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# Health Impacts of Natural Gas Flaring

## A Literature Review of Nigeria, Iraq, and Brazil

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**Health Impacts of Natural Gas Flaring: A Literature Review of Nigeria, Iraq, and Brazil**

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# Acronyms

| | |
|---|---|
| **BC** | Black carbon |
| **BMI** | Body mass index |
| **BCM** | Billion cubic meters |
| **CO** | Carbon monoxide |
| **$CO_2$** | Carbon dioxide |
| **$CO_2e$** | Carbon dioxide equivalent |
| **COP** | Conference of the Parties |
| **DBP** | Diastolic blood pressure |
| **DHS** | Demographic Health Survey |
| **EPA** | Environmental Protection Agency |
| **GHG** | Greenhouse gas |
| **Hb** | Hemoglobin |
| **$H_2S$** | Hydrogen sulfide |
| **ILCR** | Incremental Lifetime Cancer Risk |
| **LGA** | Local Government Area |
| **MDA** | Malondialdehyde |
| **$NH_3$** | Ammonia |
| **$NO_2$** | Nitrogen dioxide |
| **$NO_x$** | Nitrogen oxides |
| **NMVOCs** | Non-Methane Volatile Organic Compounds |
| **OGI** | Optical Gas Imaging |
| **PAHs** | Polycyclic Aromatic Hydrocarbons |
| **PEFR** | Peak Expiratory Flow Rate |
| **PM** | Particulate matter |
| **$PM_{0.1}$** | Ultrafine particulate matter |
| **$PM_{10}$** | Particulate matter ≤10 µm |
| **$PM_{2.5}$** | Particulate matter ≤2.5 µm |
| **RBC** | Red blood cells |
| **SAH** | Systemic arterial hypertension |
| **SBP** | Systolic blood pressure |
| **SCAR** | Social cost of atmospheric release |
| **$SO_2$** | Sulfur dioxide |
| **$SO_x$** | Sulfur oxides |
| **TVOCs** | Total Volatile Organic Compounds |
| **UN** | United Nations |
| **VOCs** | Volatile Organic Compounds |
| **WHO** | World Health Organization |
| **ZRF** | Zero Routine Flaring |

# Foreword

Gas flaring and venting—the burning or release of natural gas associated with oil production—is responsible for roughly one quarter of methane emissions from human activity, and its health consequences for communities living near flare sites are severe and largely invisible in global policy discussions. This literature review synthesizes evidence from nearly 50 sources on the human health impacts of gas flaring in Nigeria and Iraq, two of the world's leading flaring countries, and Brazil. Drawing on epidemiological and clinical studies, biomarker analyses, environmental monitoring, satellite-based exposure assessments, and investigative reporting, it documents consistent and convergent evidence linking flaring exposure to respiratory illness, cardiovascular disease, cancer, hematological and immunological dysfunction, endocrine and metabolic disorders, renal impairment, and adverse maternal and child health outcomes. The evidence is strongest for Nigeria and Iraq, where decades of routine flaring have left a well-documented trail of harm in affected communities; Brazil's evidence base is thinner, reflecting the predominantly offshore location of its flares and the challenges of health surveillance in remote Amazon regions.

This review is part of a broader CGD-EnergyCC research project examining the case for fiscal and regulatory measures to reduce gas flaring and venting in oil and gas producing countries. Two companion blogs—*COP30: Learning from Brazil's Experience Limiting Gas Flaring* and *Gas Flaring: A $100 Billion Problem with a Policy Solution*—set out the project's core argument: that eliminating wasteful flaring is not an intractable technical problem but a policy failure, and that well-designed fiscal measures can simultaneously generate government revenue, improve public health, and advance climate commitments. This literature review provides the evidentiary foundation for the health dimension of that argument. Its central finding is unambiguous: gas flaring represents a significant and preventable public health risk, and its persistence reflects a failure of governance and enforcement that imposes heavy costs on the local communities least able to avoid them.

Mark Plant
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## Summary

Hydrocarbon gas flaring, the burning of natural gas during oil production, produces carbon dioxide and can also, when combustion is incomplete, release harmful air pollutants including volatile organic compounds, black carbon, nitrogen oxides, sulfur dioxides, and methane. This literature review synthesizes evidence on the human health impacts of gas flaring in Nigeria and Iraq, two high-flaring countries, as well as in Brazil, all of which have committed to the World Bank -led Zero Routine Flaring by 2030 (ZRF) initiative. The review draws on epidemiological and clinical studies, biomarker analyses, environmental monitoring and exposure modeling, as well as investigative reporting.

Across these contexts, the literature consistently links exposure to gas flaring emissions with increased risks of respiratory illness, cardiovascular disease, carcinogenic and cellular damage processes, hematological and immunological dysfunction, endocrine and metabolic disorders, renal impairment, and adverse maternal, neonatal, and child health outcomes. The evidence base varies in scope and type of study, and reflects common methodological constraints, including indirect exposure assessment and limited baseline health data. Moreover, with the methodologies adopted in the studies under review, the unambiguous attribution of adverse health outcomes to gas flaring as opposed to other factors remains a challenge. Nonetheless, the convergence of findings across diverse study designs and geographic contexts—supported by established toxicological mechanisms—provides a plausible basis for causal inference, although stronger study designs would be needed to establish causation more definitively.

While further studies would be helpful to quantify the adverse health impact of the toxic load from gas flaring, the weight of evidence strongly supports the conclusion that gas flaring represents a significant, preventable public health risk. Eliminating the practice would yield substantial health benefits alongside climate mitigation and economic gains, underscoring the need to integrate public health considerations into flaring reduction policies, enforcement mechanisms, and energy transition strategies.

## 1. Introduction

In the exploitation of hydrocarbon resources, gas flaring and venting release a range of greenhouse gases and toxic pollutants, contributing to climate change, affecting air quality, and posing significant public health risks while wasting nonrenewable energy resources. Gas flaring refers to the process of burning natural gas associated with oil extraction, while venting is the direct release of natural gas into the atmosphere.[1] Within the oil and gas industry, these practices are commonly justified on safety, operational, or economic grounds (see box).[2]

1 World Bank, Global Flaring and Methane Reduction Partnership. (n.d.). *Gas flaring explained*.

2 Inside Climate News. (2022, February 25). *Why the oil and gas industry is flaring and venting more natural gas.*

### Box 1. Why is gas flared?

The oil and natural gas industry defines natural gas flaring as the controlled combustion of natural gas for safety, operational, or economic reasons. From a safety standpoint, flaring is used to relieve high and variable gas pressures in oil and gas extraction and processing to prevent catastrophic explosions. Operationally, flares are used during exploration well testing or during regular operations to dispose of small volumes of waste gas or as a pilot flame for instantaneous ignition of any diverted gas flows. However, a large share of flaring is driven by economic considerations. Oil companies often judge that the associated gas does not warrant the capital costs of capture, processing, or transport, particularly in remote fields lacking markets, pipeline infrastructure, or other feasible transport options.[3]

According to the World Bank's *Global Gas Flaring Tracker Report*, global gas flaring increased by 6 percent in 2025, the third consecutive annual increase. Total upstream flaring reached 167 billion cubic meters worldwide—the highest since 2019—despite a modest rise in global oil production and long-standing commitments to reduce flaring.[4] The amount of gas flared in 2024 was comparable to Africa's total annual gas consumption, highlighting the scale of wasted energy. "Super-emitter" flares are particularly problematic, accounting for just 1% of flares but responsible for 23% of total gas flared worldwide.[5] Despite the persistence of flaring, a range of established technologies exists to reduce or eliminate routine flaring, including reinjection of associated gas to maintain reservoir pressure, on-site power generation, and conversion of gas into compressed or liquefied natural gas.[6] However, the deployment of these solutions depends heavily on regulatory, economic, and infrastructural conditions. In many oil-producing regions, routine flaring persists where regulations do not require gas utilization plans, enforcement capacity is limited, flaring volumes are poorly measured or under-reported, and flaring penalties remain cheaper for operators than investing in gas capture and utilization infrastructure.[7]

The persistence of routine flaring carries profound climate, environmental, and public health consequences. Flaring is a significant source of greenhouse gases, including carbon dioxide ($CO_2$) and methane ($CH_4$). In fact, one quarter of methane emissions caused by human activity come from flaring and venting.[8] While well-operated flares are supposed to achieve high combustion efficiency—around 98% destruction efficiency under regulatory guidance from agencies such as

3 Romsom, E., & McPhail, K. (2021). *Capturing economic and social value from hydrocarbon gas flaring and venting: Evaluation of the issues* (WIDER Working Paper No. 2021/5). United Nations University World Institute for Development Economics Research (UNU-WIDER).

4 World Bank, Global Flaring and Methane Reduction Partnership. (2026, July). *Global gas flaring tracker report*.

5 Romsom, E., & McPhail, K. (2021). *Capturing economic and social value from hydrocarbon gas: Solutions and actions* (WIDER Working Paper No. 2021/6). United Nations University World Institute for Development Economics Research (UNU-WIDER).

6 International Energy Agency. (2025). *Gas flaring*.

7 World Bank, Global Flaring and Methane Reduction Partnership. (2025). *Gas flaring explained*.

8 International Energy Agency. (2025, May 7). *Methane Tracker Data Explorer* [Data tool]. International Energy Agency.

the U.S. Environmental Protection Agency and referenced in analyses by the World Bank and the International Energy Agency among others—many flares in practice do not meet this benchmark. This results in "dirty-flaring," or incomplete combustion, which releases not only $CO_2$ but a wide spectrum of hazardous pollutants that harm human health (see Table 1).

### Table 1. Select pollutants emitted by poorly operated flares and their associated acute and chronic health impacts

| Pollutant | Health Impacts |
|---|---|
| Fine particulate matter ($PM_{2.5}$), including black carbon ("soot") | Linked to nonfatal heart attacks, irregular heartbeat, aggravated asthma, decreased lung function, and premature death.[9] Black carbon (soot) is a known carcinogen that can cause cancer, respiratory, and cardiovascular diseases.[10] |
| Nitrogen oxides (NOx) and Sulfur dioxide ($SO_2$) | Major respiratory irritants[11] that can trigger or worsen asthma and other respiratory conditions.[12] |
| Polycyclic aromatic hydrocarbons (PAHs) | PAHs can cause or increase risk of cancers (e.g., skin, lung, bladder, breast, gastrointestinal), genetic mutations, developmental abnormalities, cardiovascular diseases (e.g., atherosclerosis, hypertension, thrombosis, myocardial infarction), oxidative stress, and increase disease and mortality risk.[13] |
| Volatile organic compounds (VOCs), including Benzene | VOCs can cause nausea, difficulty breathing, damage to the central nervous system and other organs. Some VOCs can cause cancer.[14] Benzene is a known carcinogen linked to leukemia[15] and other blood disorders,[16] as well as alterations in cardiac and pulmonary functions.[17] |
| Carbon monoxide (CO) | Reduces the oxygen-carrying capacity of blood, leading to headaches, dizziness, confusion, and, at high concentrations, unconsciousness and death[18] |
| Ammonia ($NH_3$) | Causes burning of the eyes, nose, throat, and respiratory tract. High-level exposure can lead to lung damage and death[19] |
| Hydrogen sulphide ($H_2S$) | Acute exposure to high levels elicits organ toxicity, neurotoxicity, acute respiratory failure, or death.[20] |
| Methane ($CH_4$) and ground level ozone ($O_3$) | Contributes to ground-level ozone formation, a harmful air pollutant that can worsen asthma, respiratory illness, cardiovascular disease, and premature mortality.[21] |

*Notes:* Table 1 presents select pollutants associated with gas flaring and is not an exhaustive list. Communities near flare sites are typically exposed to a mixture of flaring-related pollutants, the combined health effects of which are difficult to isolate.

9 U.S. Environmental Protection Agency. (2026, January 5). Integrated science assessment (ISA) for particulate matter.

10 Niranjan, R., & Thakur, A. K. (2017). The Toxicological Mechanisms of Environmental Soot (Black Carbon) and Carbon Black: Focus on Oxidative Stress and Inflammatory Pathways. Frontiers in immunology, 8, 763.

11 Taha, S. S. (2025). *Comprehensive review of health impacts of the exposure to air contaminants from flaring and related activities. Environmental Research and Public Health*, *S2772416625001822*.

12 U.S. Environmental Protection Agency. (2025, January 10). *Sulfur dioxide ($SO_2$) basics*.

13 Mallah, M. A., Changxing, L., Mallah, M. A., Noreen, S., Liu, Y., Saeed, M., Xi, H., Ahmed, B., Feng, F., Mirjat, A. A., Wang, W., Jabar, A., Naveed, M., Li, J. H., & Zhang, Q. (2022). Polycyclic aromatic hydrocarbon and its effects on human health: An overview. Chemosphere, 296, 133948.

14 American Lung Association. (2024, October 21). *Volatile organic compounds*.

15 National Cancer Institute. (2024, August 6). *Benzene and cancer risk*.

16 D'Andrea, M. A., & Reddy, G. K. (2013, October 2). *Health effects of benzene exposure among children following a flaring incident at the British Petroleum refinery in Texas City. Pediatric Hematology and Oncology*, *31*(1), 1–10.

17 D'Andrea, M. A., Garg, N., Trehan, S. & Reddy, G. K. (2025). Cardiac abnormalities induced by benzene exposure from the flaring disaster at the BP refinery plant in Texas City. Int J Occup Med Environ Health., 38(3), 249–263.

18 State of California, California Air Resources Board. (2025). *Carbon monoxide and health*.

19 Centers for Disease Control and Prevention. (2024, September 6). *Ammonia: Chemical fact sheet*.

20 Occupational Safety and Health Administration. (n.d.). *Hydrogen sulfide: Hazards*. U.S. Department of Labor.

21 Environmental Defense Fund. (2026). How methane harms our health and what we can do about it.

Flaring also poses indirect health risks by emitting greenhouse gases that contribute to climate change. Climate change, in turn, increases health threats such as the spread of mosquito-borne diseases like malaria and dengue,[22] waterborne diseases like cholera,[23] and heat-related illness and death.[24] Methane, a potent greenhouse gas, is also a precursor to the formation of tropospheric ozone, a harmful air pollutant linked to asthma, respiratory illness, and approximately one million premature deaths per year globally, and it also damages ecosystems and crops by impairing plant growth.[25] Other flaring pollutants create additional environmental contamination pathways. For example, $NO_x$ and $SO_2$ emissions can lead to acid rain, which lowers soil pH, reduces nutrient availability and crop yields, and releases toxic substances such as aluminum. These contaminants can enter the food chain, creating long-term exposure pathways for communities.[26]

### Box 2. Social costs of natural gas flaring, venting, and leakages

Emissions from natural gas flaring, venting, and leakages generate wide-ranging socio-economic impacts at local, national, and global scales. Two working papers by Romsom and McPhail (2021) for the United Nations University World Institute for Development Economics Research (UNU-WIDER) assess these impacts using the Social Cost of Atmospheric Release (SCAR) framework.[27] SCAR estimates the total damage per unit of pollutant released by integrating four categories of impact associated with the pollutant, including:

1. health impacts from chemical toxicity;
2. health impacts from climate change;
3. regional aerosols-induced hydrologic cycle changes (i.e., changes in regional rainfall);
4. global climate impact.

The authors calculate SCAR values for key pollutants from flaring, venting, and leaks, including $CO_2$, methane, $NO_x$, $SO_x$, black carbon, VOCs, organic carbon, CO, $N_2O$, and $NH_3$. A key finding is that the SCAR (the social costs) of flaring increase significantly when the destruction efficiency drops below 98% (i.e. when less than 98% of hydrocarbons are destroyed). Venting carries an even higher SCAR. Overall, the authors conclude that the global social cost of all flaring and

22 Jackson, A. (2022, April 22). *Explainer: How climate change is amplifying mosquito-borne diseases*. World Mosquito Program.

23 United Nations Development Programme (UNDP) Climate Promise. (2024, August 30). *Climate crisis, health crisis: Here's why.*

24 Maslin, M., Ramnath, R. D., Welsh, G. I., & Sisodiya, S. M. (2025). *Understanding the health impacts of the climate crisis. Future Healthcare Journal*, *12*(1), 100240.

25 Global Methane Pledge. (n.d.). The imperative for methane action.

26 Environmental Law Research Institute (ELRI). (2021, November 4). *Impact of gas flaring on global warming and agriculture.*

27 Shindell, D. (2015). The social cost of atmospheric release. Climatic Change, 130(2), 313–326.

venting emissions exceeds the sales value of globally marketed gas by a factor of 1.5. This means the combined climate, health, and other damages from these practices outweigh the market value of the gas itself.

**UNU-WIDER Paper 1:** Evaluation of the issues
**UNU-WIDER Paper 2:** Capturing economic and social value from hydrocarbon gas flaring and venting: solutions and actions

## 2. Health impacts of gas flaring

Satellite-based observations since 2005 indicate that approximately 85% of total gas flared has occurred in developing countries.[28] As a result, the poorest and most vulnerable communities are disproportionately exposed to the health risks associated with routine flaring. This literature review examines the direct health impacts of natural gas flaring in three emerging markets economies: Nigeria, Iraq, and Brazil (see Figure 1). All three governments have formally signed on to the Zero Routine Flaring by 2030 (ZRF) initiative—launched in 2015 by the World Bank and the United Nations—under which endorsing governments and oil companies report their progress annually towards the zero routine flaring goal.[29] The need to dramatically reduce flaring is more pressing than ever. More than half a billion people in developing countries still lack dependable energy access, and governments have only five years left to fulfill their ZRF 2030 pledges.

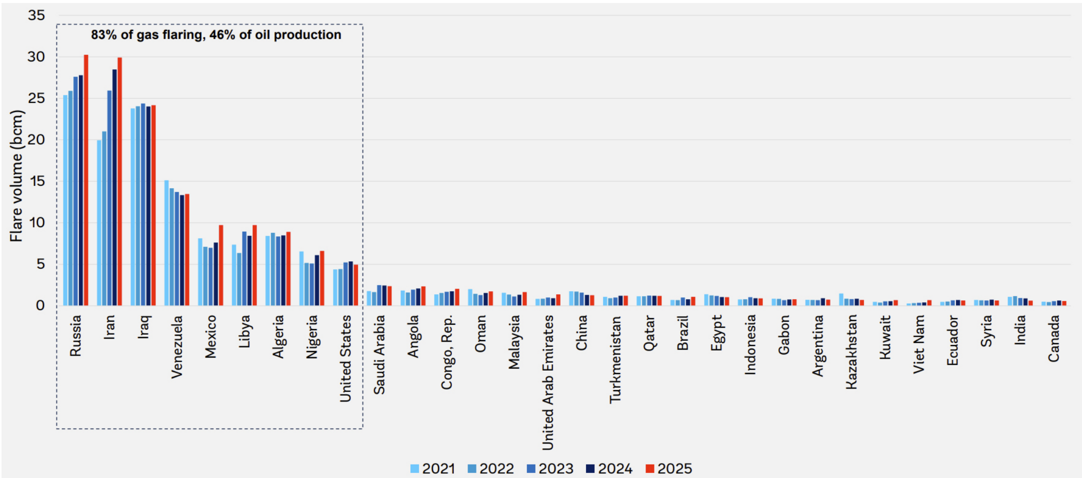
While pollution is widespread across the broader oil and gas supply chain, this review primarily focuses on health outcomes attributable to flaring exposure among communities and workers living near or based at flare sites. This literature review draws on a multidisciplinary evidence base, including epidemiological studies, clinical and biomarker research, air quality monitoring and satellite-based exposure assessments, investigative journalism and government reports. A broad, online search was conducted to identify any publicly accessible studies relevant to the three target countries. Nearly 50 sources were found and all were reviewed, alongside targeted data searches and key informant interviews to identify patterns in documented health impacts, methodological approaches, and evidentiary gaps. The three case studies that follow synthesize the current state of available evidence on flaring-related health risks, highlight methodological approaches and limitations, and identify patterns that cut across national contexts. Annex 1 provides an overview

28 Romsom, E., & McPhail, K. (2021). *Capturing economic and social value from hydrocarbon gas flaring and venting: Evaluation of the issues* (WIDER Working Paper No. 2021/5). United Nations University World Institute for Development Economics Research (UNU-WIDER).

29 World Bank. (n.d.). *Zero routine flaring by 2030 (ZRF) initiative endorsers.* Retrieved November 14, 2025.

of key findings across the evidence base, while Annexes 2–4 summarize studies by country, their methodologies, and principal findings.

**Figure 1. Flare volumes in the top 30 flaring countries (2021–2025)**
*Ordered by 2025 flare volume with top 9 countries framed*




(*Source:* NOAA, Payne Institute and Colorado School of Mines, and World Bank; World Bank Global Gas Flaring Tracker Report, 2026).

# 3. Nigeria

## Background

Nigeria was selected as a case study because it offers one of the richest bodies of empirical evidence on the health impacts of natural gas flaring. A substantial body of epidemiological, clinical, and toxicological research—conducted by national institutions such as the University of Lagos, the University of Port Harcourt, Rivers State University, and the University of Nigeria—documents the health consequences of long-term exposure to flaring-related pollution in the Niger Delta region.

As Africa's largest producer of oil and home to the continent's largest proven natural gas reserves, Nigeria is a strategically significant case study whose experience offers important lessons for other African countries expanding oil and gas production. According to the African Energy Chamber's *State of African Energy 2026 Outlook*,[30] natural gas demand across Africa is projected to increase approximately 60% by 2050, with countries such as Ethiopia, Mauritania, Mozambique, Senegal, South Africa and Tanzania, entering or expanding their roles as gas producers. Nigeria's decades-long struggle with routine flaring, and its widely documented environmental and health

30 Ayuk, N. J. (2025, December 2). *The surge in gas production and Africa's path to economic transformation*. African Energy Chamber.

impacts, therefore offers a critical early warning for new and emerging producers. Without strong governance and enforcement mechanisms, rapid oil and gas sector development risks imposing significant, long-term health burdens on local communities.

Nigeria also illustrates governance and enforcement challenges that often undermine flaring reduction efforts. Since the *Associated Gas Re-Injection Act* of 1979, several government initiatives have committed to eliminating routine flaring, most recently through the *Nigerian Gas Flare Commercialization Programme* (2016), the *Petroleum Industry Act* (2021), and the *Gas Flaring, Venting & Methane Emissions (Prevention of Waste and Pollution)* Regulations (2023). In practice, implementation and enforcement have remained weak and flare-out deadlines have been repeatedly extended, most recently to 2030. In 2024 alone, an estimated USD $1.05 billion worth of gas was flared—equivalent to 30,100 Gigawatt-hours of potential electricity—while penalties, estimated at roughly USD $602 million, were largely unenforced.[31] According to the World Bank's *2025 Global Gas Flaring Tracker Report*,[32] Nigeria's flaring volumes increased 12% in 2024, marking the second largest increase globally and the second consecutive year of rising flare in the country. Facilities operated by the national oil company, the Nigerian National Petroleum Corporation, together with several smaller companies, many with limited expertise or funding for gas utilization, accounted for 60% of total flaring and 75% of the annual increase.

The Niger Delta, where the majority of Nigeria's oil and gas production is concentrated, is one of the most profoundly affected oil-producing regions in the world. Since the onset of large-scale petroleum extraction in the 1950s during colonial rule, the region has experienced extensive environmental degradation driven by oil spills, waste discharges, and continuous gas flaring. An estimated 13 million barrels[33] of crude oil have been spilled, contaminating once-thriving fish ponds, mangrove forests, and farmlands, undermining food security, cultural identity, and livelihoods in communities that depend largely upon agricultural and piscatorial subsistence practices.[34,35] Life expectancy in many Delta communities is estimated at 41 years, compared with the national average of 61, reflecting the cumulative effects of chronic oil and gas sector pollution exposure and poor health infrastructure.[36] Attributing specific health outcomes to gas flaring alone is challenging in the Niger Delta, where communities are often exposed to multiple sources of pollution associated with oil and gas production, such as oil spills, contaminated water and soils, and waste discharges.

31 Eberu, C. V. (2025, August 30). *Expert offers pathway to gas flaring loss. Guardian Nigeria*.
32 The World Bank Group. (2025, July). *Global gas flaring tracker report*.
33 Steinhoff, N. (2025, February 17). *New study reveals the extent of ecological damage from Niger Delta oil spills*. Oceanographic Magazine.
34 Ikoku, O. (2025). *Big oil is deserting the polluted Niger Delta. Earth Island Journal*.
35 O'Farrell, J., O'Fionnagáin, D., Babatunde, A. O., Geever, M., Codyre, P., Murphy, P. C., Spillane, C., & Golden, A. (2025). Quantifying the Impact of Crude Oil Spills on the Mangrove Ecosystem in the Niger Delta Using AI and Earth Observation. Remote Sensing, 17(3), 358.
36 Ikoku, O. (2025).

The severity and duration of environmental contamination, documented health disparities, persistent governance challenges and the depth of scientific literature make Nigeria one of the most consequential settings globally for examining the public health impacts of gas flaring.

## Health impacts from gas flaring in Nigeria

The following sections synthesize evidence of the respiratory, cardiovascular, hematological, immunological, metabolic, and maternal and child health outcomes associated with flaring exposure in the Niger Delta. The studies employ a range of methodologies (see box), including predominantly cross-sectional analyses, alongside prospective cohort studies and environmental exposure assessments using spatial analysis, clinical data, and emissions modeling, and consistently link exposure to gas flaring with a spectrum of adverse health outcomes. Unlike some studies from Basra, Iraq—later cited in this paper—that examine gas flaring exposure and cancer incidence, Nigeria-focused literature primarily reports biological risk markers (including inflammation, oxidative stress, immune dysregulation, and DNA damage) that are recognized precursors to cancer.

### Box 3. Epidemiological study designs

**Prospective cohort studies (longitudinal follow-up):** Classify individuals according to exposure and follow them over time to measure changes in health outcomes or disease incidence. Best practice and evidence in environmental health.

**Cross-sectional studies (snapshot):** Assess exposure and outcome simultaneously in a defined population, often comparing groups with different levels of exposure (e.g., flaring vs. non-flaring communities).

**Environmental and exposure assessment studies:** Use air quality monitoring, satellite data, spatial analysis, or emissions modeling to estimate pollution exposure and examine associations with population-level health outcomes.

### *Respiratory illnesses*

Respiratory conditions are among the most frequently documented health effects of gas flaring exposure in the Niger Delta. Multiple community-based studies report elevated prevalence of chronic cough, wheezing, breathlessness, asthma, and reduced lung function among residents living near flare sites. For example, a 2021 cross-sectional survey conducted by the University of Lagos and University of Uyo researchers in Akwa Ibom State compared health outcomes in Ibeno–a gas-flaring community located within the Mangrove Forest Belt of the Niger Delta–with those in the non-flaring community of Etinan. It found both a higher prevalence of respiratory symptoms in Ibeno—including cough (14.8% vs. 10.1%), breathlessness (15% vs. 7.3%), and wheezing (5.7% vs. 3.1%)—and confirmed reduced lung function using spirometry, with the exposed group showing lower peak expiratory flow rate (PEFR), forced vital capacity, and forced expiratory volume in 1 second.[37] Research across five Niger Delta states (2016) found that gas flaring communities had a significantly higher respiratory rate and decreased PEFR compared to non-flaring communities located 35 kilometers away, with the effects worsening with longer exposure duration.[38] These findings are corroborated by a 2012 study in Delta State, which compared the gas-flaring community of Ugberikoko with the non-flaring community of Irhodo and also found statistically significant ($p<0.05$) reduced lung function (reduced PEFR) across all age groups.[39] Further, the mean PEFRs significantly decreased with longer duration of exposure to gas flaring.

A 2021 study in the Niger Delta States of Rivers and Bayelsa combined spatial analysis of gas flaring with air quality monitoring and a review of 4-year clinical records (2013–2016), finding that $NO_2$ and $PM_{10}$ levels exceeded WHO limits. The study established strong statistical associations between pollutants and respiratory and dermal diseases, with air pollution from the flares accounting for up to 89.2% of breathing difficulties and also being significantly correlated with chest pain and eye irritation.[40] In addition to recommending the reduction and phase-out of gas flaring, the researchers from the toxicology departments of multiple national universities advised the use of face masks for the most vulnerable residents (children, women, and the elderly) living near gas flaring stations.

> *"You can hear the coughing in the community; it's become a common problem. The air feels heavy with pollutants, and it's taking a toll on our health."*
>
> — John Nwosu, Egbema resident (HumAngle, 2024)

## *Cardiovascular diseases*

Evidence linking gas flaring exposure to cardiovascular disease in the Niger Delta points to an association between gas flaring exposure and adverse cardiovascular outcomes. A large household survey conducted in Bayelsa and Rivers States in 2017 combined a modified

37 Ekwere, E. M., Umoh, I. O., Peters, G. E., Udo, A. I., Effiong, A. E., Peters, E. J., & Bandele, E. A. (2021). The health impact and lung function indices of adult residents of Ibeno Community exposed to gas flaring in south-south Nigeria. Ibom Medical Journal, 14(4), 507–515.

38 Ovuakporaye Simon Irikefe, Igweh C. John, Aloamaka Chukwma Peter. 2016. "Impact of Gas Flaring on Cardiopulmonary Parameters of Residents in Gas Flaring Communities in Niger Delta Nigeria". Journal of Advances in Medicine and Medical Research 15 (6):1–13.

39 Ovuakporaye, S. I., Aloamaka, P. C., Ojieh, A. E., Enaibe, B. U., & Odigie, O. M. (2012). Effect of Gas Flaring on Lung Function among Residents in Gas Flaring Community in Delta State, Nigeria. Research Journal of Environmental and Earth Sciences, 4(7), 733–737.

40 Nwosisi, M. C., Oguntoke, O., Taiwo, A. M., Agbozu, I. E., & Noragbon, E. J. (2021, April 10). *Spatial patterns of gas flaring stations and the risk to the respiratory and dermal health of residents of the Niger Delta, Nigeria. Scientific African*, *12*, e00762.

WHO-STEPS questionnaire with direct blood pressure measurements across 600 households. The study found that residents of gas-flaring communities (Nedugo, Oton-Yasere, Mbodo-Aluu) were 1.75 times more likely to be hypertensive than residents of non-flaring communities (Sampou, Ibada-Elume, Omerelu), with approximately one quarter of respondents in gas flaring communities classified as hypertensive.[41] A 2013 cross-sectional survey in Imo State demonstrated that prolonged exposure to gas flares from Shell Petroleum Development Company operations in Egbema was associated with increased risks for hypertension, with exposed individuals showing a statistically significant ($p<0.05$) increase in systolic blood pressure, diastolic blood pressure (DBP), and mean arterial blood pressure compared to the control group in Alaoma Owerre-Ebeiri (a non-oil and gas producing area). Hypertension prevalence was markedly higher in the exposed group: 39% (systolic) and 57% (diastolic) compared to 28% and 35% in controls.[42] These findings are consistent with a multi-state investigation from 2016 across five Niger Delta states (Delta, Akwa Ibom, Rivers, Bayelsa, Edo), which recorded significantly elevated blood pressure (184.96 vs. 123.00 mmHg) and pulse rate (100.37 vs. 78.09) in gas flaring communities compared to non-flaring communities 35 km away.[43] Further, a 2019 study published in the *International Journal of Cardiology and Angiology* compared Delta State communities exposed to gas flaring and oil contamination (Agbarho and Bomadi) with a non-exposed community (Abraka). The study found clear duration-dependent cardiovascular effects, with statistically significant increases in systolic blood pressure and mean arterial pressure among individuals exposed to gas flaring for 6–10 years compared with those exposed for 1–5 years (control).[44]

### *Hematological and immunological outcomes*

Several clinical studies have documented the adverse effects of gas flaring exposure on hematological and immunological parameters. A 2010 study by the University of Port Harcourt College of Health Sciences in Rivers State compared hematological parameters among residents of gas-flaring (Ebocha) and adjacent (Okwuzi) communities and a non-exposed farming community located more than 20 km away. Venous blood samples were collected and analyzed for packed cell volume, hemoglobin concentration, red and white blood cell counts, and red cell morphology. The study found statistically significant hematological alterations among exposed individuals, including reduced packed cell volume, hemoglobin, and red blood cell count, as well as increased white blood cell count and abnormal red cell morphology compared to the control ($p<0.05$). Abnormal red blood cells morphology was 167% higher in exposed males

41 Maduka, O., & Tobin-West, C. (2017). Is living in a gas-flaring host community associated with being hypertensive? Evidence from the Niger Delta. BMJ Global Health, 2(4), e000413.

42 Egwurugwu, J. N., & Nwafor, A. (2013). Prolonged Exposure to Oil and Gas Flares Ups the Risks for Hypertension. American Journal of Health Research, 1(3), 66–72.

43 Ovuakporaye Simon Irikefe et al., 2016.

44 Ana, G. R. E. E., Ovuakporaye, S. I., & Ojieh, A. E. (2015). Duration-and Gender-Variations of Gas Flaring and Crude Oil Contamination Exposures on Blood Pressure in Delta State, Nigeria. Journal of Environmental and Public Health, 2015, 1–7.

and 795% higher in exposed females compared to controls.[45] In the predominantly farming, rural Delta community where the study was conducted, women tend to spend more time at home or on their farms, while men are generally more mobile. As a result, women likely experienced greater exposure to flaring pollutants, which may explain why changes in the measured parameters were more pronounced among females than males, highlighting a gendered inequity in environmental health exposure.

A 2025 study of the Ibeno community in Akwa Ibom State—where ExxonMobil has conducted oil and gas operations, including gas flaring, since the 1970s—provides evidence of immune system alterations associated with chronic flare exposure. Researchers compared 110 residents from Ibeno with 80 residents from Afaha Udoe, a non-exposed control community. Residents of the exposed community exhibited significantly elevated white blood cell counts that were 1.6 times higher than controls, which is consistent with inflammation and a heightened immune response. Pro-inflammatory cytokines were also markedly increased, with Interleukin-4 levels 2.35 times higher in exposed individuals, a pattern commonly associated with heightened risk of respiratory and allergic diseases. In contrast, key anti-inflammatory and tumor-suppressing proteins were significantly lower, with Interleukin-10 and Transforming Growth Factor-Beta reduced by up to 3.15 times. This imbalance suggests impaired ability to regulate inflammatory responses and suppress tumor growth, thereby increasing cancer risk.[46] In 2021, the same research team investigated cellular damage in Rivers State by analyzing serum antioxidant biomarkers in the gas-flaring Eleme community versus the non-flaring Nkpolu-Oroworukwo community. They found residents from the flaring community had significantly depleted antioxidant defenses and a 45% increase in malondialdehyde (MDA), a key marker of cellular damage that is a known precursor to cancer and heart disease.[47]

### *Maternal, neonatal, and child health*

The impacts of gas flaring also extend to maternal, neonatal and child health outcomes. A 2022 prospective cohort study followed 1,418 pregnant women in the Niger Delta, finding that those in high oil pollution and gas flaring areas (Delta and Rivers States) had a higher risk of premature rupture of membranes (8% vs. 4.6%) and postpartum hemorrhage (7.3% vs. 3.5%) compared to women in low exposure areas (Ondo and Edo States).[48] A 2025 cross-sectional study

45 Adienbo, O. M., & Nwafor, A. (2010). Effects of Prolonged Exposure to Gas Flaring on Some Haematological Parameters of Humans in the Niger Delta Region of Nigeria. Journal of Applied Sciences and Environmental Management, 14(1), 13–15.

46 Onwuka, N. A., Imananagha-amene, B., Lemii, B. C., Onwuka, K. S., & Nwankpa, N. N. (2025). Evaluation of Haematological and Cytokine Indices of Humans in a Gas Flare-Impacted Community. American Journal of Environment Studies, 8(1), 21–39.

47 Onwuka, N. A., Imananagha-amene, B., Lemii, B. C., Onwuka, K. S., & Nwankpa, N. N. (2021). Impact of Gas Flaring on the Serum Antioxidant Biomarkers of Eleme Residents in Rivers State, Nigeria. Journal of Advances in Medicine and Medical Research, 1–8.

48 Oghenetega, O. B., Okunlola, M. A., Ana, G. R. E. E., Morhason-Bello, O., & Ojengbede, O. A. (2022). *Exposure to oil pollution and maternal outcomes: The Niger Delta prospective cohort study.* PLOS ONE, 17(3), e0263495.

in Yenagoa, Bayelsa State, Nigeria found that neonates born to mothers with daily self-reported exposure to gas flaring had lower mean birth weights (2.69 kg) compared with those whose mothers were occasionally exposed (3.09 kg), indicating an association between maternal gas-flaring exposure and reduced neonatal weight.[49] According to the WHO, low birth weight is associated with higher fetal and neonatal mortality and morbidity, impaired growth and cognitive development, and increased risk of noncommunicable diseases later in life.[50]

Further, a 2022 World Bank study examined the health impacts of gas flaring on children under five in Nigeria's Niger Delta by linking satellite-detected flare locations and volumes with georeferenced child health data from the 2013 and 2018 Nigerian Demographic and Health Surveys (DHS). Using satellite observations, researchers identified flaring sites and estimated flare volumes from both onshore and offshore operations. Exposure was calculated at the DHS cluster level using an inverse-distance weighted measure that accounted for both proximity to multiple flare sites and the volume of gas flared. Researchers then examined associations between flaring exposure and child health outcomes, including respiratory illness, cough, fever, diarrhoea, anthropometric indicators of nutritional status, and mortality. The study found that higher flaring exposure was significantly associated with increased incidence of cough, respiratory symptoms, and fever among children under five, as well as higher probabilities of wasting and underweight status, while no statistically significant associations were observed for diarrhoea or child mortality.[51]

### *Other health impacts*

Other documented health impacts of gas flaring in the Niger Delta include renal dysfunction, heavy metal bioaccumulation, and metabolic disorders. A 2013 study in the Imo East Senatorial zone of Imo State compared serum biomarkers of renal function among residents of a gas flaring community (Egbema) and a demographically similar non-oil and gas producing community (Alaoma Owerre Ebeiri). Blood samples were analyzed for indicators including urea, creatinine, potassium, uric acid, and inorganic phosphate, and the study found statistically significant increases in all measured renal dysfunction biomarkers among exposed individuals, suggesting elevated risk of kidney disease with prolonged exposure to chronic, low-level gas flaring.[52]
In Bayelsa State, a pair of studies by Ifenkwe et al. compared the gas-flaring community of Imiringi with the non-flaring community of Odi. Their 2018 study found that exposed residents had significantly higher levels of heavy metals (including Cadmium, Chromium Mercury,

49 Uvoh, S. M., Osuwo, E., Emmanuel, O., Nnamdi, C. N., & Dirime, J. T. (2025). *Impact of gas flares on neonatal weight and health profile in Yenagoa Bayelsa State, Nigeria*. Journal of Advances in Medicine and Medical Research, 37(6), 269–276.

50 World Health Organization. (n.d.). *Low birth weight*. (Accessed November 21, 2025)

51 Alimi, O. B., & Gibson, J. (2022). The Impact of Gas Flaring on Child Health in Nigeria. World Bank Policy Research Working Paper, (10153).

52 Egwurugwu, J. N., Nwafor, A., Chike, C. P., & Iwuji, S. C. (2013). Impact of Prolonged Exposure to Oil and Gas Flares on Human Renal Functions. International Research Journal of Medical Sciences, 1(11), 9–16.

Lead, Selenium) and a key marker of lipid peroxidation, indicating cellular damage from oxidative stress.[53] A separate 2017 study by the same lead author also found evidence of DNA damage, with significantly elevated levels of the oxidative DNA damage marker 8-OHdG in the same exposed community.[54] Further, a 2022 study by University of Port Harcourt researchers linked gas flaring to metabolic problems that can lead to diabetes. By comparing women in the gas-flaring Ogoni land with a non-flaring community in Cross River State, researchers found that prolonged exposure to flare pollutants like lead, cadmium, and vanadium made the body less responsive to insulin. The study found that 78% of women in the exposed community had insulin resistance, a major risk factor for developing type 2 diabetes, compared to just 22% in the control group.

# 4. Iraq

## Background

Ranking third in 2024 behind Russia and Iran, Iraq consistently ranks among the world's top three gas-flaring countries.[55] Iraq's flaring features several large fields in the Basra Governorate, located in the southeast of the country and home to nearly three million people.[56] Basra is among the world's top gas flaring hotspots, with major oil fields operated by BP (Rumaila), Eni (Zubair), ExxonMobil (West Qurna), and Lukoil (West Qurna 2) (see Figure 2).[57] A 2024 study by the University of Basrah College of Science measured black carbon, PM2.5, PM10, formaldehyde, and total volatile organic compounds (TVOCs) at six stations in the Basra Governorate, including near flare locations and within the city center (39 km away). Except for TVOCs, all pollutants exceeded local and WHO permissible limits, including near the city center. Predominant northwesterly winds act as a vector for carrying air pollutants in the form of smoke plumes toward the populated and residential areas of Basra city center, resulting in chronic exposure for the city's over 1 million residents.[58]

53 Ifenkwe, J. C., Nwanjo, H. U., Nwosu, D. C., Solomon, E. A., & Yakubu, B. (2018). Heavy Metal Bioaccumulation and Lipid Peroxidation Damage in Residents of a Gas Flaring Community. International Journal of Advances in Scientific Research and Engineering, 4(7), 140–150.

54 Ifenkwe, J. C., Nwanjo, H. U., Nwosu, D. C., & Bassey, O. I. (2017). Toxicological Studies on Heavy Metal Bioaccumulation and Oxidative DNA Damage in Residents of a Gas Flaring Community. International Journal of Science and Research, 6(12), 1867–1875.

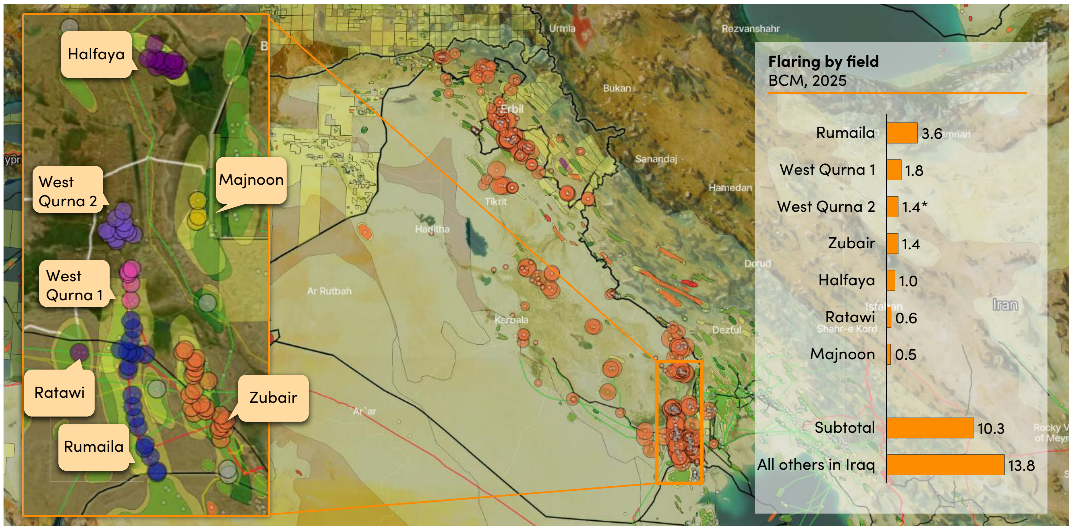
55 World Bank, Global Flaring and Methane Reduction Partnership. (2025, July). *Global gas flaring tracker report*.

56 Bernstein, A., et al. (2025, June). *Igniting action to reduce gas flaring: Real opportunities. Real projects. Real results. Country case study: Republic of Iraq (Federal Iraq).* Columbia Center on Sustainable Investment & Capterio.

57 Seigneur, M., & Gauer, P. (2025, June 2). *Big oil is fueling a rise in cancer in Iraq's Basra*. New Lines Magazine.

58 Khreebsh, H. T., & Azeez, N. M. (2024). Assessment of Gas Flaring on Air Quality in the Al-Rumaila Oil Field Region in Basra Governorate, Iraq. EnvironmentAsia, 17(3), 105–115.

**Figure 2. Iraq: Gas flaring from major Basra oil fields**




*Notes:* Map showing flaring in billion cubic meters (BCM) for seven major oil fields in the Basra area.
*Figure shown is Capterio's estimate.
*Sources:* Capterio's flare-tracking tool FlareIntel (2025) and World Bank (2026).

Iraqi officials have publicly linked rising cancer rates to oil production pollution, and leaked health data from the Basra Health Directorate, reported by the BBC, suggest cancer incidence may be over three times higher than official Ministry of Health figures.[59] Basra provides a high-priority case study with strong literature evidence illustrating the impacts of natural gas flaring on community health. Basra also has a hot desert climate and receives abundant sunshine and clear skies approximately 75% of the year.[60] Limited cloud cover enables highly reliable satellite detection of flaring activity ((i.e. data on flare location, volume, composition, frequency, pollution dispersion), strengthening the attribution of observed health outcomes to gas flaring–related pollution.

The scale of flaring in Basra, the intensity of its population exposure, and the availability of convergent environmental, epidemiological and investigative evidence make Basra a high-priority case study for examining the public health impacts of routine gas flaring.

## Health impacts from gas flaring in Iraq

### *Cancer and cellular damage*

A growing body of evidence links large-scale gas flaring in Basra to increased cancer incidence and the underlying cellular damage that causes it. A 2021 study by University of Basrah researchers analyzed time-series data on gas flaring and cancer incidence in Basra and found a very strong

59 Stallard, E. (2022, October 17). *Iraqi minister admits gas flaring cancer link*. BBC News.
60 Tyson, P. J. (2003). *Sunshine guide to Basra and the Shott-el-Arab, Iraq*. Climates.com.

positive correlation (r=0.91754) between the volume of gas flared and reported cancer cases.[61] As flaring increased, reported cancer cases nearly doubled, rising from approximately 1,200 in 2007 to 2,300 in 2018. Carbon dioxide emissions from gas flaring, a proxy for flaring volume, also increased steadily over the same period, reinforcing the statistical relationship between the volume of gas flared and the incidence of cancer. These findings align with leaked Iraq Ministry of Health documents published by the BBC in 2022,[62] which attributed a 20% increase in cancer cases in Basra between 2015 and 2018 to flaring pollution. A second leaked document from the Basra Health Directorate, also revealed by BBC, indicated a deliberate downplaying of the crisis. While the Ministry officially reported 2,339 new cancer cases in 2020, the internal records documented 8,587 cases—more than three times higher.[63]

Environmental contamination pathways further compound carcinogenic risk. A 2023 study measured 16 polycyclic aromatic hydrocarbons (PAHs), a group of carcinogenic chemicals, in surface water and sediments at 12 sites near oil refiners along the Tigris River and its estuaries. The study found that PAH concentrations were dangerously high across all sites, with the highest water contamination recorded in the Shatt al-Basra waterway near the South Refineries Company in Basra. Using the U.S. EPA's Incremental Lifetime Cancer Risk (ILCR) model, the researchers concluded that all examined sites posed a high risk of carcinogenicity to the 40 million Iraqis who depend on the river and its estuaries for irrigation, fishing, agriculture, and even drinking water.[64]

### *Cardiovascular diseases*

A 2025 clinical study by University of Basrah researchers compared 90 male petroleum workers at crude oil well sites in Basra with 90 unexposed male controls. The researchers investigated the relationship between exposure to ultrafine particles (PM0.1) and biomarkers for cardiovascular disease. The study found that exposed oil sector workers had significantly higher levels of toxic pollutants (benzopyrene and cadmium), which led to increased cellular damage from oxidative stress, weakened antioxidant defenses, and elevated triglycerides. The researchers concluded that these biomarkers indicate a high risk for atherosclerosis and cardiovascular disease (heart attacks, strokes) in the exposed workers.[65] This finding underscores that workers at crude oil well sites with flaring face even greater health risks than nearby residents, due to their prolonged, direct exposure to flaring pollutants.

61 Al Muhyi, A. H. A., & Aleedani, F. Y. K. (2021). The Effect of Natural Gas Flaring on Air Pollution and its contribution to Climate Change in Basra City. Al-Kitab Journal for Pure Science, 5(1), 26–39.
62 Stallard, E. (2022, October 17). Iraqi minister admits gas flaring cancer link. BBC News.
63 Seigneur, M., & Gauer, P. (2025, June 2 ). Big Oil Is Fueling a Rise in Cancer in Iraq's Basra. New Lines Magazine.
64 Grmasha, R. A., et al. (2023). Ecological and human health risk assessment of polycyclic aromatic hydrocarbons (PAH) in Tigris river near the oil refineries in Iraq. Environmental Research, 227, 115791.
65 AL-Lami, N. J. K., Awad, N. A. N., & Al-Taher, S. S. H. (2025). Clinical study on the relationship between exposure to ultrafine particles (PM0.1) and cardiovascular diseases in petroleum workers. Toxicology Reports, 15, 102119.

### *Respiratory diseases*

Respiratory morbidity is also documented in gas flaring-affected areas. A 2015 study by the University of Basrah College of Medicine examined oil field workers exposed to low-level hydrogen sulfide ($H_2S$) from sources including extinguished gas flares. The study found that the inhalation of $H_2S$ caused upper respiratory tract epithelial damage that caused nasal bleeding (affecting 53% of exposed workers), chronic sinusitis, nasal soreness, common cold, rhinitis, gingivitis, and acute bronchitis.[66]

### *Hormonal and metabolic disruptions*

A 2022 study by Rafad A. Al-Hulfi and colleagues from the University of Basrah examined oil refinery workers exposed to petroleum-related air pollution. Compared to a local control group, regularly exposed workers had significantly lower levels of pituitary hormones (thyroid-stimulating hormone, follicle-stimulating hormone, luteinizing hormone), indicating disruption of endocrine function. They also showed altered liver enzyme profiles suggesting hepatotoxic effects linked to pollutant exposure. The findings highlight occupational health risks for workers in gas-flaring, oil industry sites, which are even more severe for smokers.[67]

# 5. Brazil

## Background

Over the past decade, Brazil has played a leadership role in reducing natural gas flaring from upstream oil and gas operations. Since 2012, the volume of gas flared in Brazil decreased from 1.8 billion cubic meters to 1.1 billion cubic meters in 2024, even as oil production increased by 45% from approximately 2.1 to 3.5 million barrels per day.[68] Since 2020, Brazil has eliminated "super-emitter" flares, a significant accomplishment that positioned the country as the 26th largest flarer globally in 2024 despite being the 9th largest oil producer. Brazil's success in reducing flaring emissions is largely driven by the national oil company, Petrobras, which is responsible for roughly three-quarters of national oil and gas production. The company set ambitious emissions targets, linked executive compensation to performance, and invested in gas monetization, including the Urucu–Manaus pipeline, which reduced flaring while expanding energy access.[69] Petrobras also advanced responsible Amazon development through the Manaus Charter, which established

66 Mousa, H. A.-L. (2015). Short-term effects of subchronic low-level hydrogen sulfide exposure on oil field workers. Environmental Health and Preventive Medicine, 20, 12–17.

67 Al-Hulfi, R. A., Al Salem, B. A. M., & Al-Naiema, I. M. (2022). The Effect of Air Pollutants on Liver Enzymes and Pituitary Gland Hormones of Smokers and non-smokers of Oil Refinery and Gas Station Workers in Basra/Iraq. Indian Journal of Forensic Medicine and Toxicology, 16(3), 297–301.

68 McPhail, K., & Romson, E. (forthcoming): Brazil's Natural Gas Flaring: an Overview.

69 Hicklin, J., McPhail, K., & Romsom, E. (2025, November 16). COP30: Learning from Brazil's Experience Limiting Gas Flaring. Center For Global Development.

guidelines for oil and gas operations in the region—including requirements to meet high environmental and security standards, demonstrate respect for local cultures, and implement a "heavy incident response system"—and by constructing the pipeline without an access road to limit deforestation and community impacts.

Despite Brazil's relative success in reducing gas flaring in recent years, and eliminating "super-emitter" flares, the practice remains present across the country's oil and gas sector. In 2024, Brazil had 102 active flares, the majority located offshore (56 of 102), with the remainder distributed across coastal regions and a small number of inland sites, including in Amazonas State. A nearly year-long cross-border investigation by *InfoAmazonia* ("Every Last Drop") estimated that 167,992 people in Brazil's Amazon region are exposed to gas flaring.[70] Investigative reporting by Earthworks and the Brazilian environmental NGO Instituto Internacional Arayara in 2023 used optical gas imaging cameras to document extensive plumes of methane and volatile organic compounds (VOCs) emitted from oil and gas facilities across multiple Brazilian states.[71] Speaking at the 2025 WHO Conference on Air Pollution and Health, Indigenous activist Fany Kuiru, who has gained international recognition for her work to protect the Amazon, condemned gas flaring from oil and gas operations in the Amazon for its deadly impacts on Indigenous communities.[72]

> "Each gas flaring system is a death system for the Amazon and its inhabitants."
> — Fany Kuiru, Leader of the Coordinating Body of Indigenous Organisations of the Amazon Basin (COICA), WHO Air Pollution and Health Conference, 2025

In November 2025, Brazil hosted the 30th Conference of the Parties (COP30) to the UN Framework Convention on Climate Change and will retain the COP Presidency through COP31 in November 2026. This leadership role places Brazil at the center of international debates on climate and environmental policy and governance, the energy sector, and a just and inclusive transition to a sustainable, low-carbon, and climate-resilient economy. Examining the health implications of gas flaring in Brazil is therefore particularly relevant for both domestic policy discussions and broader global efforts to align energy development and access with climate commitments, public health protection, and environmental justice.

## Health impacts from gas flaring in Brazil

Peer-reviewed literature directly examining health outcomes associated with gas flaring in Brazil remains limited. Nevertheless, the available evidence, particularly from occupational health studies, documents tangible health consequences for workers and populations exposed to pollution from the country's oil and gas sector.

70 InfoAmazonia. (2025, March 24). *Every Last Drop—Gas flaring in the Amazon* [Story map]. InfoAmazonia.
71 Rodriguez, P. (2024, February 12). Brazil at a crossroads: The environment or oil and gas. NACLA.
72 Fletcher, E. R., & Samantaroy, S. (2025, March 26). Make our lungs healthy again. Health Policy Watch.

A 2024 cross-sectional study of 537 workers at a Petrobras oil refinery in Paulínia, São Paulo, found that nearly half of participants (49.1%) had systemic arterial hypertension. Notably, 73.5% of hypertensive workers had not previously been diagnosed, indicating a substantial silent health crisis within the workforce. The highest prevalence was observed among workers aged 30–49.[73] A study published in the *Pan American Journal of Public Health* assessed liver health among oil refinery workers in Bahia, Brazil, compared with a non-exposed reference population.[74] The prevalence of liver abnormalities (elevated gamma-glutamyl transferase and alanine aminotransferase enzymes that indicate liver stress) was 15.3% among refinery workers compared with 3.8% in the reference group, indicating that refinery workers were 3.56 times more likely to exhibit signs of liver stress.

Community-level evidence further suggests adverse respiratory outcomes linked to proximity to petrochemical activity. A 2010 cross-sectional study in Guamaré, Rio Grande do Norte examined respiratory health among 209 children and adolescents living within 5 km of a petrochemical complex. Researchers used household questionnaires to assess wheezing symptoms and collected air pollution data from a fixed monitoring station downwind of the facility, which continuously measured $PM_{2.5}$, $PM_{10}$, BC, $SO_2$, $NO_2$, $O_3$, and VOCs including benzene, toluene, and xylenes. Children living downwind of the facility were twice as likely to experience wheezing in the previous 12 months compared to those living in upwind reference communities. This increased risk was observed even though average pollutant concentrations remained within WHO-acceptable limits, underscoring the health risks of chronic, low-level exposure to petrochemical emissions.[75] A prospective cohort study in Cubatão, São Paulo, followed a cohort of 600 children with repeated spirometric assessments alongside continuous air pollution monitoring across sites situated near a dense petrochemical and industrial complex. Higher particulate matter ($PM_{10}$) exposure was significantly associated with reductions in lung function over time, with the most pronounced impairments observed among children residing closest to petrochemical and industrial emission sources, suggesting cumulative respiratory effects of sustained exposure.[76]

73 Pinto, C. J. M., Félix, C. S. S., Bazilio, J., Assis, E. F., Silva, A. L. M. S., & Paleari, R. M. (2024). Prevalence of arterial hypertension among workers in a petrochemical industry. Research, Society and Development, 13(2), e12513245113.

74 Costa, M. F., de Jesus, R. P., de Aguiar, A. S., & de Castro, V. (2005). Liver changes in workers at an oil refinery and in a reference population in the state of Bahia, Brazil. Occupational Medicine, 55(2), 111–115.

75 de Moraes, A. C. L., de Almeida, A. C. G., da Silva, J. V., de Andre, P. A., Saldiva, P. H. N., & de Faria, M. G. (2010). Wheezing in children and adolescents living next to a petrochemical plant in Rio Grande do Norte, Brazil. Jornal Brasileiro de Pneumologia, 36(4), 437–443.

76 Spektor, D. M., Hofmeister, V. A., Artaxo, P., Brague, J. A., Echelar, F., Nogueira, D. P., Hayes, C., Thurston, G. D., & Lippmann, M. (1991). Effects of heavy industrial pollution on respiratory function in the children of Cubatão, Brazil: A preliminary report. Environmental Health Perspectives, 94, 51–54.

Recent legal developments in the Amazon basin highlight how gas flaring affects public health and Indigenous rights, and how communities are pursuing accountability:

### Box 4. The fight for justice in the Ecuadorian Amazon

Between 2012 and 2023, oil operations across the Amazon flared 17.6 billion cubic meters of gas, with flares in the Ecuadorian Amazon accounting for 75% of this total (InfoAmazonia, 2025). In early 2021, nine Indigenous girls aged 9 to 13 won a landmark lawsuit against the Ecuadorian government and the state oil company PetroAmazonas (Amazon Frontlines). The court ruled that gas flaring was unconstitutional, recognizing its violations of the rights to health and a healthy environment, as well as its contribution to greenhouse gas emissions, and ordered the gradual elimination of flares by 2030. Despite the ruling, enforcement has fallen short. Hundreds of flares continue to burn—many within Indigenous communities—releasing toxic pollution linked to cancer and respiratory illness, and leaving affected communities fighting for accountability.

The limited evidence base on community-level health impacts of gas flaring in Brazil likely reflects structural constraints and data limitations. For instance, the majority of Brazil's gas flares occur offshore, which can reduce opportunities for conventional exposure assessment and community-level epidemiological study. Further, many oil operations affecting Indigenous communities occur in remote Amazon regions, where limited healthcare infrastructure, incomplete medical records, and logistical barriers increase the cost and complexity of conducting field-based epidemiological studies. Further, many Latin American countries still lack systems that effectively integrate Indigenous environmental knowledge with formal scientific monitoring and public health data. Research and documentation can also be constrained by broader security risks facing environmental defenders in the region. A 2023 Global Witness analysis found that the Amazon region is one of the most dangerous places in the world to be an environmental defender, with more than one in five recorded killings of environmental defenders occurring there.[77] There is therefore a need for more targeted epidemiological research on health outcomes among populations living near and downwind of flaring sites, expanded and systematic air quality monitoring in flaring-affected areas, and stronger integration of public health evidence and Indigenous knowledge into decisions governing oil and gas expansion, particularly in regions of high ecological and social vulnerability.

77 Global Witness. (2023, Sept. 13). Almost 2000 land and environmental defenders killed between 2012 and 2022 protecting the planet.

# 6. Conclusion

This literature review finds strong and convergent evidence that hydrocarbon gas flaring is associated with a wide range of serious adverse health impacts in oil-producing regions of emerging markets and developing economies. Evidence from Nigeria, Iraq, and Brazil links exposure to flaring-related emissions with increased risks of respiratory and cardiovascular disease, carcinogenesis, hematological and immunological dysfunction, endocrine and metabolic disorders, renal impairment, and adverse maternal, neonatal, and child health outcomes. While the scale of the evidence base varies by country, the direction, coherence, and biological plausibility of findings are highly consistent.

Nigeria provides the most extensive and methodologically diverse body of empirical evidence. Studies spanning more than two decades document associations between gas flaring exposure and respiratory illness (i.e., chronic cough, wheezing, breathlessness, asthma, bronchitis, reduced lung function); cardiovascular disease (i.e., systemic arterial hypertension, elevated systolic and diastolic blood pressure); oxidative stress and immune dysregulation (i.e., elevated lipid peroxidation markers, inflammatory cytokine imbalance, depleted antioxidant defenses); hematological abnormalities (i.e., anemia, abnormal red blood cell morphology, leukocytosis, platelet reduction); renal dysfunction; and metabolic disorders (i.e., insulin resistance, hyperinsulinemia, dyslipidemia). Maternal and child health studies also link flaring exposure to adverse pregnancy and early-life outcomes, including premature rupture of membranes, postpartum hemorrhage, low birth weight, childhood respiratory illness, and increased incidence of acute illness (i.e., coughing, respiratory symptoms, fever), as well as higher risks of wasting and underweight among children under five. Several studies demonstrate duration- and proximity-dependent effects, strengthening the plausibility of a causal relationship, although additional longitudinal cohort studies would further strengthen the evidence base.

In Iraq, a growing body of evidence links large-scale flaring in the Basra Governorate to severe air pollution and a substantial disease burden. Peer-reviewed studies, air quality monitoring, occupational biomarker analyses, and investigative reporting—supported by leaked government health data—consistently associate flaring intensity with carcinogenic outcomes and cellular damage (i.e., increased cancer incidence, notably leukemia, oxidative stress, lipid peroxidation, DNA damage); elevated cardiovascular risk (i.e., biomarkers indicative of atherosclerosis, elevated cardiometabolic risk); respiratory injury (i.e., chronic sinusitis, bronchitis, nasal bleeding, and upper respiratory tract damage); and endocrine and hepatic dysfunction (i.e., disruption of pituitary and thyroid hormones, altered liver enzyme profiles). The alignment between epidemiological trends, mechanistic evidence, and official acknowledgements by Iraqi authorities provides particularly strong support for a flaring-related public health crisis.

Brazil presents a more limited evidence base consisting of primarily occupational health studies. Available research documents cardiovascular and metabolic risk among oil refinery and petrochemical workers, including a high prevalence of systemic arterial hypertension—often undiagnosed—and liver enzyme abnormalities indicative of hepatic stress. Community-level studies link residence near petrochemical complexes to respiratory effects in children, particularly increased wheezing, including effects observed even when monitored air pollutant concentrations fall within WHO guideline limits, suggesting the risks of chronic or cumulative exposure.

The consistency of findings across diverse methodological approaches and across the three country case studies strengthens confidence in the overall conclusions of this review. Although many studies rely on indirect exposure proxies (e.g., proximity to flare sites, duration of residence or employment, satellite-detected flaring volumes) rather than individualized exposure monitoring, the repeated observation of similar health outcomes across independent methods, populations, and geographies provides a strong evidentiary foundation. Methodological constraints, including limited baseline health data, exposure misclassification, confounding from co-located industrial pollution, and underdiagnosis in weak health systems, reflect institutional data limitations rather than weaknesses in the underlying science. Notably, documented underreporting of disease in multiple contexts suggests that existing estimates likely understate, rather than exaggerate, the true health burden attributable to gas flaring.

With the methodologies adopted in the studies under review, the unambiguous attribution of adverse health outcomes to gas flaring as opposed to other factors remains a challenge. A key limitation of the evidence base is that populations living near flare sites are often simultaneously exposed to other sources of pollution associated with oil and gas production, including oil spills, produced-water discharges, refining and broader petrochemical activity. As a result, while many studies identify adverse health outcomes associated with flaring exposure, the flaring-attributable fraction of these observed health effects is often difficult to distinguish from the impacts of other co-occurring environmental exposures. Nonetheless, the convergence of findings across diverse study designs and geographic contexts—supported by established toxicological mechanisms—strengthens the plausible basis for causal inference, although stronger study designs would be needed to establish causation more definitively.

While further studies would be helpful to quantify the adverse health impact of the toxic load from gas flaring, the weight of evidence reviewed here strongly supports the conclusion that gas flaring is a significant and preventable public health risk. Its persistence beyond emergency use and despite available mitigation technologies and longstanding policy commitments reflects a failure of governance and enforcement. Eliminating the practice beyond emergency use would deliver immediate and long-term benefits by reducing disease burden, alleviating pressure on health systems, and advancing climate mitigation goals.

# Annex 1. Overview of findings

| Nigeria (Niger Delta) | Iraq (Basra) | Brazil |
|---|---|---|
| • Community surveys, lung-function studies, and air monitoring research consistently link gas flaring to **respiratory illness** (higher rates of cough, wheezing, breathlessness, asthma, bronchitis, and reduced lung function) in both adults and children.<br>• Cardiovascular studies show higher **hypertension** and **elevated blood pressure** in flaring communities, with residents in some surveys 1.75 times more likely to be **hypertensive and cardiopulmonary stress** worsening with longer exposure.<br>• Hematological, cytokine, and oxidative stress studies document biological damage from chronic exposure, including **anemia, abnormal red blood cell morphology**, **elevated white blood cells**, **immune dysregulation**, **depleted antioxidant defenses**, **DNA damage**, and **heavy metal bioaccumulation**.<br>• Renal and metabolic studies link flaring exposure to **kidney dysfunction, insulin resistance, hyperinsulinemia, and other cardiometabolic abnormalities**.<br>• Maternal and neonatal health studies associate oil-pollution and flaring exposure with **pregnancy complications and lower birth weights**, including higher risks of premature rupture of membranes and postpartum hemorrhage.<br>• Satellite-linked population health research found that higher flaring exposure increases **respiratory illness and undernutrition among children under five**, including higher rates of cough, respiratory symptoms, fever, wasting, and underweight in communities exposed to nearby onshore and offshore flare sites. | • Investigative journalism and leaked government health data document **unusually high cancer incidence** in flaring regions, including **leukemia** clusters near major oil fields and evidence of underreported cancer cases in Basra.<br>• Time-series epidemiological analysis shows a **very strong correlation between flaring volumes and cancer incidence** in Basra, with reported cancer cases nearly doubling between 2007 and 2018 as flaring increased.<br>• Air quality monitoring studies near major flaring sites detect $PM_{2.5}$, $PM_{10}$, black carbon, and other **pollutants far exceeding WHO limits**, exposing large urban populations to chronic air pollution.<br>• Clinical biomarker studies of petroleum workers exposed to ultrafine particles detect elevated **carcinogenic pollutants**, **oxidative stress, and lipid abnormalities** indicating increased risk of cardiovascular disease.<br>• Clinical studies of refinery and gas-station workers show **endocrine disruption and liver damage**, including reduced pituitary hormone levels and elevated liver enzymes indicating hepatotoxicity from petroleum exposure.<br>• Occupational exposure studies link hydrogen sulfide from flaring and oil operations to **respiratory tract damage**, including **nasal bleeding**, **sinusitis**, **rhinitis**, **and acute bronchitis**. | • Cross-sectional studies of children living near petrochemical plants show higher **respiratory symptoms**, with exposed children about twice as likely to experience wheezing, especially among younger children.<br>• Occupational health studies report high cardiovascular risk among refinery workers, with nearly half diagnosed with **systemic arterial hypertension**, many previously undiagnosed.<br>• Cross-sectional study shows refinery workers are more than three times as likely to exhibit **liver damage**, based on elevated liver enzyme biomarkers associated with petroleum exposure.<br>• Investigative environmental monitoring using optical gas imaging documents methane and VOC emissions from oil and gas facilities, pollutants associated with cancer risk, respiratory illness, and birth defects in surrounding communities. |

## Annex 2. Summary of Nigeria studies

| Title | Study Design & Methods | Summary |
|---|---|---|
| *Is Living in a Gas-Flaring Host Community Associated with Being Hypertensive? Evidence from the Niger Delta Region of Nigeria (2017)* Link | Cross-sectional 600-household survey in Niger Delta. Exposed group (n=475, 52.1%) from 3 gas-flaring communities: Sampou and Nedugo (Bayelsa State), Omerela and Mbodo-Aluu (Rivers State) (≥10 years gas flaring exposure within 5km radius); control (n=437, 47.9%) from three non-gas-flaring communities: Ibada-Elume and Omerelu (Rivers State), Oton-Yasere and Mbodo-Aluu (Bayelsa State). Measured blood pressure using Omron 3 Series monitor, administered modified WHO-STEPS questionnaire. | Gas-flaring residents were 1.75 times more likely to be hypertensive (adjusted odds ratio [AdjOR]=1.75; 95% CI=1.11–2.74) vs. non-gas-flaring residents. Hypertension prevalence: 25.3% in gas-flaring vs. 20.7% in non-gas-flaring communities. Mean age (AdjOR=1.05) and body mass index (BMI) category were also predictors of hypertension. Hypertension risk highest among residents aged 20–40 and 60–80 years in gas-flaring communities. |
| *The Respiratory Effects of Chronic Exposure to Gas Flaring Among Residents of Some Communities in the Niger Delta Region of Nigeria (2024)* Link | Cross-sectional survey in Niger Delta. Exposed group (n=386, ≥2 years residency) from Ibeno; control (n=414, age/sex/height matched) from Etinan. Excluded past and current smokers. Assessed respiratory symptoms and health challenges via questionnaire. | Symptoms suggestive of respiratory disorders were significantly higher among exposed Niger Delta subjects than controls: cough (14.8% vs. 10.1%), breathlessness (15% vs. 7.3%), and wheezing (5.7% vs. 3.1%). |
| *Gas Flaring Attendant Impacts of Criteria and Particulate Pollutants: A Case of Niger Delta Region of Nigeria (2019)* Link | Long-term emissions analysis (1965–2015) of CO, $NO_x$, $SO_x$, NMVOCs, $PM_{2.5}$, and OC using historical gas flaring volumes and IPCC Tier 1 emission factors, with uncertainty quantification, Air Quality Index assessment, and correlation analysis between $PM_{2.5}$ and life expectancy. | Correlation coefficient of 0.6717 between $PM_{2.5}$ emissions and reduced life expectancy in the region, indicating a moderate positive relationship between pollution exposure and adverse health outcomes. |
| *Effect of Prolonged Exposure to Gas Flaring on Some Haematological Parameters of Humans in the Niger Delta Region of Nigeria (2010)* Link | Cross-sectional study in Rivers State. Exposed group (n=110, ages 18–45, >5 years residency) from Ebocha (active gas flaring ~37 years) and Okwuzi (~2 km from Ebocha); control (n=80) from farming community >20 km from gas flaring. Measured packed cell volume (PCV), hemoglobin (Hb), red blood cells (RBC), white blood cells (WBC), and RBC morphology. | Exposed group showed decreased PCV, Hb, and RBC but increased WBC and abnormal RBC morphology ($p<0.05$) vs. control. Abnormal RBC morphology: males 167.05% increase, females 795.50% increase. Effects more marked in females than males. Study concluded prolonged gas flaring exposure causes marked hematological deterioration. |
| *Niger Delta Communities Grappling with Health Impacts of Gas Flaring (2024) – Investigative Journalism* Link | Investigative journalism combining interviews with victims and health professionals, hospital record review (2013–2023), and field air quality testing measuring CO, $SO_2$, $NO_2$, $O_3$, $PM_{2.5}$, and $PM_{10}$ at the Obiafu-Obrikom gas flare site and 400 m away in the community. | Hospital records documented 1,345 respiratory cases in Obrikom and 2,124 in Egbema (2013–2023). Air quality measurements exceeded WHO limits across all pollutants—CO was 2,720× higher at the flare site, $SO_2$ was 64× higher, and $PM_{2.5}$ exceeded limits at both locations. Residents living within 4 km of flare sites experience bronchitis, asthma, eye irritation, and deteriorating eyesight, with 1.75× higher hypertension risk compared to non-flaring areas. |

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| Title | Study Design & Methods | Summary |
|---|---|---|
| *Health Impact of Gas Flares on Igwuruta/ Umuechem Communities in Rivers State (2009)* Link | Nine-month study (May 2007–Jan 2008) at Agbada II flow station, Igwuruta/Umuechem, Rivers State with control site at Ayama. Four concentric sampling stations (upwind, midpoint, downwind, control) measured hourly air quality (TSP, $PM_{10}$, $PM_7$, $PM_{2.5}$, $PM_1$, CO, $SO_x$, $NO_2$, $H_2S$, VOCs). Compared 4-year medical records and conducted epidemiological survey (500 questionnaires). | Dry season particulates exceeded limits—TSP: 447.2 µg/m$^3$, $PM_{10}$: 297.5 µg/m$^3$ vs. wet season (22.0 and 17.8 µg/m$^3$). Pollution-related diseases (asthma, cough, breathing difficulty, eye/skin irritation) accounted for 22.4% of cases in Igwuruta vs. 5.9% in Ayama—a 4:1 ratio. Most common: fever (29.1%), cough (17.1%). |
| *Duration and Gender Variations of Gas Flaring and Crude Oil Contamination Exposures on Blood Pressure in Delta State, Nigeria (2019)* Link | Cross-sectional study in Delta State comparing cardiovascular parameters among 360 subjects (ages 18–45). Exposed group (n=240) from Bomadi and Agbarho (gas flaring sites); control (n=120) from Abraka (non-flaring). Measured systolic blood pressure (SBP), diastolic blood pressure (DBP), pulse pressure (PP), and mean arterial pressure (MAP). | Duration-dependent blood pressure increases in exposed populations. Males with >10 years gas flaring exposure: SBP 145 mmHg vs. 123 mmHg in controls (p<0.05). Females with >5 years oil contamination: elevated SBP and DBP. Males had higher cardiovascular parameters than females across all groups. Gas flaring and oil contamination confirmed as potent elicitors of hypertension. |
| *The Impact of Gas Flaring on Child Health in Nigeria (2022)* Link | Study linked satellite-detected gas flaring locations and volumes (2012–2018) with Nigerian Demographic Health Survey data from 2013 and 2018 for children aged 0–5 living in Niger Delta states (Abia, Akwa Ibom, Anambra, Bayelsa, Delta, Edo, Imo, Ondo, Rivers) and Cross-River State. Exposure was estimated using an inverse-distance weighted measure of flare volume from both onshore and offshore flaring sites. Examined associations between flaring exposure and child health outcomes using both cluster-level and individual-level regressions, focusing on disease incidence (cough, respiratory issues, fever, diarrhoea), anthropometric measures (height-for-age, weight-for-height, weight-for-age), and child mortality. | Found strong positive associations between gas flaring exposure and respiratory illness in children under five. Individual-level regressions showed that greater flaring exposure increased cough (coefficient 0.0294, p<0.001), respiratory issues (0.0278, p<0.001), fever (0.0260, p<0.001), and wasting (0.0093, p<0.05). Cluster-level analysis also confirmed elevated cough (0.0966, p<0.01) and respiratory symptoms (0.0848, p<0.01) in areas with greater flaring exposure. Positive associations were also observed for indicators of child undernutrition, including wasting and underweight, suggesting broader health and environmental impacts of chronic flaring exposure. No statistically significant associations were found for diarrhoea or child mortality outcomes. |
| *Prolonged Exposure to Oil and Gas Flares Ups the Risks for Hypertension (2013)* Link | Cross sectional survey in Imo East Senatorial zone, Niger Delta. Exposed group (n=475) from Egbema (gas flaring by Shell Petroleum Development Company for >45 years); control group (n=315) from Ahaoma-Ebieri (non-flaring). Participants aged 18–80, >5 years residency, matched for age, sex, occupation, education. Measured systolic blood pressure (SBP), diastolic blood pressure (DBP), pulse pressure (PP), mean arterial pressure (MAP) using mercury sphygmomanometer after 10-minute rest. | Exposed group had higher SBP (134.1 vs. 129.10 mmHg, p=0.01), DBP (89.48 vs. 82.97 mmHg, p=0.01), and MAP (104.37 vs. 98.47 mmHg, p=0.01) compared to controls. Hypertension prevalence: 39% (systolic) and 57% (diastolic) in exposed vs. 28% and 35% in controls. |

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| Title | Study Design & Methods | Summary |
|---|---|---|
| *Impact of Prolonged Exposure to Oil and Gas Flares on Human Renal Functions (2013)* Link | Comparative cross-sectional study in Imo East Senatorial zone, Imo State, Niger Delta. Exposed group (n=475) from Egbema (gas flaring for >45 years); control group (n=315) from Alaoma Owerre Ebeiri (non-flaring). Participants aged 18–80, >5 years residency, matched for age, sex, education, socioeconomic status. Measured serum biomarkers: urea, creatinine, potassium, uric acid, inorganic phosphate, calcium. | Exposed group had elevated renal dysfunction biomarkers: urea (4.93 vs. 4.27 mmol/L, p=0.01), creatinine (111.70 vs. 97.98 µmol/L, p=0.01), potassium (4.71 vs. 4.18 mmol/L, p=0.019), inorganic phosphate (3.01 vs. 1.97 mmol/L, p=0.01), and uric acid (8.59 vs. 5.21 mg/dl, p=0.01). Calcium decreased (2.00 vs. 2.17 mmol/L, p=0.01). Overall, exposed individuals more predisposed to developing kidney diseases, with potential loss of up to 50% renal capacity before clinical detection. Males showed higher biomarker elevations than females. |
| *Heavy Metal Bioaccumulation and Lipid Peroxidation Damage in Residents of a Gas Flaring Community (2018)* Link | Comparative cross-sectional study in Bayelsa State, Niger Delta. Exposed group (n=200) from Imiringi, Kolo Creek, Ogbia LGA (gas flaring); control group (n=200) from Odi, Kolokuma/Opokuma LGA (non-flaring). Measured blood heavy metals (Cd, Cr, Hg, Pb, Se), lipid peroxidation marker 8-Iso-Prostaglandin F2α (8-Iso-PGF2α), hematological parameters, and liver/kidney function biomarkers. | Imiringi residents had elevated heavy metals: Cr (0.025 vs. 0.004 ppm, p<0.0001), Hg (0.817 vs. 0.109 ppm, p<0.0001), Se (2.35 vs. 0.051 ppm, p=0.014), and lipid peroxidation marker 8-Iso-PGF2α (508 vs. 259 pg/ml, p=0.01). Liver/kidney dysfunction markers significantly elevated (p<0.05). Lower Hb, WBC, and platelets (p<0.05) with prolonged bleeding (13.87 vs. 12.74 seconds). Study concluded higher probability of diseases associated with metal toxicity and oxidative stress damage in gas flaring communities. |
| *Spatial Patterns of Gas Flaring Stations and the Risk to the Respiratory and Dermal Health of Residents of the Niger Delta, Nigeria (2021)* Link | Spatial analysis and health assessment at eight gas flaring stations in Rivers and Bayelsa states, Niger Delta. Measured air pollutants ($NO_2$, $SO_2$, CO, volatile organic compounds [VOC], $PM_{10}$) across dry/wet seasons. Collected 4-year clinical records (2013–2016) from six primary health care centers near GFS. Surveyed 200 residents. Used nearest neighbor analysis to assess GFS clustering. | Gas flaring stations exhibited clustered spatial pattern (Z-score -2.06, p=0.039). $NO_2$ and $PM_{10}$ exceeded WHO limits. Respiratory and dermal ailments accounted for 21.1–76.3% of hospital visits; most frequent: eye irritation and chest pain. Steady increase in respiratory cases ($r^2$=0.01–0.78) from 2013–2016. Strong associations between air pollutants and respiratory/dermal diseases (r=-0.877 to 0.831; $r^2$=0.238–0.892; p<0.05). Residents at high risk due to proximity and continuous exposure. |
| *Impact of Gas Flaring on Cardiopulmonary Parameters of Residents in Gas Flaring Communities in Niger Delta Nigeria (2016)* Link | Cross-sectional study across five Niger Delta states. Exposed group (n=504) from gas flaring communities: Agbarho- otor/Ughelli (Delta), Ibeno (Akwa Ibom), Oshi (Rivers), Imiringi (Bayelsa), Oben (Edo); control group (n=504) from non-flaring communities 35 km away: Eku, Ikot Ekpene, Ahoada, Ogbia, Ekiadolor. Measured blood pressure, pulse rate, respiratory rate, peak expiratory flow rate (PEFR). Stratified random sampling, ages 12–70. | Gas flaring communities showed elevated cardiovascular and respiratory stress: higher blood pressure (184.96 vs. 123.00 mmHg), faster pulse (100.37 vs. 78.09), faster breathing (33.63 vs. 23.83), and reduced lung function (PEFR 272.78 vs. 460.83). Effects worsened with longer exposure (>10 years had worst outcomes). |

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| Title | Study Design & Methods | Summary |
|---|---|---|
| *Cardiopulmonary Functions of School Children in Oil-Spilled and Gas-Flared Niger-Delta and Rural-Riverine Lagos Communities (2019)* Link | Cross-sectional study comparing school children (ages 6–9). Exposed group from Kegbara-Dere, Rivers State (oil-spilled and gas-flared); control (n=300) from Makoko, Lagos State (rural-riverine, non-exposed). Measured cardiovascular parameters (systolic blood pressure, diastolic blood pressure, heart rate, rate pressure product, and pulmonary functions (forced expiratory volume in 1 second [$FEV_1$], forced vital capacity [FVC], peak expiratory flow rate [PEFR]). | Children in oil-spilled/gas-flared community showed higher cardiovascular stress: elevated systolic blood pressure (112.99 vs. 111.12 mmHg), heart rate, and rate pressure product (10655.00 vs. 11187.45). Reduced lung function: lower $FEV_1$ (1.02 vs. 1.25 L), FVC (1.58 vs. 2.24 L), and PEFR. All differences significant ($p<0.05$). |
| *Study of the Impact of Gas Flaring on the Health of Communities in Delta Region of Nigeria (2021)* Link | Mixed-methods PhD research involving household surveys, exposure histories, and community interviews across Delta communities chronically exposed to flaring. | In a Niger Delta, a self-administered health survey (questionnaire) of 487 adults, had 90% of respondents report negative health impacts from gas flaring, with 62% reporting stress and 25–33% reporting respiratory problems, with higher frequency reported among those living near flare sites. |
| *Toxicological Studies on Heavy Metal Bioaccumulation and Oxidative DNA Damage in Residents of a Gas Flaring Community (2017)* Link | Comparative cross-sectional study in Bayelsa State. Exposed group (n=200) from Imiringi, Kolo Creek, Ogbia LGA (gas flaring); control (n=200) from Odi, Kolokuma/Opokuma LGA (non-flaring). Measured heavy metals (Cd, Cr, Hg, Pb, Se), oxidative DNA damage marker 8-hydroxy-2-deoxyguanosine (8-OHdG), hematological parameters, and liver/kidney function biomarkers. | Imiringi residents showed significantly elevated heavy metals and oxidative DNA damage marker 8-OHdG (all $p<0.0001$), lower Hb, WBC, and platelets, and prolonged bleeding time. Liver and kidney dysfunction markers were highest in exposed group. Study concluded higher probability of diseases associated with metal toxicity and oxidative stress in gas flaring communities. |
| *Impact of Gas Flaring on the Serum Antioxidant Biomarkers of Eleme Residents in Rivers State, Nigeria (2020)* Link | Comparative cross-sectional study in Rivers State. Exposed group (n=100) from Eleme LGA (gas flaring); control (n=100) from Nkpolu-Oroworukwo, Port Harcourt City LGA (non-flaring). Ages 18–50. Measured serum antioxidant biomarkers: reduced glutathione (GSH), glutathione peroxidase (GPx), glutathione-S-transferase (GST), superoxide dismutase (SOD), malondialdehyde (MDA), and catalase (CAT). | Eleme (gas flaring exposed) residents showed depleted antioxidant defenses: decreased GPx, GST, CAT, and SOD levels ($p\leq0.05$), with increased oxidative stress marker MDA ($p\leq0.05$). Study concluded chronic exposure to gas flaring pollutants alters human stress levels and deteriorates endogenous antioxidant status. |
| *Exposure to Oil Pollution and Maternal Outcomes: The Niger Delta Prospective Cohort Study (2022)* Link | Prospective cohort study of 1,720 pregnant women across Niger Delta. High exposure areas: Delta and Rivers States (oil-producing with oil spills and gas flaring); low exposure areas: Ondo and Edo States (non-oil producing). Followed from pregnancy to delivery (2011–2019). Assessed maternal outcomes: premature rupture of membrane (PROM), caesarean section, postpartum hemorrhage (PPH), pregnancy-induced hypertension. | Women in high oil pollution exposure areas (including gas flaring) had higher risk of PROM (adjusted relative risk [ARR]=1.96; 95% CI: 1.24–3.10) and PPH (ARR=2.12; 95% CI: 1.28–3.36) compared to low exposure areas. No association found with pregnancy-induced hypertension or caesarean section. |

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| Title | Study Design & Methods | Summary |
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| *Impact of Gas Flares on Neonatal Weight and Health Profile in Yenagoa Bayelsa State, Nigeria (2015)* Link | Cross-sectional descriptive design study in gas-flaring communities in Yenagoa, involving 32 neonates and their mothers. Maternal exposure to gas flaring was assessed through self-reported questionnaires, based on proximity to flaring sites, duration of residence, and frequency of perceived gas-flare odor inhalation. Neonatal birth weight was compared across self-reported exposure levels. | Neonates born to mothers with regular, close exposure to gas flaring had significantly lower average birth weights (2.69 kg) compared to those whose mothers were only occasionally exposed (3.09 kg), indicating a negative association between gas flaring exposure and neonatal weight. |
| *Persistence Exposure to Toxic Oil and Gas Flaring Pollutants-Mediated Insulin Resistance and Hyperinsulinemia Among Populations in the Niger Delta (2022)* Link | Cross-sectional study in Rivers and Cross River States. Exposed group (n=94, ages 18–50, ≥10 years residency) from Khana and Gokana LGAs, Ogoni, Rivers State (oil and gas flaring exposure); control (n=90) from Boki and Yakurr LGAs, Cross River State (non-petroleum areas). Measured insulin resistance using Homeostasis Model Assessment, beta cell function, blood glucose, lipid profile, BMI. | Insulin resistance prevalence: 78% in exposed vs. 22% in control. Cardiometabolic risk ratio (TG/HDL-C) prevalence: 63.6% in exposed vs. 36.4% in control. Insulin resistance and hyperinsulinemia showed age and time-dependent increase with exposure duration.This study validates both insulin resistance and toxic pollutions of oil and gas flaring as sensitive indicators of multiple metabolic abnormalities. |
| *Effect of Gas Flaring on Lung Function Among Residents in Gas Flaring Community in Delta State, Nigeria (2012)* Link | Cross-sectional study in Delta State (April–December 2011). Exposed group (n=400: 183 children, 217 adults) from Ugberikoko (gas flaring community); control (n=400: 183 children, 217 adults) from Irhodo (non-gas flaring). Ages 13–60. Measured peak expiratory flow rate (PEFR) using Wright peak flow meter spirometric device. | Gas flaring community residents showed reduced lung function across all age groups ($p<0.05$). Peak expiratory flow rate (PEFR) values: children 270.05 vs. 432.05, young adults (18–30 years) 222.7 vs. 420.75, older adults (41–50 years) 245.00 vs. 428.57. PEFR decreased with longer duration of gas flaring exposure. Study concluded gas flaring significantly impairs respiratory function. |
| *The Health Impact and Lung Function Indices of Adult Residents of Ibeno Community Exposed to Gas Flaring in South-South Nigeria (2021)* Link | Cross-sectional study (March–May 2014) in Akwa Ibom State. Exposed group (n=386, ≥2 years residency) from Ibeno (gas flaring for >30 years); control (n=386, age/sex/height matched) from Etinan (non-flaring). Measured respiratory symptoms via questionnaire and lung function using spirometer: peak expiratory flow rate (PEFR), forced vital capacity (FVC), forced expiratory volume in 1 second ($FEV_1$). | Higher respiratory symptom prevalence in exposed vs. control: cough (57 [14.8%] vs. 39 [10.1%]), breathlessness (58 [15%] vs. 28 [7.3%]), wheezing (22 [5.7%] vs. 12 [3.1%]). Reduced lung function in exposed group: PEFR (300.6±2.15 vs. 342±2.16 L/min), FVC (2.58±8.43 vs. 2.27±0.82), $FEV_1$ (2.01±0.76 vs. 2.13±0.75). Study concluded gas flaring negatively impacts lung function and worsens respiratory symptoms. |
| *Evaluation of Haematological and Cytokine Indices of Humans in a Gas Flare-Impacted Community (2025)* Link | Cross-sectional study in Akwa Ibom State. Exposed group from Ibeno (gas flaring by ExxonMobil since 1970s); control group from Afaha Udoe (>60 km away, no gas flaring). Measured hematological parameters (red blood cells [RBC], hemoglobin [Hb], white blood cells [WBC], platelets) using electrical impedance method. Measured cytokines (interleukin-4, transforming growth factor-beta [TGF-β], interleukin-10 [IL-10]) using enzyme-linked immunosorbent assay (ELISA). | Exposed group showed reduced RBC, hemoglobin, and platelets but increased WBC vs. control. Cytokine dysregulation: elevated Interleukin-4 but decreased TGF-β and IL-10 in exposed group. Study concluded hematological and cytokine alterations suggest imminent dangerous health conditions and compromised immune system from gas flaring exposure. |

## Annex 3. Summary of Iraq studies

| Title | Study Design & Methods | Summary |
|---|---|---|
| *The Effect of Air Pollutants on Liver Enzymes and Pituitary Gland Hormones of Smokers and non-smokers of Oil Refinery and Gas Station Workers in Basra/Iraq (2022)* Link | Cross-sectional study in Basra, Iraq (February–January 2020). Three groups: oil refinery workers (n=33), gas station workers (n=23), and control group (n=24 local volunteers with non-oil jobs). All male participants who had worked for at least one year. Measured three liver enzymes (GOT, GPT, ALP) and three pituitary hormones (FSH, LH, TSH) from blood serum samples. | Oil refinery workers showed significant decreases in pituitary hormones compared to controls, indicating hypothalamic-pituitary dysfunction. Liver enzyme GOT significantly increased, suggesting liver cell destruction. GPT and ALP decreased, indicating zinc/magnesium deficiency. Gas station workers showed similar but less severe trends. Non-smoker oil refinery workers had lower FSH than smokers from the control group, suggesting petroleum exposure causes more hormonal damage than smoking alone. |
| *The Effect of Natural Gas Flaring on Air Pollution and its contribution to Climate Change in Basra City (2021)* Link | Environmental analysis of gas flaring impacts in Basra Governorate, Iraq. Analyzed Iraqi government air quality and health data (2018–2019), global gas flaring rankings (2014–2019), and computed heat release and $CO_2$ emissions from flaring. Used Pearson correlation to examine the relationship between gas flaring volumes and cancer incidence in Basra. | Air quality monitoring revealed PM10 levels of 627.326 $\mu g/m^3$ (annual average), far exceeding international safety limits, and acid rain with pH below 5.6 near oil fields. Very strong positive correlation (r=0.91754) between gas flaring and cancer incidence, with annual cancer cases in Basra increasing from ~1,200 (2007) to ~2,300 (2018), directly proportional to flaring increases. Heat emissions from flaring contributed to record temperatures in Basra. |
| *Assessment of Gas Flaring on Air Quality in the Al-Rumaila Oil Field Region in Basra Governorate, Iraq (2024)* Link | Air quality monitoring study at Al-Rumaila oil field (world's 3rd largest production field) in Basra, Iraq, from Sept. 2023 to April 2024. Measured black carbon (BC), $PM_{2.5}$, $PM_{10}$, formaldehyde (HCHO), and total volatile organic compounds (TVOCs) at six stations: four located 400–500 m from flares, one 3 km away, and one near the city center (39 km away). Used one-way ANOVA and correlation analysis with meteorological factors. | All measured pollutants except TVOCs exceeded local Iraqi and WHO permissible limits. Station 3 near heavy industrial activity recorded the highest BC (47,845 $ng/m^3$). Prevailing northwesterly and southwesterly winds transport pollutants from flaring sites toward populated areas in Basra city center. Negative correlations between pollutants and temperature/wind speed indicated pollutant build-up under calmer, cooler conditions. |
| *Short-term effects of subchronic low-level hydrogen sulfide exposure on oil field workers (2015)* Link | Observational study of 34 male oil field workers (age 22–60) in Basra, Iraq (February 2012–December 2013). Compared workers exposed to subchronic low-level $H_2S$ (4–50 ppm) from extinguished gas flares, oil-separation stations, and leaking wells to control workers from three oil fields with little or no $H_2S$. Data collected via questionnaires on $H_2S$-related symptoms. | Among exposed workers, nasal bleeding was most frequent (52.9%), with 41.2% experiencing nasal bleeding alone. Other bleeding symptoms in exposed workers: pharyngeal bleeding (14.7%), gum bleeding (8.8%), bloody saliva (11.8%). Associated illnesses: chronic sinusitis, rhinitis, gingivitis, acute bronchitis. $H_2S$ concentrations peaked at 50 ppm before sunrise, nearly disappearing at midday (0–2 ppm) due to sunlight. Concluded nasal mucosa most vulnerable to $H_2S$, causing upper respiratory tract epithelial damage and bleeding. |

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| Title | Study Design & Methods | Summary |
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| *Clinical study on the relationship between exposure to ultrafine particles (PM0.1) and cardiovascular diseases in petroleum workers (2025)* Link | Comparative cross-sectional study of 90 male petroleum workers at crude oil well sites in Basra, Iraq, compared to 90 unexposed controls. Measured ultrafine particles (PM0.1) in blood: benzopyrene diol epoxide (BPDE, a PAH metabolite), cadmium, malondialdehyde (MDA, lipid peroxidation marker), superoxide dismutase (SOD, antioxidant enzyme), and lipid profile. | Exposed workers had significantly higher levels of toxic pollutants (BPDE, cadmium), increased cellular damage from oxidative stress, weakened antioxidant defenses, and elevated triglycerides. These biomarkers indicate high risk for atherosclerosis and cardiovascular disease (heart attacks, strokes). Study directly links PM0.1 from oil extraction to heart disease risk in workers. |
| *Gas Flaring and its Socioeconomic Implications for Rural Communities in Kurdistan Region of Iraq (KRI): Reflections on the Impact of Gas Flaring in Tawke Community (2024)* Link | Qualitative case study using in-depth interviews with DNO employees, public sector workers, and ~30 farming families near the Tawke oil field in Kurdistan Region of Iraq. Examined impacts of gas flaring on health, agriculture, and livelihoods. | Gas flaring at Tawke (routinely 20+ mmscf/d) linked to chronic respiratory illness, heart disease, increased cancer risk, and acid rain from $SO_2$ emissions. Agricultural impacts included contaminated soil/water, reduced crop yields, and disrupted local food production. Socioeconomic consequences: poverty, loss of farming livelihoods, migration, cultural disruption. Peshkabir and Tawke fields released 639,200 tons $CO_2$e (2019), representing >$2 billion in lost economic value. |
| *Iraq Gas Flaring Tied to Cancer Surge (2023) – Commentary* Link | Commentary piece synthesizing findings from BBC and Unearthed investigations on gas flaring and health impacts in Basra, Iraq. References leaked Iraq Health Ministry report and statements from Iraqi government officials. | Iraq is the world's 2nd largest gas flaring country after Russia. Leaked Health Ministry report showed 20% rise in cancer in Basra (2015–2018), with actual cases three times higher than publicly disclosed. Flaring releases benzene (human carcinogen causing leukemia). Iraq's former environment minister confirmed oil pollution as the main reason for cancer rate increases in Basra. The article documents the death of Ali Hussein Jaloud (early 20s) from leukemia in Rumaila, attributed by family to gas flaring pollution. |
| *Unearthed: Big oil's dirty secret in Iraq (2022) – Investigative Journalism* Link | Multi-month investigative journalism combining World Bank satellite flaring data analysis, cross-checking with independent organizations, on-the-ground BBC reporting in Basra, leaked internal oil company documents, and interviews with Iraqi officials and residents. Focus on the Rumaila oil field (BP lead contractor since 2009). | Rumaila flared 3.39 bcm gas (2021), emitting 9.5 million tonnes $CO_2$e. BP's share: 4.52 million tonnes $CO_2$e (double entire UK oil industry flaring). BP excludes Rumaila from annual reports via the "non-operated asset" loophole; inclusion would double BP's reported 2021 flaring emissions. Leaked 2013 BP document pledged <10,000 tonnes $CO_2$e/year—actual emissions many times higher. Flare stacks located within 5 km of homes (violates 10 km legal minimum). Locals link flaring to high leukemia/cancer rates; former oil minister confirmed link to "poisonous gases." |
| *BP in oil field where 'cancer is rife' (2022) – News Report* Link | Investigative journalism in Basra oil fields including first independent pollution monitoring (two-week air testing in five communities, urine samples from 52 children), satellite data analysis, leaked government documents, and interviews with residents and officials. | Rumaila (BP lead contractor) flares more gas than any site globally. Flaring found <250 m from homes (violates 10 km legal minimum). Air tests: benzene reached/exceeded Iraq's national limit in ≥4 places. 70% of 52 children had elevated 2-Naphthol (cancer-causing). Columbia expert: "strikingly high levels." Leaked Health Ministry report: 20% cancer rise in Basra (2015–2018). North Rumaila is called "the cemetery" due to high leukemia among teens. Local scientist: cancer "like the flu." The UN called areas "modern sacrifice zones." Fatima Falah Najem (13) died of leukemia; flares 2.6 km from home. |

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| Title | Study Design & Methods | Summary |
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| *Big Oil Is Fueling a Rise in Cancer in Iraq's Basra (2025) – Investigative Journalism* Link | The New Lines investigation used field reporting, interviews with residents, leaked health data, and environmental studies to document how extensive gas flaring and pollution from major oil operations in Basra are linked to a dramatic increase in cancer cases, and how government authorities and oil companies downplay or deny the health crisis and obstruct accountability. | In the heavily impacted town of Aradah, a local volunteer documented more than 3,000 new cancer cases in a population of about 51,000 over two years, and internal health data showed 8,587 new cancer diagnoses in 2020 versus the officially reported 2,339, indicating significant undercounting. Legal cases against oil companies have consistently failed due to lack of officially recognized causation. |
| *Iraqi minister admits gas flaring Cancer Link (2022) – News Report* Link | BBC News investigation examining the environmental and health impacts of Iraq's oil industry, focusing on southern Iraq near Basra. Draws on BBC-led pollution monitoring, interviews with affected families and officials, and previously undisclosed government positions to assess links between gas flaring and public health outcomes. | Found that gas flaring releases carcinogenic pollutants such as benzene into nearby communities, with monitoring suggesting exposure levels that raise leukemia and cancer risks. Iraq's environment minister told the BBC that pollution from oil production is the primary cause of rising cancer cases in the region (a rare official admission), yet affected families report no compensation, weak regulation, and limited enforcement. |

## Annex 4. Summary of Brazil studies

| Title | Study Design & Methods | Summary |
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| *[Abstract] Liver changes in workers at an oil refinery and in a reference population in the state of Bahia, Brazil (2005)* Link | Cross-sectional study in Bahia, Brazil, comparing 692 oil refinery workers with a reference group of 377 office workers with no occupational chemical exposure. Researchers analyzed blood samples to measure serum levels of two liver enzymes: gammaglutamyltransferase (GGT) and alanine aminotransferase (ALT). The study also collected data on co-variables like alcohol use, smoking, and obesity. | The prevalence of liver changes was over four times higher in refinery workers (15.3%) compared to the reference population (3.8%). After adjusting for other factors, logistic regression analysis confirmed that refinery workers had a 3.56 times greater prevalence of liver damage. The authors concluded that occupational exposure was likely a major factor in the observed liver changes. |
| *Wheezing in children and adolescents living next to a petrochemical plant in Rio Grande do Norte, Brazil (2010)* Link | Cross-sectional study in Guamaré, Rio Grande do Norte, Brazil. Study included 209 children and adolescents (aged 0–14 years) living within 5 km of the Guamaré Petrochemical Complex for at least 1 year. Researchers used the International Study of Asthma and Allergies in Childhood questionnaire and monitored air quality for $PM_{10}$, $PM_{2.5}$, black carbon, $SO_2$, $NO_2$, $O_3$, benzene, toluene, and xylene from March to July 2006. Communities were categorized as exposed (downwind) or reference (upwind) based on wind direction. | Children in exposed communities were 2.01 times more likely to have experienced wheezing in the last 12 months compared to reference communities, after adjusting for age and gender. Preschoolers (ages 0–6) were five times more likely to have wheezing than older children. Boys were 2.5 times more likely to experience wheezing than girls. Concluded that respiratory symptoms were associated with living downwind of the petrochemical plant, even though pollutant levels remained within WHO acceptable limits. |
| *Effects of Heavy Industrial Pollution on Respiratory Function in the Children of Cubatao, Brazil: A Preliminary Report (1991)* Link | Prospective cohort study in Cubatao, Brazil, following 600 kindergarten children over the 1988 school year (March—November). The study area included a dense concentration of industrial sources, including petrochemical, steel, fertilizer, and cement plants. Children underwent monthly spirometry testing, while air quality was continuously monitored at six school-based stations for particulate matter ($PM_{10}$) and other pollutants. Schools were selected to capture variation in proximity to industrial and petrochemical emission sources. | $PM_{10}$ concentrations ranged from 59 to 240 $\mu g/m^3$ across sites, substantially exceeding the U.S. annual standard of 50 $\mu g/m^3$. Increased particulate exposure was significantly associated with reductions in multiple respiratory function measures, including $FEV_1$, peak expiratory flow rate (PEFR), and forced expiratory flow ($FEF_{25-75}$). The most pronounced impairments were observed in schools located closest to dense industrial and petrochemical activity, including areas near petrochemical and styrene plants. Children with prior residence in highly polluted industrial zones exhibited larger decrements in lung function even after relocation, suggesting cumulative effects of sustained exposure to industrial emissions. |
| *Prevalence of arterial hypertension among workers in a petrochemical industry (2024)* Link | Cross-sectional study conducted in Paulínia, São Paulo, Brazil, between April and June 2023, involving 537 workers from a Petrobras oil refinery and a third-party company providing general services. Participants (96.3% male, average age 41.6 years) worked in refinery equipment maintenance. Blood pressure was measured during work hours (7:30am–10:30am) following Brazilian Hypertension Guidelines, after 20 minutes of rest. | Overall, 49.1% of participants had systemic arterial hypertension, with 50.4% of men affected. Among the 264 hypertensive workers, 73.5% reported not having a previous diagnosis of the disease. The highest prevalence of undiagnosed hypertension was among workers aged 40–49 years (37.5%), followed by ages 30–39 (37.0%). Among hypertensive workers, 78.8% had Stage I hypertension, 13.6% had Stage II, and 7.6% had Stage III. An additional 13.8% of participants had pre-hypertension, a clinically significant risk factor for cardiovascular disease. |

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| Title | Study Design & Methods | Summary |
|---|---|---|
| *Brazil at a Crossroads: The Environment or Oil and Gas (2024)* *Link* | Investigative report by Earthworks and Instituto Internacional Arayara conducted in April and May 2023 across seven Brazilian states with heavy oil and gas presence. Researchers used Optical Gas Imaging (OGI) cameras to document emissions and collected water samples around potential contamination sites in communities near oil refineries, gas processing facilities, and thermoelectric plants in Rio Grande do Norte (Guamaré, Alto do Rodrigues), Ceará, and other regions. | Thermal imaging cameras revealed extensive plumes of methane and volatile organic compounds being emitted from exhaust stacks at the Potiguar refinery and Vale do Açu natural gas-fired thermoelectric plant. At the Potiguar refinery, researchers documented methane and volatile organic compounds spewing from two exhaust stacks in processing units. The report notes that emissions from oil and gas facilities (including methane and other volatile organic compounds from extraction sites, refineries, and processing stations) are linked to cancer, respiratory problems, and birth defects. |