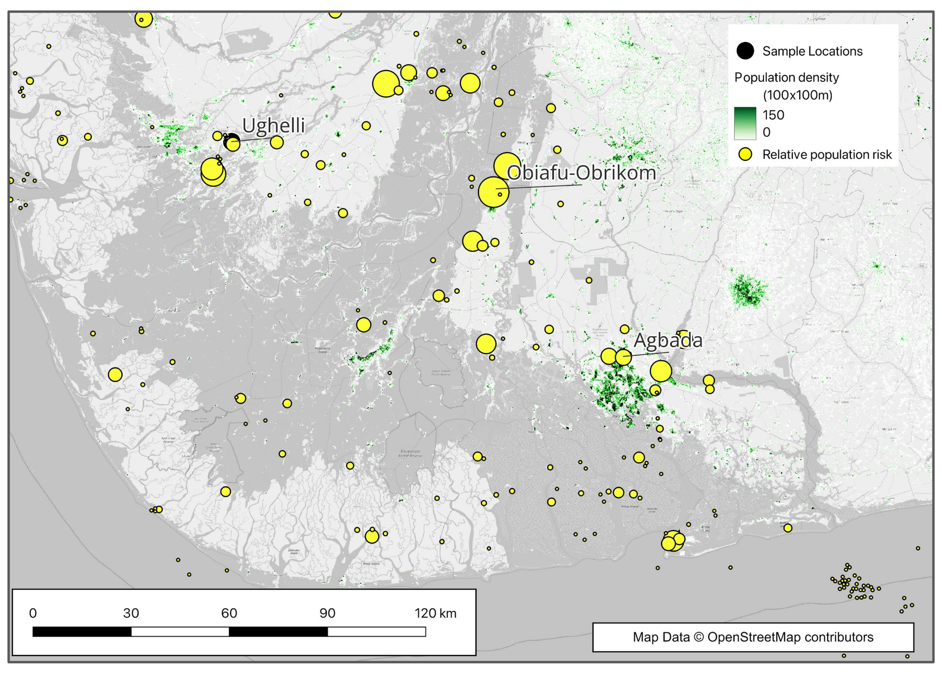
- Satellite derived estimates of annual gas flare volume from the Earth Observation Group, Payne Institute for Public Policy, Colorado School of Mines (Zhizhin et al 2021, Elvidge et al 2016, Elvidge et al 2013) were combined with gridded population estimates (WorldPop and National Population Commission of Nigeria 2021, WorldPop, 2018) to identify locations where populations exposure to VOCs associated with oil and gas production could be greatest.
- A index is used to indicate which flares have greatest potential for population exposure.
- The index relates gas flare volume, f, and the population, p, within increasing radii of the flare site (r = 100 m, 500 m, 1 km, 2 km, 3 km).

$$Index = \Sigma(f.p\,(\tfrac{1}{r^2}))$$

- Combining local population distributions, with data on the volume of gas flared, can help identify locations where risks are greatest. Sites with large nearby populations could be important for exposure, even if the nearby flares are not the largest in the region.



Map: Sampling locations (black), 2021 estimated flare gas volume (blue), population density (green)



Map: Sampling locations (black), 2021 population risk index (yellow), population density (green)

5 CONCLUSIONS

The results of field studies which investigated VOC concentrations in southern Iraq and the Niger Delta during 2021, 2022 and 2023 are presented.

- Community VOC measurements can improve understanding of VOC exposure especially in locations where there are no established air quality monitoring efforts.
- Many different sources, including, but not limited to oil industry activities are likely to contribute to atmospheric VOC loading.
- Analysis of satellite derived gas flare volumes and population data can indicate at risk populations.
- Measured concentrations of health-relevant VOC species provide evidence that populations may be exposed to non-negligible health risks from ambient air pollution in these oil producing regions, adding further to risks relating to other, non-VOC air pollutants.
- Longer-term monitoring of VOC species in the study regions are needed to assess sources and potential health risks in greater detail.

Iraq 2021

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